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Open System Infrastructure for Process Automation in Iron and Steel Making

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Abstract

Since the 1960s, Nippon Steel & Sumitomo Metal Corporation has applied computer systems to process automation in iron and steel making. In the 1990s, to cut costs significantly and apply recent IT technology, the NS SEMI SYSTEM, which is middleware for the open system process control using personal computers, was developed for the first time in the mission-critical steel automation process. In the 2010s, the system has been applied to the entire process automation area, such as hot strip mills. Also in the field of PLC and DCS, the open system application technology has been developing. Nowadays, a new platform is being developed to apply IoT, AI technology, etc. easily. This paper outlines the long-term development of open system application technology.

1. Introduction

In computer systems for steel works, a large-scale hierarchical system is configured for an extremely large process and facility, to enable production of a diverse range of product types at high quality (**Fig. 1**). However, there is a strong need to build diverse systems that reduce cost and exploit IT technology. So instead of using conventional dedicated process computers, which are highly functional but expensive (hereinafter referred to as “process computer”), more and more facilities are using general purpose computers with open specifications. This report introduces the development of open system application technology in the fields of process computer, electrical/instrumentation, and the actual case of using open system solutions.

2. Application of Open System to Process Computer

2.1 Background

Process computers have the following functions: controlling the setting for electrical PLC and instrumentation DCS, controlling the automatic operation of production lines (tracking), collecting data, controlling operation and providing operators’ guidance (preparations, etc.), and collectively feature the following:

1) Stringency of control precision requirements of the order of μm even though extremely heavy objects are controlled
2) Reliability to withstand 24-hour continuous operation in a plant where operation never stops
3) Massive information processing due to the large scale of the facility
4) Stringency of the requirement for high response, seen in rolling equipment
5) Difficulty of stable operation and building-in of quality due to the complexity of the manufacturing process.

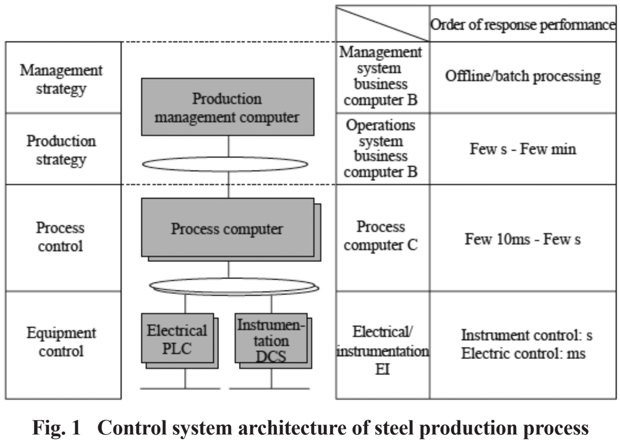

Fig. 1 Control system architecture of steel production process

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The construction of process computer systems satisfying these stringent requirements has been ongoing since the 1960s. Within this process, we will focus on the history leading up to the total in-house production of process computer software, and the application of open systems. [1)]

(1) Both hardware and software purchased from computer manufacturers (1960s)

(2) In-house production of software started, starting with control models to serve as the core (1970s)

The control models and the operation control functions of process computers that contribute to the quality competiveness in steel products were regarded as crucial from the viewpoint of securing operation know-how of product manufacturing as technical capital for ensuring corporate competitiveness.

(3) Achieved 100% of in-house production ratio of software (1980s)

The primary needs in this period were: to reduce cost and improve speed of software maintenance in routine operations and in the event of equipment improvement, and to reduce the system introduction cost when installing new lines for new products. In the process of improving the in-house software production ratio, standardization of engineering and the software structure was conducted until the mid 1980s, and a system for achieving a 100% in-house software production ratio was established. Furthermore, to take the lead in AI technology, the expert system and neural network technology were introduced to blast furnaces for trial purposes for development.

(4) Application of open systems (after 1996)

Based on the software design and development technology obtained from the shift to in-house production, Nippon Steel & Sumitomo Metal Corporation defined and developed middleware for building open process control systems (NS SEMI SYSTEM)[*1]. Presently, the open process control system based on the middleware is employed widely in areas including the hot rolling process control that provides the most stringent requirements. Furthermore, to take the lead in recent IoT, construction of a data collection platform is promoted to contribute to such state-of-the-art technologies as big data analysis and/or machine learning for providing sophisticated solutions.

