NIPPON STEEL TECHNICAL REPORT No. 73 APRIL 1997

UDC681.32:669:621.746.29

Application of Rightsizing and Open System to Continuous Casting Process

Kenji Kawahara*1
Hirokazu Kato*1
Nobuo Sumida*1
Tetsuji Fukushima*1

Abstract:

Nippon Steel led the steel industry in adopting general-purpose personal computers and operating systems as process control computer systems for ironmaking and steelmaking processes, and developing a rightsizing and open system as a future model for the steel industry. Before developing the system, an evaluation system was built and used to evaluate the real-time performance and reliability required of process computers and to predict the detailed load of the commercial system. Control middleware and support tools were originally developed as well. To ensure its reliability and maintainability, the system was equipped with enhanced RAS (reliability, availability, and serviceability) functions. Engineering productivity was improved by using commercial tools to take advantage of the open nature of the system. Basic technology was thus established for the application of rightsizing and open systems in ironmaking and steelmaking processes.

1. Introduction

The increasing severity of the environment surrounding the steel industry demands more advanced and diversified functions of steel plant process control computer systems, and strongly calls on the steel industry to reduce production costs. Under these circumstances, personal computers and other general-purpose information products have achieved higher functionality and prices are lower. Research and surveys have been undertaken to apply personal computers and related information products in the process control area. Personal computers have found widespread commercial use as process computer terminals and auxiliary line process computers[1].

In the case introduced here, open and general-purpose personal computers replaced conventional process computers for the first time in the continuous casting process, a main steelmaking line in the steel industry.

In the development of the open personal computer system, an evaluation system was built and used to assess the real-time performance and reliability of the planned system. Middleware and engineering support tools required for steel plant process control application software were originally developed. Basic technology was thereby established for building rightsizing and open systems of ironmaking and steelmaking process computers.

2. Background for Rightsizing and Open System

2.1 Characteristics of conventional process computers

Process computers are required to have high enough real-time performance and reliability for the integrated control of large and fast ironmaking and steelmaking processes 24 hours a day. For this reason, special-purpose machines and operating systems made

*1 Technical Development Bureau

by a limited number of manufacturers advanced for process computers. These closed systems, however, had the following problems:

(1) Few process computers are available in the market, so only a limited cost reduction can be achieved.

(2) Existing systems had to be expanded or modified by using machines of the same make or model. It was thus difficult to fuse existing systems with latest low-cost general-purpose products while making the most of the existing system.

(3) Spare parts had to be held in stock, and maintenance personnel had to be trained for specific models.

2.2 Characteristics of personal computers

Personal computers have markedly improved in cost performance with increasing market scale. The cost performance of central processing units (CPUs), memories, and disks is claimed to increase two times, two and a half times, and one and a half times per year, respectively. The latest personal computers on the marketplace have a capacity at least 10 times as large as that of conventional process computers if the comparison is made in CPU performance alone. For control systems, however, total performance evaluation, including the operating system, communication, and input and output as well as the CPU, is important. **Table 1** lists and compares four popular operating systems in terms of real-time performance that is a process computer requirement and openness that is a process computer issue. The operating systems are evaluated as to their openness in the following points:

(1) They have software with good portability. In other words, application software, middleware, and other software can be easily ported to other models without changing source programs.

(2) They have commercial software packages widely and cheaply available on the market.

(3) They can run on multiple platforms.

This openness is one requirement to solve problems with conventional process computers. That is,

(1) The market scale and choice increase to allow substantial cost savings.

(2) Latest machines of low cost and high performance can be adopted for expansions and modifications without supplier constraints.

(3) Spare parts and maintenance personnel can be pooled.

