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APPLICATION OF INTEGRATED CONTROL SYSTEMS TO INDUSTRIAL PLANTS

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1. FOREWORD

The general industrial field is shifting from the conventional mass production system to a multiple type, small amount production system to meet the diversification of market needs. To cope with such a production system shift, flexible and high cost-performance control systems are also being demanded for plant control systems centered about the computer and controller.

In the past, these plant control systems were composed of an electric-machinery control system (E) centered about sequential control and motor control, instrumentation system (I) based on feedback control at the direct control level, and a computer control system (C) which is responsible for production management and process management and other overall management and functions were allocated according to the application.

The development of each control system was directed toward the optimum shape for each field and original technical culture was formed and coexisted. However, with the appearance and rapid advance of the microprocessor, the functions and performance of each control system that uses the microprocessor widely was improved tremendously. As a result, all the control systems are similar to the standpoint of the basic configuration of the hardware and the disunity of equipment operation, engineering, maintenance, etc. due to the overlapping of functions and difference of the technical culture of each control system is becoming a problem. Therefore, the realization of a more flexible and good cost-performance control system by integrating the E, I, and C control systems is desired and is being practicalized.

Fuji Electric is carrying on the culture and standardizing the culture of each control system and supplies systems for practical use as EIC, EC, IC, EI integrated control systems according to the ratio of E, I, and C for general industry. This paper introduces the components and functions which make up an integrated control system with a high ratio of e.

2. INTEGRATED EIC CONTROL SYSTEM APPROACH

The steel, chemical, paper plant, and other general industrial fields have many scales and applications and diverse control systems are demanded according to the difference of the technical culture of each field. At Fuji Electric, the construction of an integrated control system that meets these needs is realized on the following five points:

(1) Supplying the optimum components for each function level.

The independence of the components of each level is increased so that a system can be built with each.

(2) Network is made three levels of upper, middle, and lower.

The upper level LAN uses an open-oriented universal LAN IEEE802.3 (TCP/IP) and the middle level control LAN uses the abundant the Fuji Electric original LAN (DPCS-F) which emphasizes fast response and a system is built with these as the nucleus. The lower level field level use the Fuji Electric field network (F-Net) which is focused on processability.

(3) Improvement of operability and supervisability

A integrated man-machine interface (MMI) is supplied between EIC and operation concept unification, programming techniques integration, and information transparency are realized.

(4) Unification of hardware architecture

For the controller, MMI, and other components, integration of the architecture is planned and application to the E and I fields is dealt with by building in expert package software.

(5) Realization of more efficient maintenance

The functions of the controller support tools are integrated and unified service that absorbs the differences of E and I is made possible for the controller.