2.2 Development of middleware for control

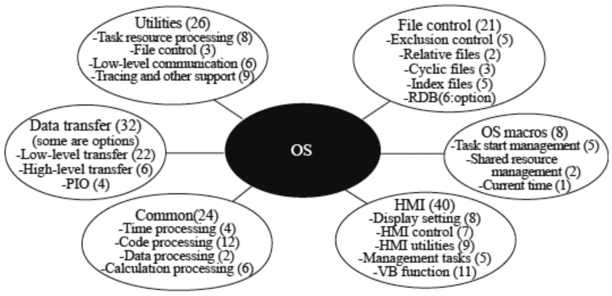
As open basic software that allows dedicated process computers for control to be replaced with commercially available work stations and personal computers (PC), Nippon Steel & Sumitomo Metal developed middleware, the NS SEMI SYSTEM, in-house, and the middleware is being widely used in open process control systems.

2.2.1 Functions and features

The middleware is equipped with API (Application Program Interface) of standard specification and supporting functions for the execution of development, maintenance, and operation, the functions and features of which are shown in **Fig. 2** and **Fig. 3** and described hereunder. [1–3)]

(1) Improvement of reliability and processing performance of the open operating system (OS) to be used for core system process control

As commercially available PCs are designed for business use in offices, and as successive processing following the sequence of order received is executed, time lag in the order of seconds in processing prioritized order takes place. Therefore, as a means for processing in the order of priority, ① The middleware is equipped with a program priority setting and controlling structure, ② A high accura-



Note: The figure in parentheses is the number of functions.

Fig. 2 NS SEMI SYSTEM function

[*1] NS SEMI SYSTEM is a trademark of Nippon Steel & Sumitomo Metal Corporation registered in Japan.

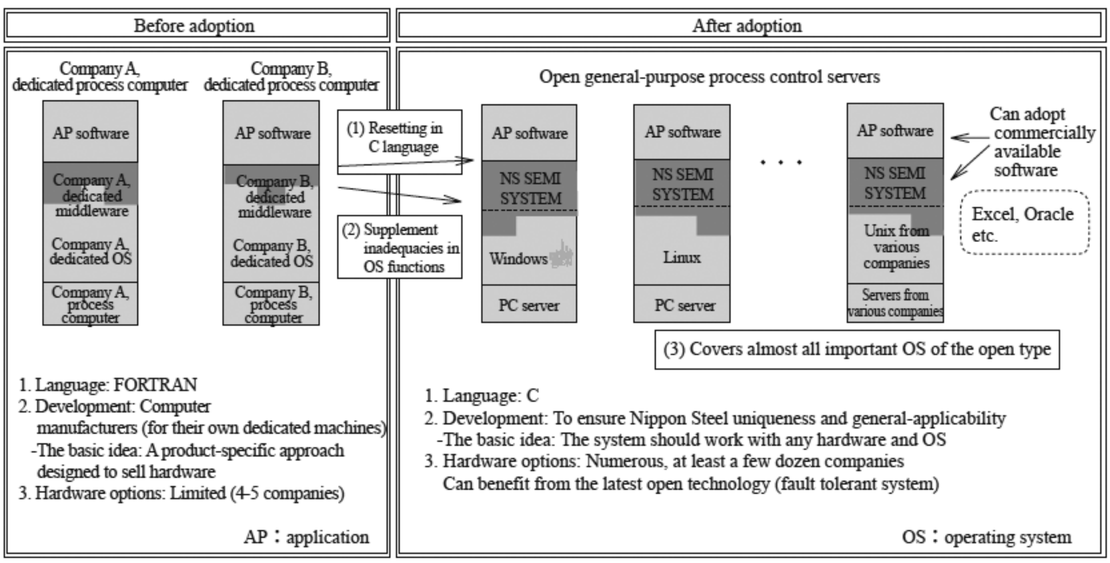


Fig. 3 NS SEMI SYSTEM features

cy timer structure is employed and, ③ OS (Linux®[*2]) extension setting was developed. These structures enabled the construction of a highly reliable core process control system of open systems with the use of general PCs and work stations. Such systems range from small-scale to large-scale types.

(2) Compatibility with almost all of the main open OS

The system is compatible with almost all of the main open OS, including Windows Server®[*3], Linux, and various types of UNIX®[*4], and this enables the selection of the optimal open server for each system. The middleware is built by analyzing the instruction of each OS (including past version) from the standpoint of compatibility and function/performance, and limiting the system only to universal OS instructions (Win32API, POSIX system calls). This ensures high reliability, minimizes the effects of specification differences due to OS upgrades, and makes it easier to keep up with the latest OS.