Table 1 Comparison of operating systems in real-time performance and openness

Legend: ○ Good, △ Fair, × Poor

Item			UNIX*1	PC real-time OS	Windows NT	OS/2*2
Developer			Various venders	Lynx*3 : Lynx Real Time System Corp. of United States iRMX*4 : Intel Corp. of United States	Microsoft Corp. of United States	IBM Corp. of United States
Supply form			Basically bundled with hardware by vendor	Supplied by developer or OEM vender	Supplied by developer or OEM vender	Supplied by developer or OEM vender
Real-time performance	Interrupt processing		△	○	○	○
	Priority designation		△	○	○	○
	Response time guarantee		×	○(Lynx), △(iRMX)	△(Driver interrupt disabling)	×
Openness	Software compatibility		Basically source program compatible. Some programs from different venders may be different in API and may not be compatible.	Basically source program compatible.	Object module compatible between same CPUs and source program compatible between different CPUs.	Object module compatible between same CPUs and source program compatible between different CPUs.
	Commercial packages		Many	Few	NT-native packages are increasing in number. Some application programs for DOS and Windows 3.1*5 can be used.	OS/2-native packages are relatively small in number. Some application programs for DOS and Window 3.1 can be also be used.
	Running machines	PC-AT compatible machines	PC UNIX	Lynx and iRMX for Windows	○	○
		PC-98*6 NEC	PC UNIX	Lynx	○	○
		Power PC*7 IBM	IBM UNIX	×	○	○
		DEC Alpha*8 DEC	DEC UNIX	×	○	×
		Other EWSs, such as those of HP and Sun	HP UNIX, Sun UNIX	×	×	×

OEM : Original equipment manufacturing, DOS : Disc operating system, EWS : Engineering work station, HP : Hewlett-Packard Co., Sun : Sun Microsystems, Inc.

*1 UNIX is a registered trademark of X/Open Co., Ltd., licensed in the United States and other countries.

*2 OS/2 is a trademark of IBM Corporation of the United States.

*3 Lynx is a trademark of Lynx Real Time System Corporation of the United States.

*4 iRMX is a trademark of Intel Corporation of the United States.

*5 Windows 3.1 is a trademark of Microsoft Corporation of the United States.

*6 PC-98 is a trademark of NEC Corporation of Japan.

*7 Power PC is a trademark of IBM Corporation of the United States.

*8 Alpha is a trademark of DEC Corporation of the United States.

3. Evaluation for Application of PC Servers to Ironmaking and Steelmaking Process Computers

One factor that hampered the use of general-purpose personal computers as process computers was the lack of major general-purpose operating systems with real-time performance. As general-purpose operating systems went 32 bits recently, products with real-time performance appeared on the market. Before they are applied to process computers, they must be evaluated as to:

(1) Total system performance, including the operating system, application software, and input and output,

(2) System reliability and maintainability.

An evaluation system was configured as shown in **Fig. 1** and used to measure and evaluate various products. The system components are as follows:

(a) Windows NT*[1] was adopted as the operating system. This is because Windows NT is an open and multiplatform operating system with real-time performance and is judged as a promising server operating system among the general-purpose personal computer operating systems listed in **Table 1**.

(b) Nippon Steel formerly developed and implemented the steel plant control application interface NS-CASE (Nippon Steel Computer-Aided Software Engineering System for the FORTRAN language) between the operating system and application software. This application programming interface (API) was revised for the C language. Middleware based on the API was newly developed on Windows NT. The interface and middleware were both evaluated.

(c) In the system configuration that includes electrical equipment (programmable logic controllers or PLCs) and instrumentation (digital control system or DCS), importance was also attached to openness, and Ethernet*[2] (TCP/IP) was adopted as a basic communication method.

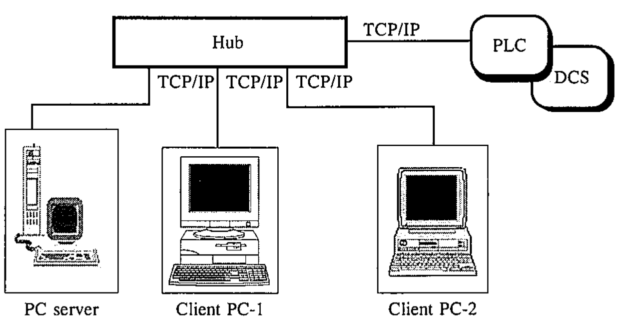
In the evaluation system, important performance items of process computers were measured, and system development issues were considered. Based on the findings thus obtained, the load of the simulated process was predicted and studied, and a commercial system was developed.

4. Load Prediction

The load prediction results of the commercial application system are given in **Table 2**. Since the system was the first steel plant main line system to exploit general-purpose personal computers, the load of the simulated process was predicted in detail. The process whose load was predicted is schematically illustrated in **Fig. 2**. The resources were the CPU, hard disk drive (HDD), control system LAN, information system LAN, and communication with upper-level computers (binary synchronous communication or BSC). The response time evaluation included the CPU processing time of the above-mentioned control middleware and application software in addition to the pure hardware resources. The base time used for the load prediction was measured by the evaluation system. The load prediction produced the following findings about the commercial application study:

(1) All resources have no load and response problems.

