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RECENT BOILER CONTROL SYSTEM FOR THERMAL POWER STATION

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1 FOREWORD

The present is the age of digitalization of process control systems based on the microprocessor, and is the age of control technology renovation never seen before.

The use of digital control systems in steel, chemical, and ceramic plants is becoming more brisk. These application as control systems for power generation boilers is also steadily advancing.

Technological innovations for coping with the diverse needs brought about by the rapid development of electronics technology and the diversification of energy for a stable energy supply which took the oil crisis of 1974 as an opportunity, the energy-saving trend, and changes in the soical and economical environment are overlapped.

The interrelationship between the diverse needs in the power generation boiler control technology field and control system expected in the future is shown in *Fig. 1* as "utility thermal power plant changes and expected control system".

Based on the needs of such an age, digitalization of various process control systems, Fuji Electric promoted digitalization of various process control systems starting from the last half of the 1960s and, at the same time, undertook the digitalization of electric power generation boiler control technology with associated technology as the background. The FAPS-8000 (registered trademark) power generation boiler digital control control system developed as a result is outlined below.

2 HISTORY OF POWER GENERATION BOILER CONTROL TECHNOLOGY DEVELOPMENT

Fuji Electric activity in this field began with the delivery of stoker combustion 34t/h x 3 boiler ACC (Automatic Combustion control) system for the Chugoku Electric Power Co., Inc. Maeda Power Plant from Siemens of West Germany in 1931. Since then, we have served to introduce European technology of the age and have attempted to expand activity in this field. To supply of electric power and steam with the growth of industry and have delivered a total of 580 units as shown in *Fig. 2*. Of these, 13 boiler control system engineering and systems have been delivered for utility thermal power plants. Especially, a record extending up to 50 units for private and utility use since we delivered Japan's first once through Benson boiler control system, which demands more complex control than a drum boiler, to the Asahi Glass Co., Ltd. Makiyama Factory in 1954 is a special feature.

In particular, in 1974 Japan's first sliding pressure operation control technology and wide range automation technology was introduced for the Tokyo Electric Power Co., Inc. Ohi Power Plant No. 3 unit and a large contribution was made to the realization of the current 350MW class DSS (Daily Startup and Shutdown) operation. Moreover, updating of the Tokyo Electric Power Co., Inc. Kawasaki Power Plant No. 6 unit control system was implemented by incorporating a sliding pressure operation system corresponding to the demands of the age with improvement of control system aging countermeasures and controlability and operability as a precondition, and the control system is reborn as an invincible system in new thermal power plants. Such Fuji Electric power generation boiler control technology is matched to the state of affairs of the country and has been accumulated through the design and manufacture of original control systems with the first Siemens control technology as the nucleus.