(3) Achievement of high portability of AP software

High portability is achieved by formulating and standardizing a universal interface with AP software suited to the distinctive features of the C/C++ language (like function types and structures).

(4) Realization of a human interface (HMI) with outstanding real-time performance

The system is equipped with a function to automatically update display data at a fixed cycle or in response to events and set components for the wealth of graphs and other displays required for process control. It also has functions for central monitoring of alarms that occur over multiple servers, and the use of HMI on web browsers is also enabled.

(5) Arrangement of a wealth of interface menus for linking with other systems

In the areas of middleware of communication and process I/O, the system has an expensive track record of linking with a diverse variety of electrical sequencers/PLCs, instrumentation DCS and other computers, using methods like TCP/IP, BSC, and no-protocol, so it is easy to connect with various systems and devices.

(6) System structure incorporating sophisticated IT devices

Standardized communication software that enables simple connection with other various advanced IT devices was developed. For example, real-time display of the manufacturing situation of products on tablets has been realized. Furthermore, the system is designed for operators to utilize with ease the imagery and/or the audio representations that the conventional process computers failed to provide, and such operator supporting technology incorporating IT technology supports the production capability in the alteration of generations.

(7) Development of high-speed process input and high-speed calculation processing function

The high-speed process input structure of process computers realizing the response performance in the order of less than 20 milliseconds for the processing and output of a change at a contact of a sensor was developed at reduced cost with the use of general PLC and the C language controller. Such performance could never be achieved by an open system, and the structure is applied in the wider range of high-speed-requiring process computer systems such as that of heavy plate mills (**Fig. 4**).[4] Furthermore, a high-speed calculation structure for exact mathematical models and multi-purpose optimization control loops was developed by incorporating a general parallel calculation processing unit of GPGPU (General Purpose Graphics Processing Unit). The structure realized a calculation speed several tens of times higher than that of general CPU in the hot stove control and the heavy plate mill set-up[5], and contributes greatly to the improvements of thermal efficiency and quality.

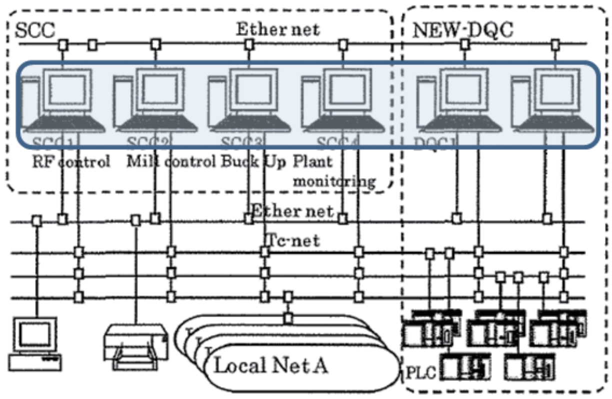


Fig. 4 Hot rolling process computer system using NS SEMI SYSTEM

(8) Incorporation of state-of-the-art system technology

In the control system, application of a general virtual platform was a difficult issue from the viewpoint of securing responsiveness. However, a test was conducted to evaluate the limit of the performance in the long run and under abnormal cases, and by calculating applicable indexes, the application of a virtual platform to actual equipment is being promoted, starting from the process computer wherein the requirement for responsiveness is rather tolerant.[6] Furthermore, the system is equipped with an interface structure that supervises the database and the communication of the state-of-the-art function such as big data analysis and machine learning.

2.2.2 Current status of application and future outlook

Full-scale development of the NS SEMI SYSTEM was started in 1995, and after a continuous endurance test over a long period of time, the Windows-NT®PC server was applied to the No.5 continuous casting machine of the Kimitsu Works in 1997 as the first in the world for the control of core systems in the iron and steel making process.[1] Also in 2001, in the Kimitsu No.3 blast furnace repair and improvement project, the most advanced Linux and its relational database were employed for the first time in the world.[1] In 2003, in the blast furnace, full integration of EIC operation was realized at reduced cost with the open system by means of a large screen interface. The technology received the NIKKEI Digital Engineering Award of Most Excellence in 2003 (**Fig. 5**). The HMI was built on the Web base utilizing the Internet technology, and various display setting components for process control were developed. Remote monitoring is also possible.