(2) The CPU response time measured by the evaluation sys-



Evaluation items
1. OS functions and performance: Real-time performance (interrupt, multitask and priority processing), processing time measurement, timer start accuracy, maximum number of tasks registered, and file read/write time measurement
2. Network performance: Activation of tasks in other systems, input and output of files in other systems, data communication with PLC and DCS, and measurement of various processing times
3. Maintainability: Network status monitoring and trouble analysis (system diagnosis and software run trace)
4. Reliability: Check of long-run endurance against nonsynchronous events from outside

Fig. 1 Rightsizing and open system evaluation system

Table 2 Results of load prediction

Item	Average load (%)	Response time (s)	
		Average	Maximum
CPU	10	0.1	0.2
HDD Cache access Drive access		 0 0.2	 0 0.4
LAN (information/control system)		0.3	0.7
Communication with upper level computers (BSC)		0.4	0.8

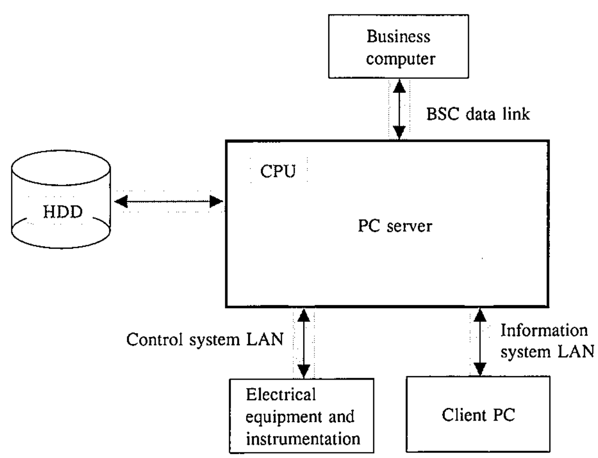


Fig. 2 Conceptual diagram of devices as targets for load prediction

*[1] Windows NT is a trademark of Microsoft Corporation of the United Sates.

*[2] Ethernet is a trademark of Xerox Corporation of the United States.

tem (Pentium*[3]) is acceptable. When the commercial system was purchased, Pentium Pro*[4] was adoptable and provides faster response time. (The latest seed technology can be exploited in this way.)

(3) The cache size is sufficiently large as compared with the application programs and assures nearly 100% cache hits. The task response depends on the CPU performance; and the HDD access time is short enough to pose no problems.

(4) Communication with electrical Sequencers is bottlenecked by processing on the sequencer side. The commercial system will employ concurrent processing with multiple Sequencers and improve in response.

Reliability was evaluated by a long-run endurance test under more severe conditions than those of actual transactions. Without any problems arising from the operating system, the commercialization of the system was judged to be fully possible.

According to these results, the system was commercially implemented as described in the next chapter.

5. Commercial Application System

5.1 Description of system

The functions of the commercial system are conceptually illustrated in **Fig. 3**. The process to be controlled is a continuous caster. The functional range of the process computer includes the arrival of a ladle of molten steel, casting of the molten steel into slabs, and cutting, marking and delivery of slabs (loading of freight cars with slabs by a crane). The application software is mainly designed for tracking and data collection. An essential consideration with respect to the system load is the need for tracking slabs in 10 zones at the slab production pitch. This translates into transactions at an average pitch of 3 seconds.

As far as the equipment arrangement is concerned, the PC server that corresponds to the process computer proper and program development personal computers are installed in the computer room. Cathode-ray tube terminals are installed in the central control room and transportation command room. A mimic panel (LED (light emitting diode) display panel) is installed at the casting floor. The computer room is located at a distance of about 1.5 km from the continuous caster and is usually unattended. For these reasons, the computer room is equipped with the function of remote maintenance from the field as described later.

5.2 Configuration of system

The configuration of the system is shown in **Fig. 4**. It is characterized by the use of general-purpose products as basic hardware and software. It is configured as a multivendor system combining different makes and models by taking advantage of its openness (see **Table 3**).