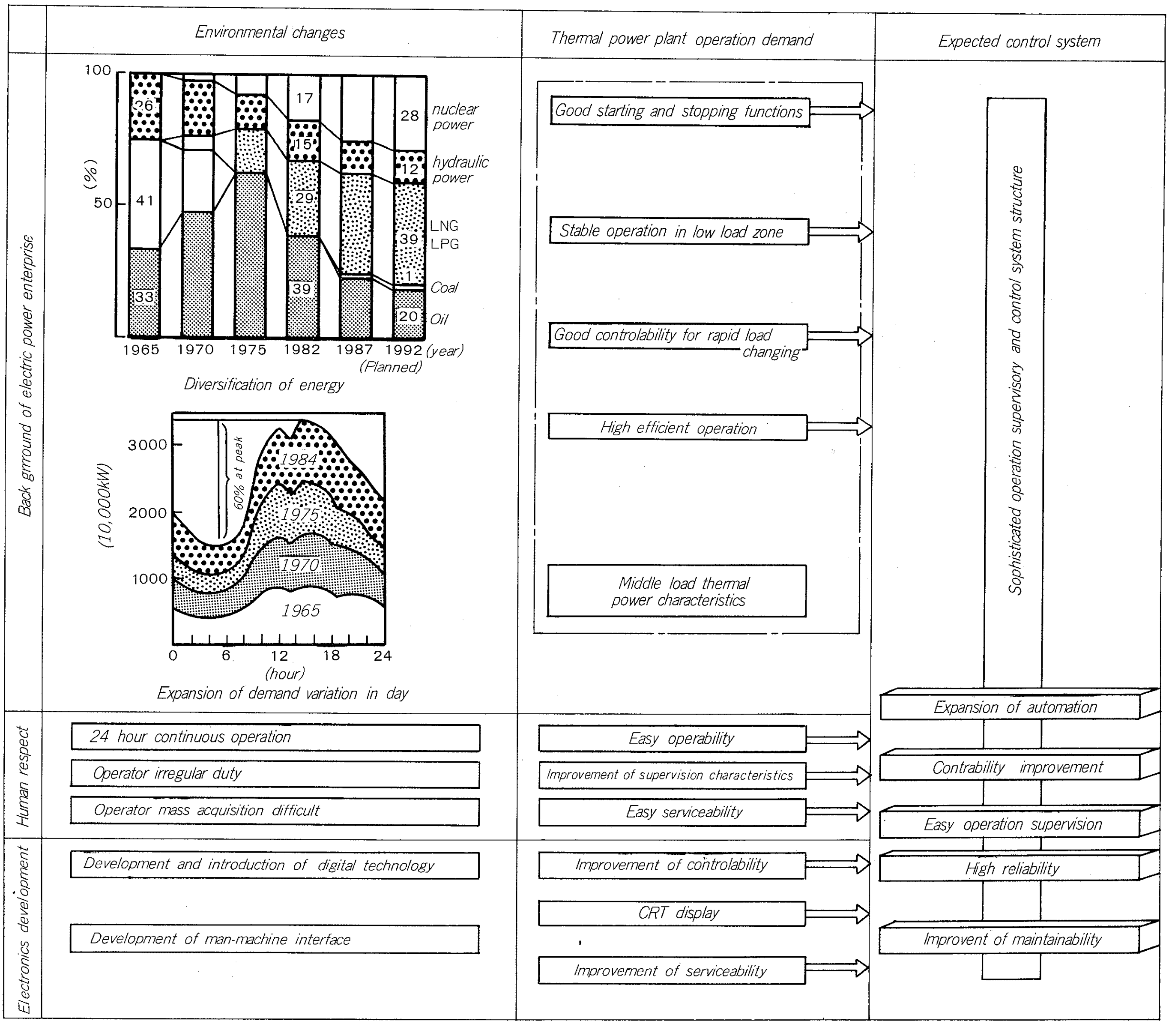
In recent years, to meet various needs due to the scaling up of facility capacity, pursuit of efficiency, energy saving countermeasures, diversification of operation, etc. (see *Fig. 1*), the features of digital technology, that is, high reliability, improvement of operability, ease of maintenability, easy interfacing with a high level computer system, realization of high quality control functions by numerical models, etc., are being demanded in power generation boiler control systems.

3 OUTLINE OF FAPS-8000 POWER GENERATION BOILER CONTROL SYSTEM

3.1 Development of power generation boiler control system digitalization

To inherit the advantages of analog control technology

Fig. 1 Utility thermal power plant changes and expected control systems



and meet the needs of boiler control technology, which have become diverse in recent years, Fuji Electric has undertaken digitalization of a power generation boiler control system and has accumulated actual verification of its applicability step by step.

When applying a digital control system, various studies were made on the affect on controlability of the sampling period, backup system for a high reliability system structure, and system for securing the independence of the control system, etc.

Controlability studies by plant simulation using a house machine and system high reliability countermeasures were added and application to an actual machine was performed. Examples are delivery in 1979 to Ube Industries, Ltd. as a boiler coal mill control system by MICREX-P (registered trademark), delivery in 1980 to Nippon Steel Corp. as a power generation boiler control system and, delivery of various boiler control systems by compact controller:CC-F (registered trademark). The delivery experience of these has been accumulated and the various performances of digital control technology, that is controlability, operability, reliability. maintainability, etc., have been confirmed. This system was developed as a dedicated power generation boiler model based on the Fuji Electric boiler control technology accumulated over many years like this, newest control technology, and computer system technology.