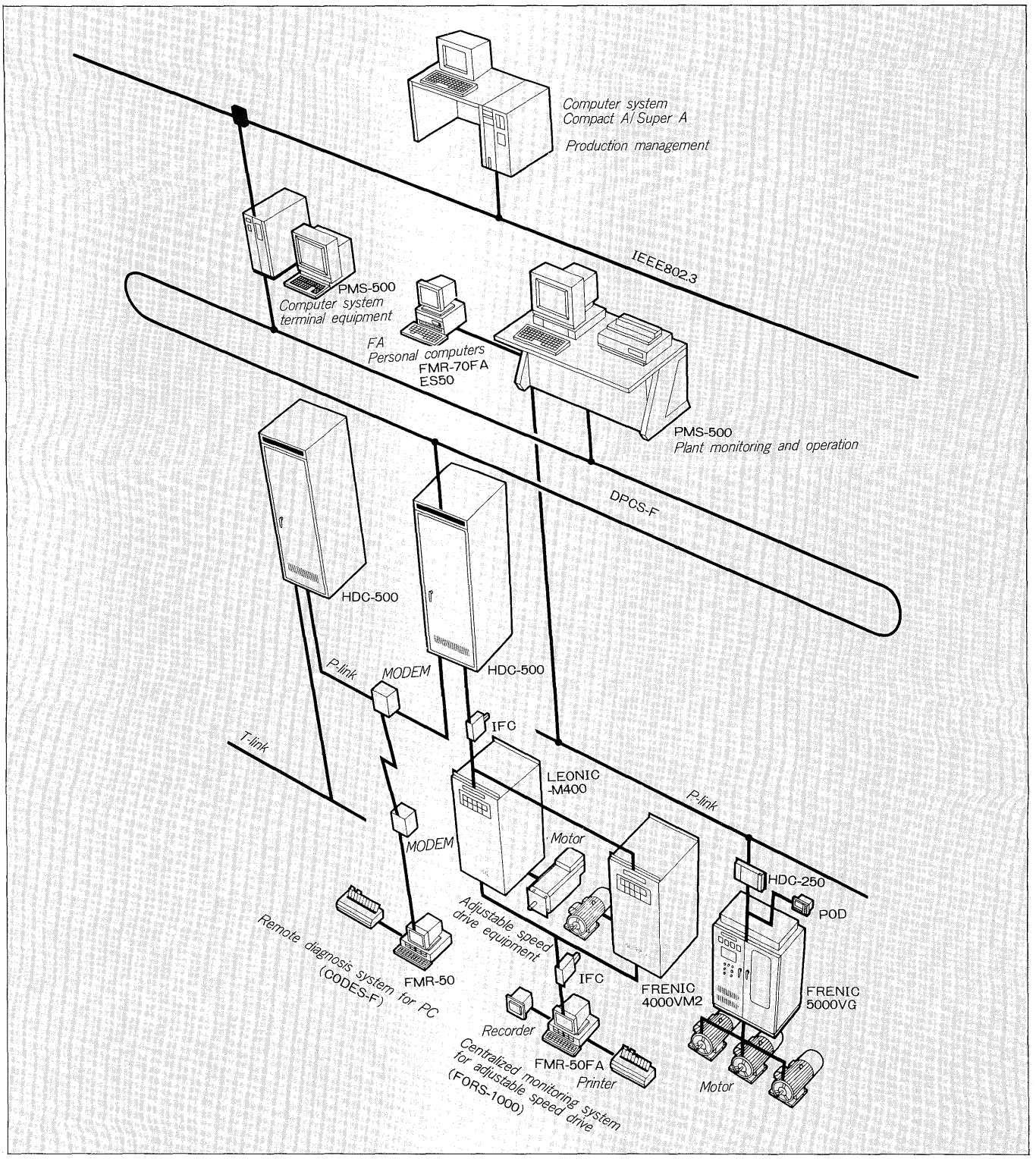
3. APPLICATION EXAMPLES

3.1 Large-scale EC system

3.1.1 System configuration

An information processing and power electronics fusion system in the steel, cement, chemical, paper making, and other general industry field is introduced. This system is centered about an EIC integrated controller MICREX-F500 Series and consists of a computer system, variable speed drive system, field instruments and other functional-

Fig. 1 System block diagram for large-scale EC system



ly hierarchical system components, and a 3-level network which organically integrates these.

The system block diagram is shown in *Fig. 1.*

3.1.2 Components

(1) Computer system

A 32-bit super minicomputer "Compact A" or "Super A" is used as the system which decides the production and operation schedule and performs production management by means of results data. It has a 32-bit high-speed bus, high-speed disk drive and other hardware and powerful real-time execution functions based on an open network environment and high reliability and an excellent cost-performance system is realized.

(2) Man-machine interface (MMI)

A man-machine station "PMS-500" is used as the MMI which realizes operation functions on a plant operation status monitoring and setting operation etc. operation level.

As an MICREX-F500 Series product, the control functions part of the PMS-500 consists of the same hardware and software as the 32-bit high-speed, high-performance programmable controller (PC) "HDC-500". It also has display, operation, and logging data processing functions. This composite function controller is capable of simultaneous parallel processing.

Integration of the hardware, which is an important element of an integrated control system, is strived for and the perfect MMI environment for real-time plant monitoring and operation in the high-speed control demanded by the electric field is realized.

The PMS-500 is also used as the computer system terminal equipment. Work is performed with individual MMI for conventional site use and for computer system use and detailed information is supplied to the operator by displaying and setting the data-interfaced site data and computer data at the same screen and operability is improved by common operation and unified data management can be performed as a common MMI in an integrated control system.

(3) Controller

For the control use controller, a 32-bit high-speed, high-performance PC "HDC-500" is used in main trunk control which demands fast response as a control objective and a compact high level functions PC "HDC-250", which is a lower level model of the HDC-500, is used for other control and a control system aimed at the optimum function allocation and distribution is built.

The HDC-500 is a controller with electric field oriented packages installed in a MICREX-F500 Series EI integrated controller. The hardware basic bus system uses the 32-bit multiprocessor bus "MULTIBUSII", which is an international standard bus, and is integrated by uniform hardware which is internationally interchangeable with the previously described man-machine station "PMS-500".

A 32-bit custom LSI is used at the CPU section. It power is displayed in high-speed control by speeding up floating operation and interrupt function by multitask processing, not to mention the sequence control and various operation functions.