The architecture of the system is such that the PC server, program development personal computers, and client personal computers are all IBM PC-AT compatible machines. As a result, parts can be shared without dependence on particular manufacturers.

The mimic panel installed on the casting floor is a dot-type LED character display panel that indicates the casting speed and other information. The information to be displayed is edited into a special transmission format through the client server from the PC server and periodically shown at the field via the RS-232C interface (see **Fig. 5**).

A front-end processor (FEP) for processing quality statistics alone uses Windows 95*[5] as the operating system on which to mount an PI/O (parallel input/output) board driver. The FEP is schematically shown in **Fig. 6**.

The other system configuration features are as follows:

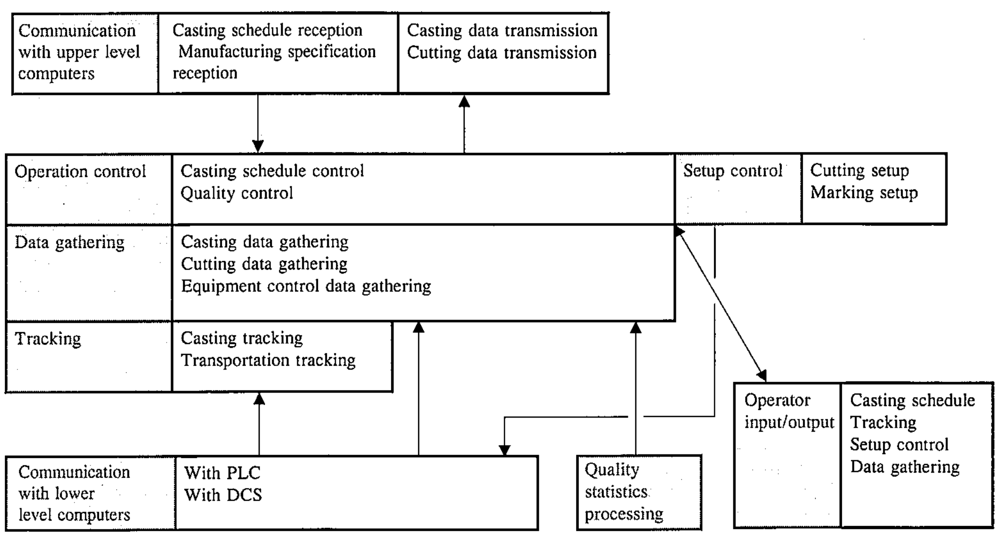


Fig. 3 Schematic diagram of CC system functions

*[3] Pentium is a trademark of Intel Corporation of the United States.

*[4] Pentium Pro is a trademark of Intel Corporation of the United States.

*[5] Windows 95 is a trademark of Microsoft Corporation of the United States.