Application of the largest scale to a hot strip mill rolling process computer was started in 2010 and presently, the open system covers all the process computer areas as shown in **Fig. 6**.[2] As of 2016, about two thirds of about 1 100 process computers in the company have been equipped with the NS SEMI SYSTEM, and the application will be further promoted as well for the total replacement of obsolescent process computers, further enjoying the merit of the open system.

As for future evolution, the construction of platforms wherein virtualization technology can be used hierarchically by improving

[*2] Linux is a registered trademark of Linus Torvalds.

[*3] Windows, Microsoft Office, Word, Visio are registered trademarks or trademarks of US Microsoft Corporation in the US and or in other countries.

[*4] UNIX is a registered trademark in the US and or in other countries exclusively licensed by X/Open Corporation Limited.

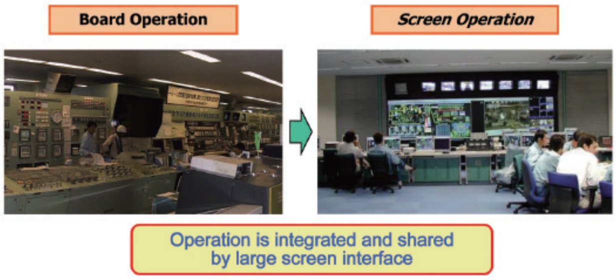


Fig. 5 New IT technology applied to Kimitsu Works-No.4 BF

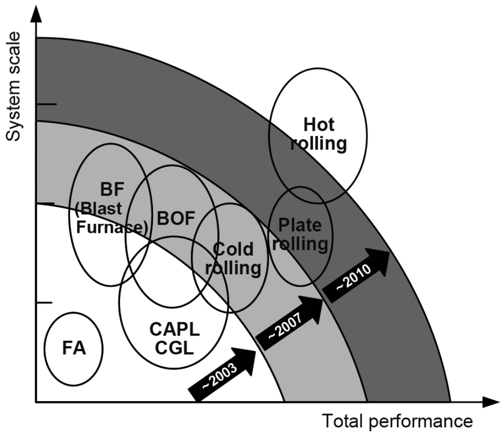


Fig. 6 Expanded use of open-system hardware for process control

the calculation processing performance and the networking performance is on-going. Speed-up of company-wide evolution of advanced solution technology, and the total significant cost cutting in system operation and management in the replacement of obsolescent process computers will be promoted.

2.3 Improvement and development of reliability and quality of open system

In 2004, the development of a language converter was started aiming at minimizing the equipment investment cost by utilizing the AP software assets of existing and running equipment. In 2005, for replacement of the obsolescent system, development was started for system diagnosis technologies such as the parallel-running tool that compares the operations of the newly-developed system and the running system so that the occurrence of problems is avoided, and for a tool effective in avoiding problems in the network. These tools have realized the enhancement of productivity and smooth start-up in the event of renewal and conversion to the open system of large-scale obsolescent heavy electric hot rolling process computer systems.[7)]

2.3.1 Development of system diagnosis technology

As the application of the open system to large-scale processes with e.g. total network length of about 20 km, about 500 switch ports, 5 process computer servers, 50 terminals, program steps of 500–1 000 k, progressed, growth of difficulty in finding causes and solutions in network problems have become problematic and measures therefor are being sought.

To the request that arose in the maintenance department for general standard tools that can isolate problems with ease, a system diagnosis tool was developed. The system deployable at low cost by simply adding a diagnosis PC locates problems with ease through