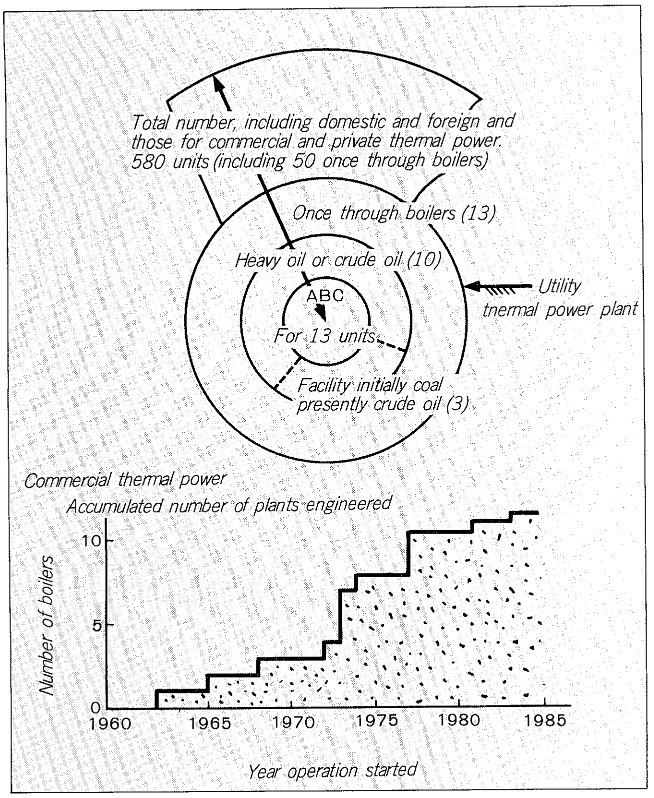
3.2 System positioning

From the standpoint of constructing a power generation boiler control system, the trend is toward CRT operation and consolidation of the following three systems must be performed to centralize operation and supervision.

(1) Feedback control (Closed Loop Control) system for ABC (Automatic Boiler Control)

(2) Sequential control (Open Loop Control) system for motor, etc. starting and stopping

Fig. 2 Record of Fuji Electric boiler control technology



(3) Computer system for automation of power plant starting and stopping operation

These control systems are connected by a dataway (DPCS: Distributed Process Control system, N:N serial transmission system, transmission speed 1.5M bits/sec) and form a part of a power plant automation system.

3.3 System composition

The control concept of a large thermal power generation boiler using this system is shown in *Fig. 3*. The control functions necessary are grouped hierarchally into three main categories like they are divided into MCU, LCU, and OMU in the figure.

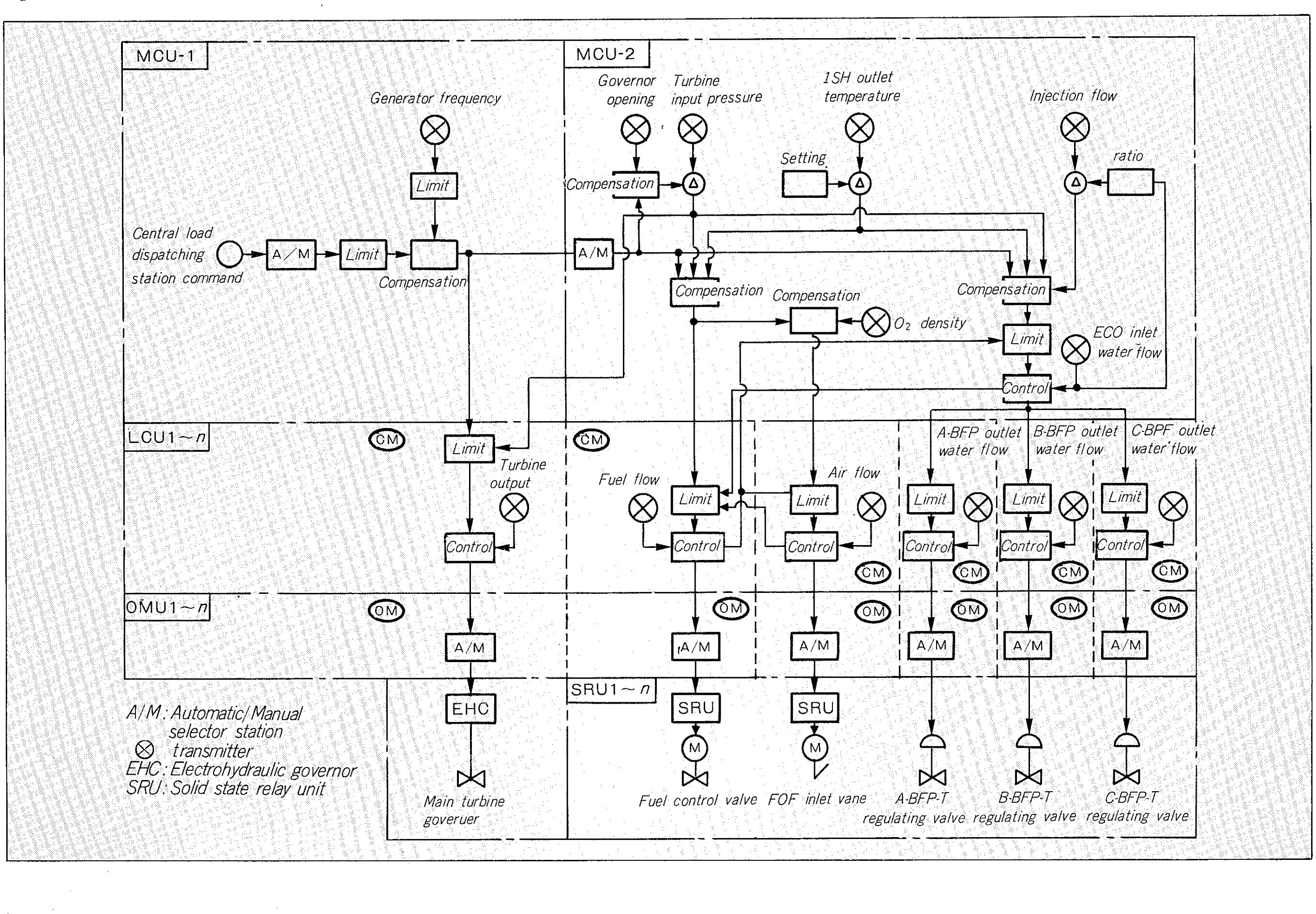
(1) Master control unit (MCU)