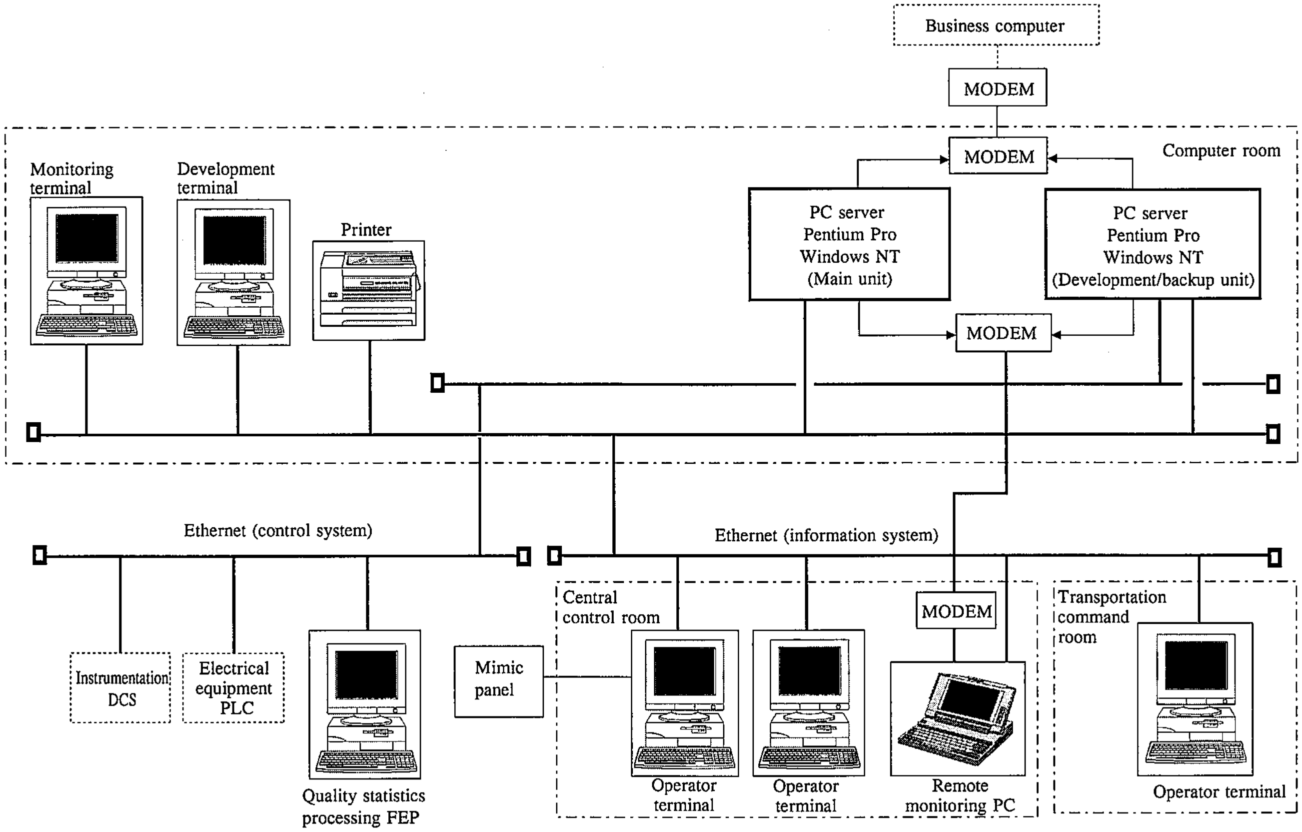


Fig. 4 Schematic diagram of system configuration

Table 3 Component devices of duplex system

Device	Manufacturer	Specification	Remarks
1. PC server	N Company	CPU: Pentium Pro	OS: Windows NT
2. Development PC	No brand	CPU: Pentium	OS: Windows NT
3. Printer	F Company	Page printer	Windows NT network compatible
4. Client PC	I Company	CPU: Pentium	OS: Windows NT
5. Client display	E Company	17-inch	
6. Quality statistics processing FEP	I Company	CPU: Pentium	OS: Windows 95 Equipped with analog input board
7. Remote monitoring notebook-sized personal computer	N Company	CPU: Pentium	OS: Windows NT Equipped with RAS package
8. LAN	A Company	Bridges, repeaters, hubs	

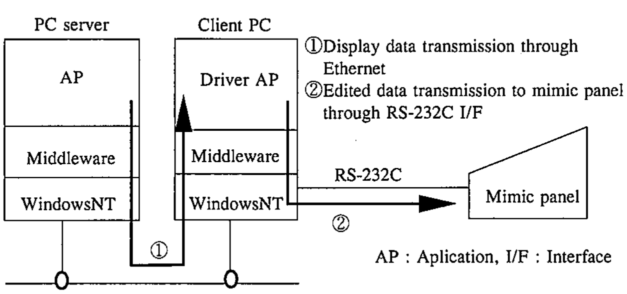


Fig. 5 Conceptual diagram of mimic panel

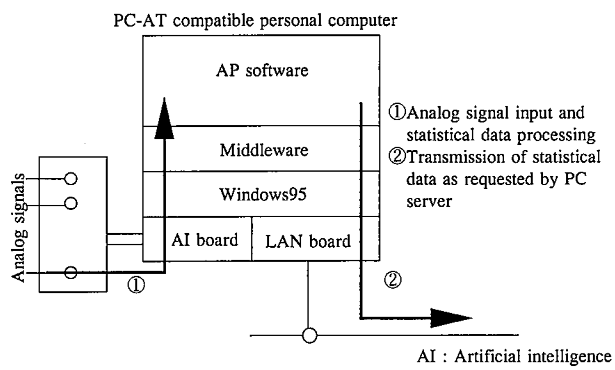


Fig. 6 Quality statistics processing FEP unit

(1) There are two PC servers as process computers. One is the main unit, and the other is a development and backup unit.