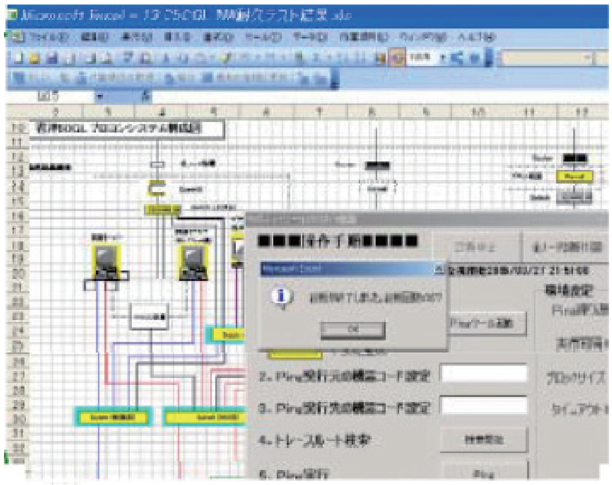


Fig. 7 Screen example of system diagnosis tool

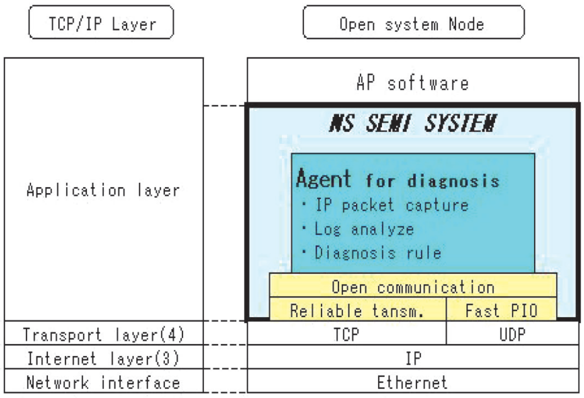


Fig. 8 Agent for diagnosis configuration

prepared diagnostic procedures (**Fig. 7**).[8)]

With a PC connected to the general network and by collecting the resource information of the server on a second-time-base interval, and by collecting the packet in the network on a real-time basis, a standard structure capable of diagnosing the entire open system was developed. For each edge node, an agent structure that does not influence the real-time control processing was developed (**Fig. 8**) and arranged at each node of the system (**Fig. 9**).[9)]

As for other functions, complicated parameter settings for network devices were automated, and the construction of prevention measures for humane errors and system security has also been promoted. Together with the improvement of skills in the maintenance department, the restoration time of the network-related problems have been shortened to one seventh and the number of problems has been reduced drastically.

2.3.2 Development of integration test support technology

In the conventional integration test, a malfunction that takes place occasionally at a time when unfavorable conditions emerge coincidentally, particularly of the OS drivers, could not be detected in the load test focused on CPU, disk, and network, and occasionally a malfunction emerged after the start of formal operation.

Therefore, features of the process computer in the respective processes were described in a scenario-like form, and a composite test method was developed as a standard that enables the execution

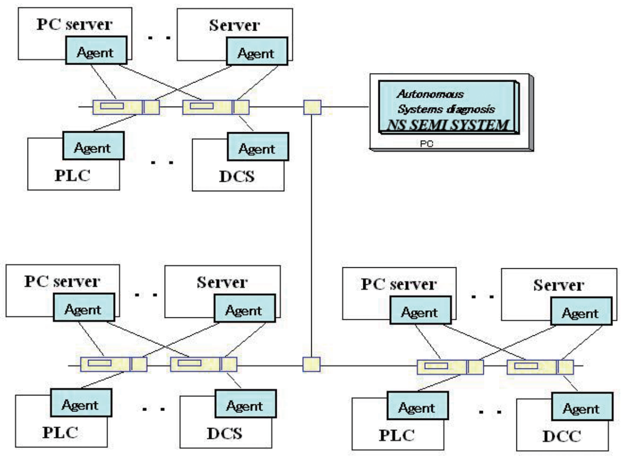


Fig. 9 System diagnosis configuration

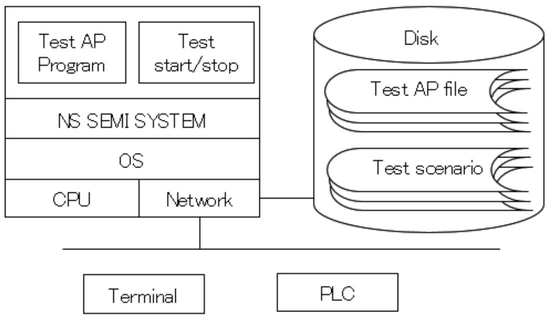


Fig. 10 Integration test system configuration

of an acceleration test for the concerned subject process under a condition close to the actual operating condition. The occurrence of system problems after the start of formal operation is suppressed by detecting and modifying malfunctions prior to the start of formal operation (**Fig. 10**).[7]

In addition to the conventional middleware function of transferring the existing system to the open test system in the event of replacement of obsolescent systems with open systems, a general parallel running test support system was developed to minimize the influence of the transfer of the existing system by capturing the data and the PIO packets being transferred in the network.