Hardware architecturally, the HDC-250 is positioned as the highest level model in the MICREX-F Series universal PC series. However, it can be positioned as a low level model of the HDC-500 as a PC which executes the function type control language FCL (Functional Control Language) which is used by the MICREX-F500 series to realize high-speed arithmetic processing by high-performance custom LSI and to integrate the control software.

Here, the controller (HDC-500/250) and MMI (PMS-500) are machine which can both execute FCL and much package software can be used in common and interchangeability is excellent and the support tools can also be integrated. In other words, production, testing, operation, and maintenance labor saving and higher efficiency are aimed at by software integration at the integrated control system.

Function units standard software packages which allow construction of various control system software by a building block system are installed in these machines and high software reliability is realized.

(4) Adjustable speed drive equipment

In an electric-machinery control system, whether or not important electric machine can be controlled safely, smoothly, and as intended, that is, the performance of the adjustable speed drive equipment, has a large affect on the entire system.

In the past, to satisfy high-precision speed control and fast response, direct current machines (DC variable speed control equipment) was used, but with the development of power electronics and adjustable speed control technology, at the present time at which electronification of control equipment and mounting of microprocessors, of course, and practicalization of modern control theory are strived for, the use of alternating current machines (AC variable speed control equipment) with their many merits, including maintenance-free operation by brushless construction, are becoming the mainstream.

Fuji Electric supplies optimum adjustable speed drive equipment according to the application and scale to meet these needs and uses function allocation and distributed controller and the following variable control equipment which can be organically connected by a network as components which make up the integrated control system:

(a) Main motor high capacity DC motor used
DDC Thyristor Leonard for plant "LEONIC-M400"

(b) Main motor peripheral AC motor use
DDC transistor inverter for plant "FRENIC 4000VM2"

(c) Auxiliary motor related AC motor use
Vector controlled general-purpose transistor inverter "FRENIC 5000VG"

The LEONIC-M400 and FRENIC4000VM2 are for plant use and the controller is all digitalized (DDC) and high accuracy, high level functions, and fast response are realized. Mounting of observer control by modern control theory and other newest technology are crystallized.

Both have a high-speed transmission interface (IFC) "F-NET P-link" with the high-level PC and operation sequence signals, speed and various set values, and PI constants and other parameter set values from the controller (HDC-500), which is responsible for main trunk control, and operation status signals, alarm signals, and voluminous other data from the controller are interfaced rapidly and smoothly.

A maintenance network (P-link) independent from the control system transmission line can also be connected to these variable speed control equipments and real-time operation data acquisition by centralized monitoring system for adjustable speed drive equipment "FORS-1000" described in item (5) and trace-back of trouble and operation data before and after the set trigger timing, etc. make

maintenance centralized and more efficient.

The FRENIC5000VG is a general industry oriented general purpose inverter FRENIC5000 Series product. High-speed control accuracy, wide variable speed range, and fast transient response are realized as a vector controlled transistor inverter and brushless variable drive is realized to field corresponding to the conventional DC motor by combining it with a dedicated totally enclosed, fan cooled, cage rotor type induction motor.

For the FRENIC5000VG, a PC interface unit (MCAII-TL "F-NET T link" is available as an option and it can be used from conventional stand alone application to use as an ideal component in an integrated control system by connecting it to a PC (HDC-250).

(5) Engineering and maintenance tools

The following three tools realize concentrated and more efficient engineering and maintenance:

- Software engineering support for PC "ES-50"
- Remote diagnosis system for PC "CODES-F"
- Centralized monitoring system for adjustable speed drive equipment "FORS-1000"

(a) Software engineering support system for PC "ES-50"

ES-50 is a consolidated tool which supports generation of programs to their testing, maintenance, and documentation uniformly from MICREX-F Series low end models to high end models. It also supports controller diagnosis, etc. and is a software product which runs on a universal personal computer.

Substantial labor-saving and higher efficiency can be realized in software production, testing, operation, and maintenance by integration of software for the controller (HDC-500/250) and MMI (PMS-500) and integration of support tools.

(b) Remote diagnosis system for PC "CODES-F"

CODES-F is a trouble diagnosis support system for PC (MICREX-F500 Series) which is operated in the maintenance contract system concluded between Fuji Electric and the user.

In the modern plant control field, the PC is a process direct control level device and with the development of software support by improved software performance (increase of number of input/output points, increase of program memory and data memory and higher level functions by completion of various operation processing instructions and other high-speed processing) and a control system based on digital control theory (introduction of advanced control, etc., including modern control theory), it is becoming more complex and advanced so that the functions processed by 2 or 3 PC in the past are now performed by one PC. When the reliability of the system is considered here, first the ability for the system to operate trouble-free is essential and the ability to minimize the affect on the plant and effect repair in a short time if trouble should occur due to aging and physical hardware degradation are said to be absolute conditions.