(2) There are two Ethernet (TCP/IP) LANs: an information system LAN (related to human-man interface or HMI) and a control system LAN (related to electrical equipment, instrumentation and FEP). The information system that must handle large volumes of data and the control system that must respond rapidly are separated to distribute the computing load.

5.3 Control middleware

The application software of the system consists of about 60 ksteps (written in the C language) and is of relatively small scale for process computers. The application software does not directly call the API of the Windows NT. As already described, the control middleware originally developed by Nippon Steel is used as the operating environment of the application software (see **Table 4**). The middleware has the following features:

(1) It is based on NS-CASE (C/C++ language version) and has functions required of ironmaking and steelmaking process control application software.

(2) It is independent of the API characteristic of a particular operating system and ensures the portability of the application software. (The application software of the system is program source compatible with the application software based on the C/C++ language version of NS-CASE for UNIX.)

(3) It has a network (TCP/IP) communication API and allows the flexible configuration of a distributed system.

(4) It has such functions that general-purpose personal computers can be used as human-machine interfaces (HMIs) for control purposes.

(5) It conceals resource identification (ID) control and occupancy control, so that novices can easily program. It also has resource registration control tools to facilitate system building.

(6) It performs necessary consistency check internally to prevent careless programming mistakes and to ensure the high quality and homogeneity of application software.

(7) It has a trace function to journal the detailed historical information about the fact that it has been called by the application software. This feature makes for efficient trouble analysis and debugging.

Table 4 Some of control middleware functions

Classification	Function
OS macro	Request to activate task with message
	Task activation request and message fetch
	Predetermined-time task activation
	Shared resource occupancy
	Shared resource release
File	File use declaration
	File use end declaration
	File data reading
	File data writing
HMI	Document output request
	CRT screen display request
	CRT screen display data output request
	CRT screen setup data input request
Communication	Communication with upper level computers (BSC)
	Network communication (TCP/IP)
Common	Steelmaking time and shift/crew conversion
	Code conversion (JIS8/ASCII/EBCDIC/BCD)
	Data transmission

ASCII : American standard code for information interchange
EBCDIC : Extended binary-coded decimal interchange code
BCD : Binary-coded decimal

5.4 RAS functions

The system has the enhanced functions of reliability, availability, serviceability (RAS), a process computer requirement as important as real-time performance.

(1) Duplication of hardware

The PC server is duplicated so that a hardware problem can be repaired in a short time. The two PC servers are configured as a duplex, manual backup system. The necessity for making an instant switch between the PC servers is slight in view of sharing of functions with the electrical and instrumentation systems

The switching procedure mainly consists of replacing the HDD of the faulty main machine by that of the backup machine and starting the backup machine. In Ethernet (TCP/IP) communication, the IP address of the main machine is inherited by the backup machine through the relocation of the HDD. This means that the parent node can be recognized without changing the child nodes (electrical equipment, instrumentation, and client PCs).

(2) Duplication of HDD[2)]

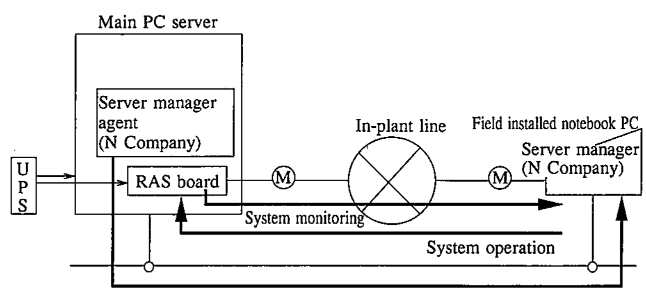
The HDDs are mirror disks based on RAID-1 (Redundant Array of Independent Disks level-1). The double writing mechanism of the disk array units allows one unit to continue operating when the other unit goes down. A faulty HDD can be replaced while the system is operating. When a disk is inserted, the data of the on-line HDD can be automatically copied to the inserted HDD. This makes for maintenance without affecting the on-line operation of the system.

(3) Remote maintenance

The system has the main PC server located about 1.5 km from the field terminals. Rapid fault recognition and restoration calls for the functions of system status monitoring and remote maintenance from the field terminals. The remote maintenance functions are shown in **Fig. 7**. There are two signal lines: one for a system status monitoring LAN and the other for a system operating modem. The monitoring functions include operating system (OS) and hardware operating status display, and alarm output and fault log data storage when a fault is detected. As remote maintenance functions, the main PC server can be shut down through the modem line/RAS board from the field, and the hardware can be reset and booted by turning on the power of the system.