Furthermore, by using the screen input function of the existing HMI, the software of the test system was incorporated to operate compatibly with the existing software, and a parallel running HMI system, which can effectively confirm the identity of the results of the calculations of the existing process computer model and the new to-be-installed process computer model and display the output results on a screen, was developed. Significant reduction in the renewal period and the renewal cost for the existing process computer and total operation immediately after the renewal were realized.[10]

3. Application of Open System to Electric (E) System

3.1 Background

Until the 1990s, we relied on the electrical control devices (PLC) exclusively developed by manufacturers. In 1993, the world standard specification programming language (IEC61131-3, hereinafter referred to as IEC language) appeared, and further to it, as the performance of the general PLC had made great progress since the latter half of the 1990s, efforts were made to develop in-house software development technology with the use of IEC language and the general PLC from around 2000.

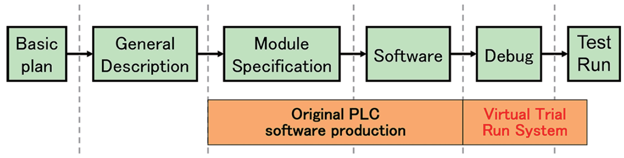


Fig. 11 Software production flow with original PLC software production and virtual trial run system

In **Fig. 11**, the electrical PLC software development flow is shown. In the production flow, there are two major steps, "software designing･development" and "software debugging" before the software is applied to actual equipment.

In software designing･development, although the ladder language was used conventionally in the software designing･development for electrical control software, with the use of IEC language, Nippon Steel & Sumitomo Metal developed the "Electrical software designing and development support system" and realized improvement of the software development capability.[11] About 140 "software components" were developed for iron and steel making plants and the software reuse ratio was enhanced.

In software debugging, as careful software verification was difficult due to various technical issues, a support function based on IEC language, "Virtual trial run system", was developed. Efforts made therefor are described in the following chapter.

3.2 Technical issues in electrical control software debugging

Conventionally, in the prior debugging of the electrical control software, generally a simulator simulating actual sensors and actuators is provided, or the debugging is conducted provided with hardware switches and lamps. However, due to the issues as stated below, prior debugging failed to confirm the entire function of the control software and accordingly, a number of malfunctions were found frequently in the subsequent trial operation of actual equipment.[11]

(1) Limited simulation range

Conventionally, as the simulator software was developed using the ladder language, the production capability and the ratio of reuse of software were low; therefore, it is difficult to develop all simulator software of all equipment. Consequently, the area of simulation became restricted and the area of software confirmed by prior debugging was limited.

(2) Limited simulator function

As it is difficult to reproduce the complicated process phenomena using the conventional ladder language, the process model such as that for controlling tension was either simplified or completely eliminated. Furthermore, even when simulation is conducted using hardware switches, it is impossible for pluralities of simulated signals to be generated or terminated with exact synchronization to actual phenomena. Therefore, large discrepancies were produced between the content confirmed by prior debugging and the content confirmed in the actual operation of equipment.

3.3 Development of virtual trial run system

In **Fig. 12**, the outline of the virtual trial run system is shown. The "Actual plant" is simulated by the "Plant simulator" and the "Virtual plant screen". The following efforts were made selectively for the plant simulator in particular.

(1) Effective production of simulator

In the production of the plant simulator, various devices (electro-

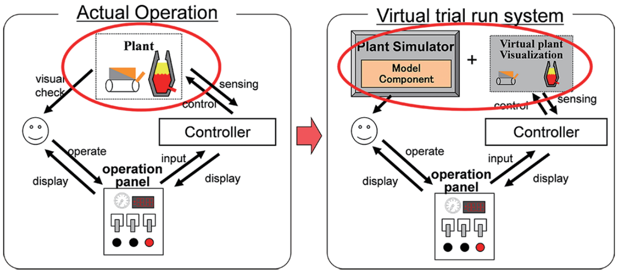


Fig. 12 Outline diagram of virtual trial run system

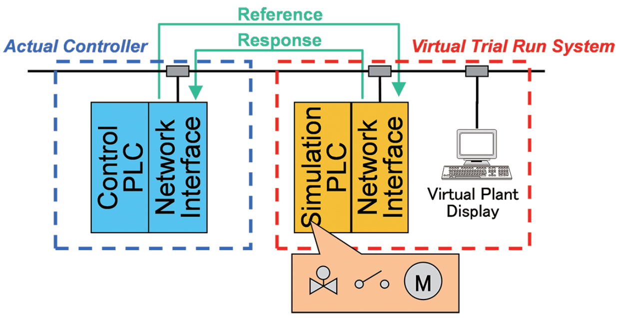


Fig. 13 Example of system configuration of virtual trial run system

magnet valve, sensors, etc.) and the physical phenomena (tension, etc.) were modularized to the software "model component" and by reusing the modularized model component, the production efficiency and the quality of the simulator software were greatly enhanced.