The master control unit is the part which has general control functions of the thermal power generation boiler. It is used as the unit master and boiler master. Since addition and subtraction, compensation computation, various rate of change computations, and other complex computations are necessary at this control unit, numerous computation modules (wafers) are available.

(2) Loop control unit (LCU)

The loop control unit receives the master control unit computation output signals as setting signals and is used in control computation centered about PID computation with various measurement signals (water flow, fuel flow, air flow

Fig. 3 Basic control block diagram for sliding pressure operation once through boiler



signal, etc.) as the feedback quantity. As a rule, the loop control unit corresponds to one module card at one actuator. Ease of understanding each loop control system and distribution of risk of the system by prevention of fault wave to other loop control systems by failure of one card are attempted.

(3) Operation module unit (OMU)

The operation module unit receives the control mode signal from the loop control unit and setters (indicated A/M in the figure) and performs loop control system automatic-manual control mode selection and outputs the operation signals in the manual operation mode.

The control system constructed based on the unique functional classification at a thermal power generation boiler control system as described above is this FAPS-8000 power generation boiler control system. Its detailed composition is shown in *Fig. 4*.

This system is realized by a card construction with the necessary functions as modules, and units are constructed by one or a combination of several module cards. These module cards are installed in shelves provided in a cubicle. An I bus (*N:N* serial transmission system, transmission speed 10M bits/sec) is used for signal transmission between module cards in the shelf and DPCS is used for signal transmission with the high level computer and organic coupling is attempted.

Moreover, there is an advanced control unit which realizes high quality control logic which is an important function of a boiler control system. The features of each unit are shown below.

(1) Master control unit (MCU)

The MCU is used at the master controller and consists of multiple module cards to enhance the arithmetic processing functions. The MCU can also have a duplexed construction.

(2) Loop control unit (LCU)

The LCU is used at the loop controller and, as a rule, consists of one module card for one actuator. This unit also incorporates a *N*:1 (8:1) backup.

(3) Operation module unit (OMU)

The OMU is used at the manual operation section, and consists of one module card for one actuator.

(4) Advanced control unit (ACU)

The ACU is used in high quality control computation by AR (Auto Regressive) method and other mathematical models, and consists of one module card.

(5) Solid state relay unit (SRU)

The SRU is used in forward and reverse control of the motor drive actuators by pulse width output which is one of the features of the Fuji Electric control system. The reliability and maintainability of this circuit have been improved by making the motor drive circuit contactless.