(4) Application software trouble monitoring

Application software 'bugs' that affect the operation of the system are permanent loops and deadlocks due to the exclusive occupancy of a resource by two or more applications. The functions of monitoring for such faults and correcting them on-line are



UPS : Uninterruptible power supply
Fig. 7 Remote maintenance functions

indispensable for the control system. The functions described below were developed.

(a) The allowable running time can be set for specific application tasks. When an application task exceeds the allowable time, it is forcibly ended, the resource exclusively occupied by it is released, and an alarm is produced.

(b) The system may be restored to normal by aborting the application or aborting and releasing the application. In the latter case, an alternative application (for example, a older version) can be released as well.

(c) These monitoring functions can be incorporated into an application by simply merging the application program source with a prepared source template.

5.5 Engineering support tools

Software engineering productivity can be improved by making effective use of support tools. The benefits of the rightsizing and open system can be enjoyed in this area as well.

(1) Functional design

In functional design, specifications are created in a groupware environment on a personal computer network, so that designers can easily exchange information with each other and flexibly communicate with users and other departments through e-mail. This has greatly enhanced the efficiency of designers' jobs. Application software developers can process, design, and produce application software on their personal computers, so that they can easily reflect the contents of functional specifications in the design and production of application programs.

(2) File design

In file design, a file design support tool was developed on the basis of commercial spreadsheet software. With the entry of basic file specifications, the tool allows the preparation of a table and the automatic creation of a structure declaration include source program. **Fig. 8** shows an example of GUI (graphical user interface).

(3) Program design and production

In program design, a commercial design support tool was adopted (see **Fig. 9**). The tool prepares processing flow on a personal computer and allows the automatic generation of a C language source program from the processing flow and the inverse conversion of the processing flow from the C language source program. The productivity of programming and the quality of documents can be improved by the tool.

(4) Program test

The following support tools were developed for program test:

(a) File scope

This is a tool to support a software developer in an arbitrarily setting and displaying the application file data required for the entry and verification of test data. It was easily developed with the application of commercial spreadsheet software (see **Fig. 10**). The file scope tool is characteristic in that data retrieval and graphic representation can be simply performed by the spreadsheet functions. It can be easily applied by the end user to analyze process data.

(b) Middleware trace

When testing and debugging programs, it is necessary to analyze the operation of application software and verify application software. The efficiency of these jobs can be improved by the above-mentioned middleware trace function. **Fig. 11** shows an example of trace display screen. For instance, the contents of the