However, in the past, daily maintenance and conservation of the user's system had many parts which depended on the user and when trouble occurred, testing, dispatch of serviceman, cause investigation, and countermeasures by the user or by telephone contact from the user took a very long time.

CODES-F is a system in which an expert board is installed in the user's MICREX-F500 series and when trouble occurs at the PC, the line is connected automatically and the trouble status information is collected and analysis and faulty section are detected by an expert system by connection to a host computer installed at the Fuji Electric conservation and maintenance department by telephone via a modem. Remote support functions are also provided and circuit monitor, data table display, data trend display, etc. can be performed.

In short, user maintenance department labor and unmanning and substantial shortening of the trouble repair time can be realized by supplying collection of trouble information, positive grasping of the state when trouble is generated, detection of the faulty section by expert system, and other optimum maintenance service via a telephone line in any area.

(c) Centralized monitoring system for adjustable speed drive equipment "FORS-1000"

Adjustable speed drive equipments, whose functions are becoming more advanced as described in item (4), are distributed in function units or facility units in the plant and are batch controlled by PC.

FORS-1000 is a maintenance work station system to improve maintainability which maintains and manages these adjustable speed drive equipments. Remote centralized monitoring of data collection and monitoring work conventionally performed at a 1-to-1 ratio at adjustable speed drive equipments and individual installation sites is possible at a 1-to-N (maximum 200 units) ratio by using a maintenance network (P-link) independent from the control system transmission line.

Since arbitrary operation data can be collected in real time and can be recorded by CRT display and pen recorder for multiple variable speed drive equipments by means of this, detailed data collection during normal operation and cause analysis when trouble occurs are performed easily. Especially, for operation status grasping and trouble analysis, etc. between adjustable speed drive equipments linked on the process line, etc., substantial rationalization and shortening of the repair time at trouble generation can be planned.

(6) Network system

The following three network systems are used for integrated control system construction by considering their application and performance:

- TCP/IP (IEEE802.3)
- DPCS-F
- F-NET

(a) TCP/IP (IEEE802.3)

Transmission Control Protocol/Internet Protocol is position at the top of the network function hierarchy and is an open network system which is most widely used to connect computers, work stations, and personal computers, etc. When expandability as a system is considered, it is suitable for connection between different systems.

The Fuji Electric computer A series and man-machine station "PMS-500" can be connected to TCP/IP and an efficient system construction can be planned.

(b) DPCS-F

DPCS-F is the Fuji Electric standard high-speed, high-level function, high reliability control local area network (LAN) system which becomes the nucleus of the integrated control system.

The EI integrated controller MICREX-F500 series, which is an integrated system component element, and various Fuji Electric computers, etc. can be organically connected.

(c) F-NET

F-NET is position at the bottom of the network functions hierarchy and the Fuji Electric standard field area network system which handles control data and process input/output data. It consists of P- and T-links.

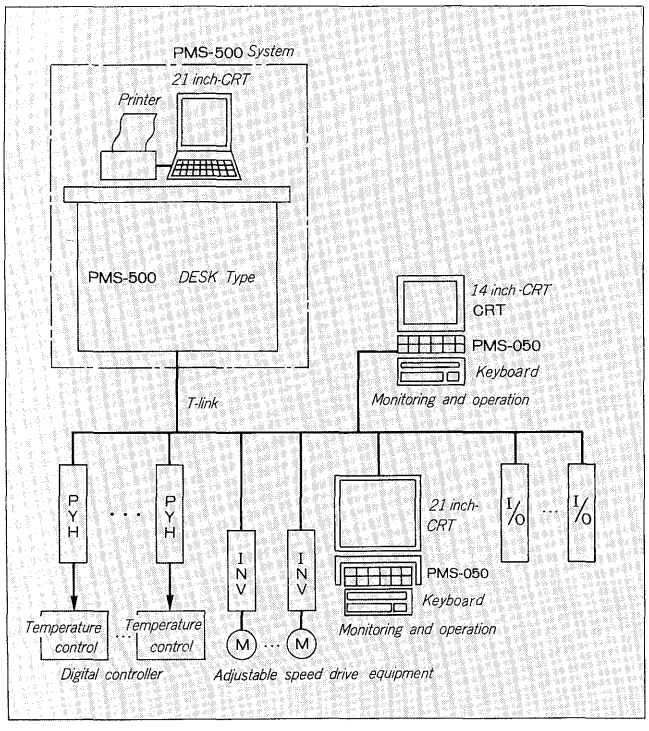
The P-link is an LAN which couples computer, controller, and other processes at a 5 Mbps transmission speed.