(2) Enhancement of simulation accuracy

As compared with the ladder language, IEC language is excellent in expressing numerical treatment, and as Nippon Steel & Sumitomo Metal possesses various model formulae, with the combination of these, simulation models of higher accuracy could be structured.

Furthermore, the system was designed so as to allow the independent setting of the electro-magnetic valve position, its actuation speed, limit-sensor installation position, etc. By setting the respective actual machine data, a simulation circumstance close to the actual equipment device actuation was realized.

In **Fig. 13**, an example of the system configuration of the virtual trial run system as described above is shown. As the control PLC and the model PLC have to transfer massive I/O information within a short cycle, in this configuration example, high-speed control LAN owned by the respective PLC manufacturer is utilized for information transfer and the simulation result is displayed on the virtual plant display screen.

3.4 Application of virtual trial run system to actual equipment and result obtained

The developed virtual trial run system was applied to the electrical control equipment of a new process line of Nippon Steel & Sumitomo Metal and the following result was obtained.[12)]

(1) Malfunctions of control software and method extracted

As the plant operation is precisely reproduced, the sequence of operation and the control logic could be confirmed, and a number of malfunctions of the control software and the method could be eliminated in advance.

(2) Rough tuning of control logic

As the actual process phenomena are precisely reproduced also, not only the confirmation of the control logic but also the tuning of parameters such as control gain could be executed, and the fine tuning time on actual equipment could be greatly shortened.

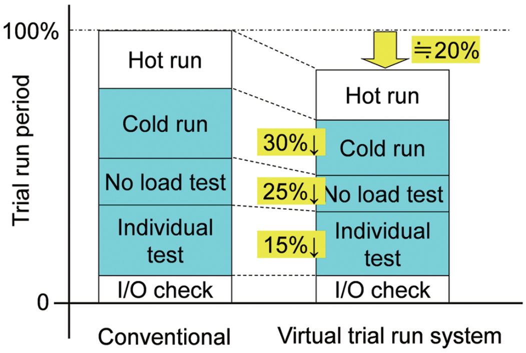


Fig. 14 Time-cost reduction of virtual trial run system

(3) Smooth confirmation of operation pattern in attendance to pre-shipment test

With the help of the plant simulator that precisely reproduces the actual equipment and device operation, and the virtual plant screen that transfers the state of operation to operators, even the operators who encountered the system for the first time could easily operate the system, feeling as if they were operating the actual equipment. With this, operators could confirm the operation pattern smoothly in the pre-shipment test of software and not only the extraction of software malfunctions, but also the extraction of new requests for improvement were enabled.

As a result of the above, software malfunctions were greatly eliminated in the prior debugging, and as shown in **Fig. 14**, the trial operation period could be shortened by about 20% as compared with the actual results of similar lines in Nippon Steel & Sumitomo Metal.

3.5 Toward the expansion of application of virtual trial run system

The following efforts are being made to expand the application of the system to the projects of replacement of obsolescent electrical control PLC and new projects in Nippon Steel & Sumitomo Metal.

(1) Expansion of availability of model component

In the early stage of the development of this system, only the model components required as minimum for small-scale process lines, e.g. tension control of a steel strip and/or the tracking of the front end and the weld point, were made available. However, later on, model components of special equipment such as of free loop, dancer roll and model components of looping equipment and loop car indispensable for a large-scale process line were newly developed, and application to nearly all process lines was realized.

Furthermore, the tracking model in a process line was made only with respect to the sheet lengthwise direction (single dimensional). However, a material tracking model was also newly developed, which is capable of tracking materials in east-west-south-north directions (two dimensional), and application was expanded to finishing lines for tracking coils and slabs in transportation (Refer to **Table 1**).