The basic specifications of each module card are shown in *Table 1* and the common specifications of the system are shown in *Table 2*.

Fig. 4 FAPS-8000 system composition

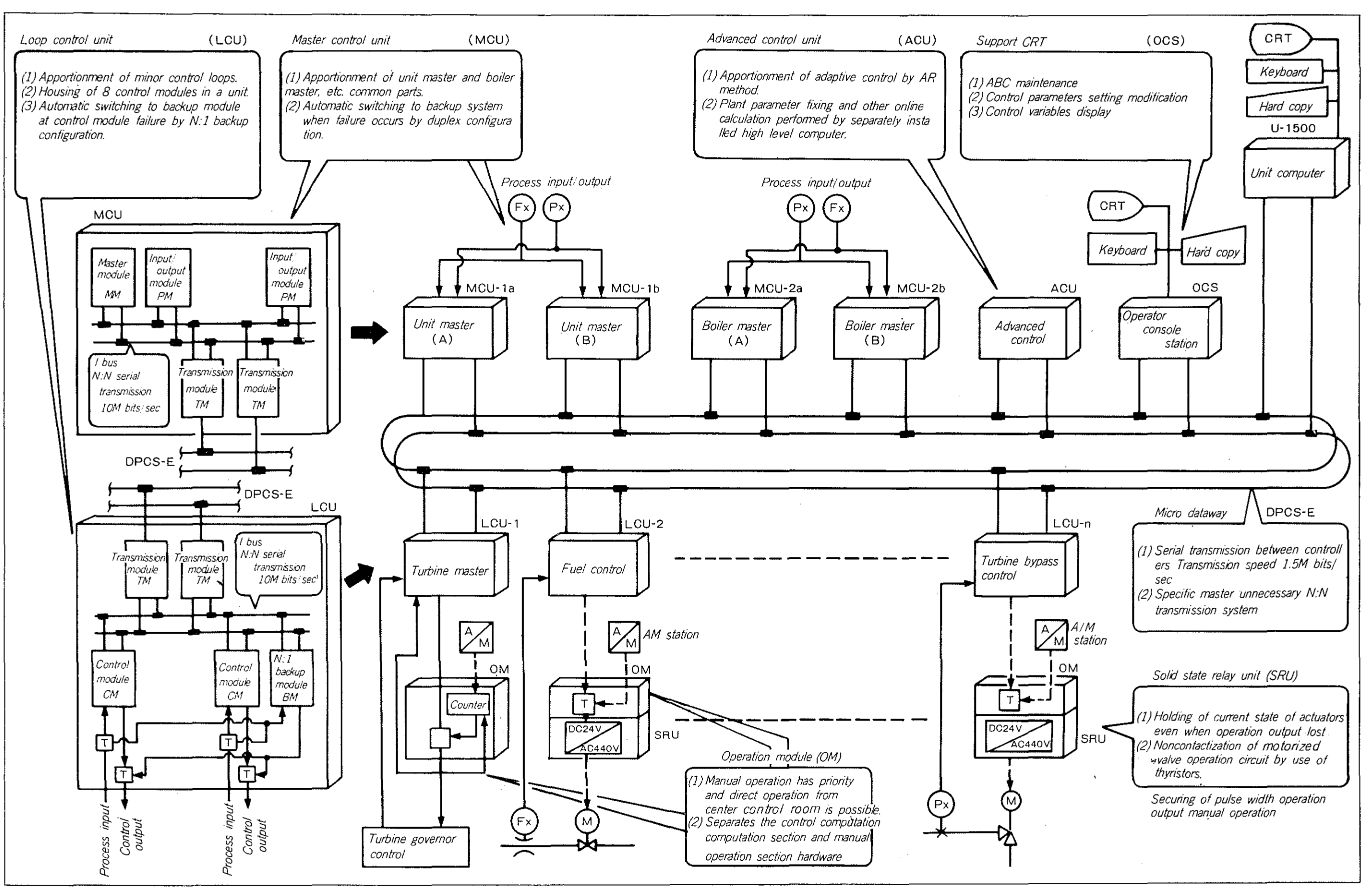


Table 1 Basic specifications of modules

Item			Control module C PMUK	Control module S PMUL	Computation module PMUM	Logic module PMUS	Backup module CB: PMULSB:PAN	Master module PMUT	I/O module PMUR	Advanced module PMUP
Unit name			Loop control unit (LCU)					Master control unit (MCU)		Advanced control unit (ACU)
Module name			CM				BM	MM	PM	AM
Basic computation unit	Computation system		Fixed point computation							Floating point computation
Basic computation unit	Application computation		Wafer system							
Basic computation unit	Processing speed After application computation		0.1s/64 Wafer					0.5s/512 Wafer	—	Addition 52.4μs Subtraction 55μs
Basic computation unit	Microprocessor used		16 bit microprocessor							
Memory			ROM 32k bytes RAM 61k bytes EAROM 4k bytes dual port RAM 4k bytes				ROM 32kbytes RAM 32k bytes Dual port RAM 16k bytes	ROM 32k bytes RAM 144k bytes EAROM 16k bytes	ROM 32k bytes RAM 16k bytes EAROM 4k bytes Dual port RAM 4k bytes	ROM 32k bytes RAM 144k bytes EAROM 4k bytes Dual port RAM 4k bytes
I/O device	Digital input	Specification	DC24V				(Note) All PI/O including the next stage output are internally used for backup.	Non-process Input/output	DC24V	Non-process Input/output
I/O device	Digital input	Number of points	14	14	12	18			12	
I/O device	Digital output	Specification	DC24V Tr. output						DC24V Tr	
I/O device	Digital output	Number of points	20	20	20	20			19	
I/O device	Analog input	Specification	DC1 ~ 5V	DC1~5V 10-100-10**					DC1 ~ 5V	
I/O device	Analog input	Number of points	8	8	7	–			7	
I/O device	Analog output	Specification	DC1 ~ 5V DC4-20mA (MV signal)				PMUU: DC4-20mA, 1 points as MV signal		DC1~5V	
I/O device	Analog output	Number of points	5	4	4	1 set			4	
I/O device	Pulse input	Specification	DC24V						DC24V	
I/O device	Pulse input	Number of points	2 sets	3 sets	2 sets	–			2 sets	
I/O device	Pulse output	Specification	DC24V Tr.output				PMUV: DC24V Tr. output 1 set as control output		–	
I/O device	Pulse output	Number of points	–	1 set	–	1 set			–	
Data transmission system, speed			I bus for mutual modules, N:N 10M bits/sec							