The P-link is also used as a network for the adjustable drive equipment "LEONIC-M400", "FRENIC 4000VM2" which require a high speed and voluminous data interface from among the adjustable speed drive equipments described in item (4) and as the network for the engineering and maintenance tools "CODES-F" and "FORS-1000" maintenance described in item (5).

The T-link is a serial transmission network which connects between process input/output devices (PIO) which are connected to various controllers and FA personal computers at a 500 Kbps transmission speed.

The T-link can also connect the adjustable speed drive equipment "FRENIC5000VG" described in item (4) and motor control center "SM1200-CMC".

Fig. 2 System block diagram for small-scale EI system



3.2 Small-scale EI system

3.2.1 System composition

A system which centralizes film and electric wire, plastic production line, etc. in a self-completion form on a comparatively small scale is introduced.

Regarding the control contents, production completion, line speed control and tension control variable speed control and material and production process temperature, pressure, flow, and level loop control (PID control) are mixed from material feed to product completion.

The composite controller functions of the man-machine station "PMS-500" are used here. Moreover, a microcontroller "PYH" which can perform PID control functions allocation processing on a local level and adjustable speed drive equipments are connected on a T-link and a small-scale EI system with a simple system composition is realized.

The system block diagram is shown in *Fig. 2.*

3.2.2 Components

(1) Man-machine station "PMS-500"

The PMS-500 realizes the following three functions with one unit:

- MMI function
- Computer function
- Controller function

(a) MMI function

Operation which performs production and operation schedule decision and results data collection operation and operation at the plant operation status monitoring and setting operation level are realized as an overall system integrated MMI.

With such a production system, at the production process per product, continuous operation in the normal state is long and the production interval is also comparatively long at machine side pre-preparation, etc. Therefore, operation can be amply handled with one MMI.

When site installation MMI are necessary, the intelligent monitoring terminal device for PC "PMS-050" to be described later can be connected. In this case, operation status monitoring and setting operation and other operation level operation can be allocated to the PMS-050.

(b) Computer function

The following functions are provided to perform production and operation schedule management, results data collection, and preparation of records by

product:

- Various setting tables by product preparation and registration function
- Operation schedule registration and operation function
- Results data collection and product record preparation function

(c) Controller function

System overall integrated control is performed by the control function section of the PMS-500. Especially, since the PID control function can be realized with a microcontroller "PYH" which can perform allocation processing on the local level by T-link connection, the control load on the PMS-500 can be lightened substantially.

(2) Intelligent monitoring terminal device for PC "PMS-050"

The PMS-050 is connected to a MICREX-F Series T-link and is a site-oriented MMI which allows remote distributed installation of multiple units.

It consists of a compact unit, CRT display, and keyboard instead of the conventional operation panel and monitoring panel and performs facility operation status display, trouble monitoring, and operation setting.

Here, the PMS-050 and PMS-500 display image describing language is interchangeable and since common use of software is possible at screens with the same format, software production, testing, operation, and maintenance labor saving and improved efficiency are possible.

(3) Microcontroller "PYH"

PYH is a compact, high level functions digital controller which can be used in press, flow, level, and other PID control, including temperature control. A voltage/current multi-input type is available, in addition to thermocouple and resistance bulb as the controller input. There is also a two outputs type capable of heating and cooling controller, in addition to on/off and continuous outputs.

If a T-link interface is installed as an option, close coupling with the PC is performed and construction of an integrated sequence control and loop control system can be easily realized.

T-link transmission interfaces the setting value (SV), control use PID constant, and other parameter setting values from the PC and control status signals, trouble signals, and other information, in addition to process variable (PV) and manipulated output value (MV), from the PYH.

Control (local operation) by PYH alone is also possible and independent operation separated from the system or if the PC should be shutdown, can be dealt with quickly.

(4) Adjustable speed drive equipment

The previously described vector controlled general purpose transistor inverter "FRENIC5000VG" which can be connected to the PMS-500 T-link is used as the adjustable speed drive equipment.

4. CONCLUSION

An example of an integrated control system was introduced above. As also introduced in other articles in this special issue, Fuji Electric supplies various control systems according to the scale and application. The integration points of all these systems are unification of hardware architecture centered about the MICREX series, network standardization, data construction standardization, unification of the operation concept of the man-machine interface section, integration of engineering techniques, etc. and correspondence by application field is realized and results accumulated by a software technology function architecture. We will continue to supply systems with superior flexibility to meet the needs of the market in the future.