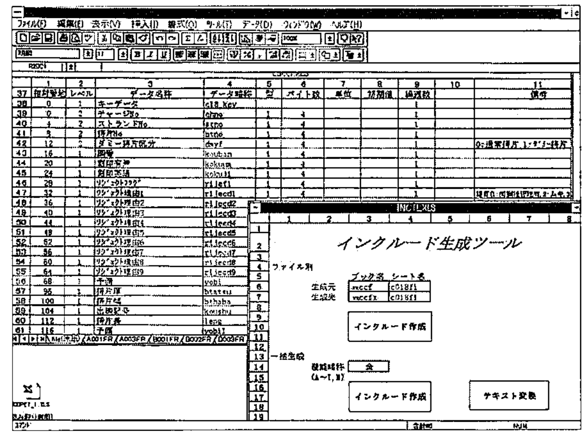


Fig. 8 Example of file specification preparation tool GUI

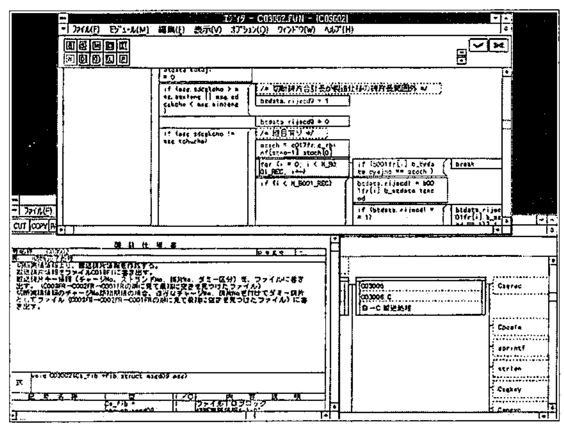


Fig. 9 Example of processing flow preparation tool GUI

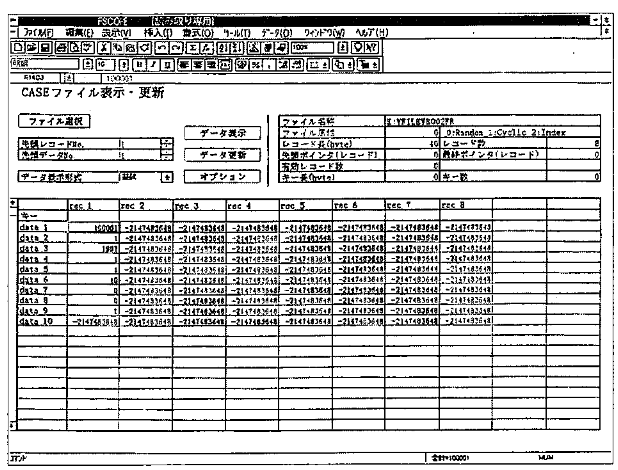


Fig. 10 Example of file scope GUI

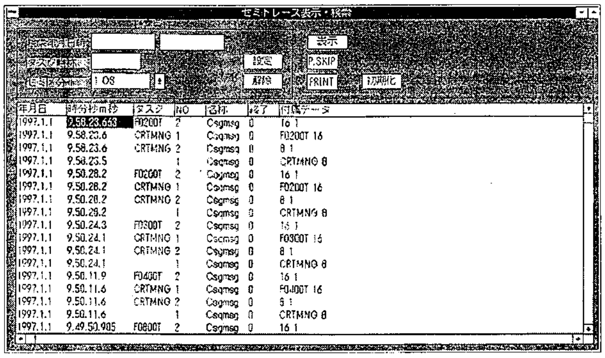


Fig. 11 Example of middleware trace GUI

trace can be retrieved and displayed by specifying a middleware name.

(c) Integrated test support tool

For smooth system integration test, a tool was developed that automatically causes application file input data setup and application task activation events according a test scenario to simulate an operating event. The integrated test support tool can set an arbitrary time scale and can advance operational simulation at high speed to a necessary point of time or inversely run the operational simulation more slowly to provide verification time. There are scenarios for specific items of equipment (such as the cast strand and runout table). Two or more such scenarios can be synchronously run, or their intermediate status can be stored.

6. Application Results of Rightsizing and Open System

The benefits of rightsizing and open systems are low cost and high scalability. In the rightsizing and open system applied as reported here, the initial cost of hardware was sharply reduced as compared with conventional process computers. The rightsizing and open system achieved scalability befitting an open system and was provided with such high expandability that does not depend on manufacturers and models. This means that the system can become a reference model in the future expansion of applications.

As far as software engineering and maintenance are concerned, design, production, and maintenance can be performed on one platform. The groupware environment and e-mail can be effectively used. Jobs can be performed more efficiently: documents and notices can be handled in a paperless manner, management can be simplified, and productivity can be improved. With a notebook-sized personal computer, one can design, produce, or test a program in the same environment as one's office while one is at home or away on a business trip. In this way a new engineering world inconceivable with conventional closed process computers is evolving.

7. Conclusions

As an application example of a rightsizing and open system, the features of the system, tools originally developed through the operation of the system, and the engineering characteristics of the system have been described above.

General-purpose personal computers and operating systems have been adopted for the first time for process computers in a main line at a steel plant. The practicality of the general-purpose personal computers and operating systems has been demonstrated. The middleware, RAS functions, and engineering support tools required for steel plant control have been developed. The basic technology for operating rightsizing and open systems has been established successfully. We are convinced that the rightsizing and open system introduced here will find widespread use in other steel plant process computer systems as well as in other industrial systems and factory automation areas. Nippon Steel's Electronics & Information Systems Division is planning to sell the system to outside customers.

References

1) Nakakita, T. et al.: Approach to Rightsizing of Steel Plant Control Systems. Journal of Society of Instrument and Control Engineers. 34 (11), 843-847 (1995)
2) NEC Corporation: Special Issue on Sever Express 5800 Series. NEC Technical Journal. (322), 48 (12), (1995)