RAS function	Reliability		Transmission module, power supply duplexing and self-diagnosis function							
RAS function	Maintainability		Module units trouble display, detailed trouble contents display by CRT							

<**> One point of 8 points is for opening use.

3.4 System Features

The features of this system are described below.

3.4.1 High reliability

When a power generation boiler is stopped by some kind of trouble, the power and steam supply is, of course, also stopped and it is accompanied by a corresponding loss for restarting. Therefore, when manufacturing a power generation boiler control system, engineering must be simple and the system must be made highly reliable.

From such a standpoint, the following high reliability

Table 2 System common specifications

Item		Specification
Analog signal		Between field and cubicles: DC4-20mA Inside cubicle: DC1-5V Cubicle monitoring instruments: DC1-5V or 4-20mA
Binary signals		DC24V (OFF) 0V (ON)
Data transmission		With high level system shelf: Micro dataway (32 ports, N:N) 1.5M bits/sec In shelf: I bus (N:N 10M bits/sec)
Power supply		System: AC100V or DC110V (Duplexed for each shelf) Setter/manual station: AC 100V or DC110V (Duplexed or triplexed for each group)
Dimensions		Setter/manual station: IEC and DIN standard 72 type and 144 type Control module: 233.4(H) x 30.5(W) x 284.5(D) (mm) Power module: 243.6(H) x 60.2(W) x 284.5(D) (mm)
Explosionproof class	Pressure resistant construction	JIS ds 2G4 by connection to FC series
	Intrinsically safe construction	JIS i 3nG5 (AC550V or less, DC 34V or less) by connection with FC series and zener barrier.
Grounding		Intrinsically safe explosionproof. . . . . . . JIS Class 1 (independent) Lighting (with arresstor) . . . . . JIS Special class 3 Others . . . . JIS Class 3
System cubicle installation conditions		0-50°C, 10-90% RH or less in operating state −10～50°C (no condensation) in storage state Vibration 0.2G Shock 5G (during shipment) 1G (during operation)

measures were taken with this system from the standpoints of hardware technology and software technology. The MTBF (Mean Time Between Failure) of a sliding pressure once through boiler control system is substantially improved by about 3000% compared to that of the analog control system.

(1) Design, manufacture, and quality control with high reliability quality control as a precondition.

(2) Reduction of failure rate by reduction of the number of parts used by using custom LSI.

(3) Redundant and duplexed system construction.
  (a) Power supply different system duplexing
  (b) MCU duplexing, LCU N:1 backup
  (c) Duplexing of dataway (DPCS) and I bus transmission.

(3) Distributed risk design
  (a) One actuator 1 module card system design at LCU
  (b) Disconnection of faulty point by use of N:N transmission system (DPCS and I bus) (fault tolerant)

(4) Securing of control output from LCU when OMU fails

(5) Use of software technology (wafer system) with a record of achievements

3.4.2 Enhancement of self-diagnosis functions

With this system, automatic switching to the backup system is performed by module card internal power fault diagnosis, control program fault diagnosis, process I/O processing unit, fault diagnosis, transmission processing unit diagnosis, and other self-diagnosis signals and automatic control is continued when one part is faulty. The current position of the control output is held and plant operation is performed even when trouble occurs simultaneously at the main system and backup system or trouble occurs at an external elements due to an abnormal transmitter signal. The self-diagnosis signals are classified into three levels of module card internal heavy fault (FLTO), internal light fault (FLT1), and external fault (FLT2). These are used at the system design stage and a transmitter duplexed, mutual diagnosis between shelves, etc. higher reliability system is constructed.

3.4.3 Operability

As the system scale becomes larger, the man-machine interface hardware also increases, and human engineering operability is especially important. With this system, an CRT operaton-oriented system construction and continuation of the operating feel of the operator from the past are considered and various setters and manual stations (with 72 type, 72 x 144 type plasma bar graph display and various control mode displays) which allow operation in the analog sense are provided.

3.4.4 Maintainability

The maintainability of the system is important to the user, and is improved by ease of trouble detection, ease of system restructuring, and the minimization of repair spare parts. FAPS-8000 maintenance tools are available with this system. When a self-diagnosis fault signal is generated by a module card, an alarm is displayed at the BTG panel (Boiler Turbine Generator Panel) and the display of the individual module cards is lighted and the faulty module card is easily detected. The detailed contents of the fault can be learned with the support CRT or the data entry unit. Replacement with a spare module is easily performed by module checker and support CRT aid.

3.4.5 System expandability

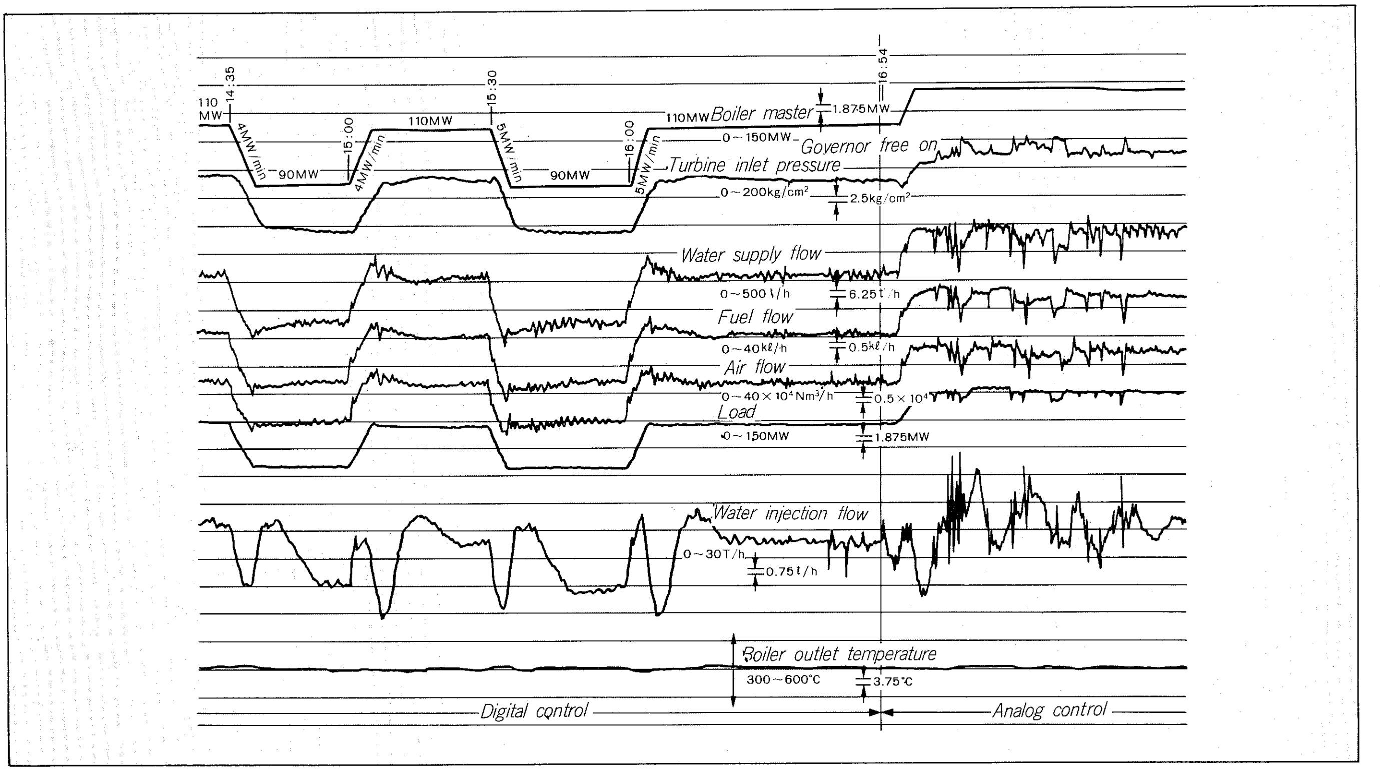
Since this system is connected to other systems by a dataway (DPCS) as shown in FAPS-8000 System Construction (see *Fig. 4*), it can easily cope with the rapidly developing man-machine interface technology and connection to a high level computer in shelf units and connection to a sequential control system are possible and, at the same time, system expansion can be easily achieved. Moreover, since the module cards in the shelf are connected by an I bus, expansion in module printed card units is also easy.

Such system expandability makes step by step expansion possible and is especially effective as a facilities updating countermeasure.

4 FAPS-8000 ACTUAL SYSTEM VERIFICATION TEST

Part of this system manufactured on the previously

Fig. 5 Load variation test recording (digital/analog system)



described development concept was incorporated into part of the analog (Fuji Electric IS Series) boiler control system of the Ishikawa Thermal Power Plant No. 2 machine (125MW, variable pressure once through boiler, 400t/h, 154kg/cm^2, 540°C) with the cooperation of the Okinawa Electric Power Co., Inc. and actual system verification tests were conducted for one year starting from March 1983. Moreover, this power generation unit is an important unit as intermediate thermal power from the standpoints of basic load operation of the Okinawa region main thermal power unit and day-nighttime power variation adjustment operation, and started operation on June 9,1983.

4.1 Actual system verification test results

The results of the actual system test performed on April 4, 1983 are shown in *Fig. 5*. The left half of this recording is the control result by this system and the right hlaf is the control result by analog system and shows that operation was switched from this system to the analog control system at 4:54 P.M.

As shown in this recording, the variation width of the main steam pressure at the sustained load test (110MW, → 90mMW) 5MW/min (4%/min) as a control result of this system is +2~−1°C. The variation width at the step test (100MW → 120MW) performed on another day was 0~+2°C and the variation width at the cyclic load test (110MW *5MW) was a good control result of ±2°C. Moreover, even during "AFC + governor free operation" and other severe load change operating states, the main steam temperature variation width and maintained at ±5°C and good results were obtained as expected.

The superior controlability, reliability, maintainability, etc. of this system was verified by about six months of actual system operation as described above.

5 CONCLUSION

Fuji Electric's newest power generation boiler digital control system FAPS-800 was introduced centered about an outline of the system. However, since there are still things which must be verified and the system will be improved in the future, improvements will be accumulated with the cooperation of all users.

Finally, the authors wish to thank the Okinawa Electric Power Co., Inc. and Kawasaki Heavy Industries Co., Ltd. for their cooperation in the actual system verification tests.