(2) Construction of simulator made easy

As shown in Fig. 13, the simulator environment is constructed using the high-speed control LAN owned by the respective manufacturer. However, for the PLC of each manufacturer, the same type of PLC has to be used for the model PLC and the control PLC for the reason described below. And furthermore, as a model component has to be constructed for the respective manufacturer's PLC, the

Table 1 Target line of virtual trial run system

Target line of virtual trial run system		Software components for modeling steel plants			
		Facility (cf. SV, motor)	Process (cf. tension, pressure)	Tracking	
				Continuous plate	Coil, pipe
STEP 1 (original)	Small scale process line	○	△	○	—
STEP 2 (present)	Large scale process line	○	○	○	—
	Transfer line	○	—	—	○

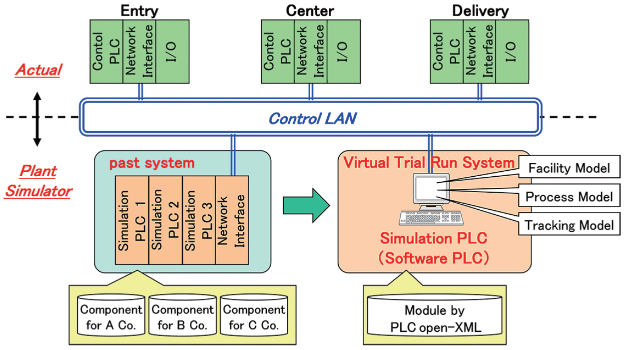


Fig. 15 Virtual trial run system with software PLC

work required is extremely labor-intensive.

① Connection of different manufacturers' PLCs with a high-speed control LAN is impossible. (Because, although most of the manufacturer's high-speed control LAN is of open specification, in many cases, they are not compatible with each other.)

② No compatibility of files for the edition of the manufacturers' PLC program

Recently, "software PLC" with which IEC language software can be executed on PCs has emerged, and as the software PLC having the following features can solve the above issue, application of software PLC to the virtual trial run system is promoted with the method as shown in **Fig. 15**.

① Compatible with each manufacturer's high-speed control LAN of open system

② Compatible with the world standard specification file format "PLCopen-XML"

With the former compatibility, communication with various types of control PLCs has become possible with one software PLC. Furthermore, with respect to the latter compatibility, only one type was sufficient for a model component group of the respective manufacturer's PLC so far constructed. Furthermore, as the software PLC conforms to the format of the world standard specification, future fluidity is also secured. As effects, although in the past pluralities of model PLC had to be prepared for each manufacturer's PLC, since a software PLC suffices for the construction of the system, reduction in cost in constructing a system was realized.

Thanks to the abovementioned efforts, this virtual trial run system is now being applied to a number of the companies' new projects and replacement of obsolescent equipment projects, and thus the expansion of the system has been realized.[13)]

3.6 Future evolution

In the evolution of electronics technologies and in the trend of application of more open systems in future, various open system technologies are expected to be created. We continue to focus on various innovative technologies and are determined to make efforts to improve debugging efficiency aiming at further expansion toward more lines.

4. Application of Open System to Instrumentation (I)

4.1 Background

In the latter half of the 1980s, in-house development of software for blast furnaces was started based on the instrumentation control device (hereinafter referred to as DCS) developed by manufacturers. In order to enhance the efficiency of software development, an instrumentation software development support tool (hereinafter referred to as instrumentation CASE) was developed. Furthermore, as a part of the development, a function that enables the coordinated operation of the exclusively-developed manufacturer's DCS software and the instrumentation CASE was developed.

In the latter 1980s, an open-system DCS was developed based on MELSEC[*5] that realized a function equivalent to that of the exclusively-developed DCS and was introduced to the market. The open DCS (brand name TECNICE[*6]) was developed with one of the affiliated group companies, Nippon Steel & Sumikin Texeng. Co., Ltd. In the early stage, the open DCS was introduced to small-scale iron and steel making facilities such as reheating furnaces. The application was expanded to middle-scale facilities from small-scale facilities along with the enhancement of CPU processing performance and network communication performance. However, as the scale of facilities grew larger, the production of documents and development of software became time-consuming and the improvement of the software development productivity became an important issue. Therefore, coordinated operation of the instrumentation CASE and the open DCS was developed and applied to actual equipment.

The open system version of the instrumentation CASE and the open DCS are introduced hereunder.

4.2 Outline of instrumentation CASE based on open DCS

Figure 16 shows the configuration diagram of the instrumentation CASE based on open DCS, the major function of which is descried hereunder.

(1) Standardization of document

- Preparation of various components conforming to the JIS symbol based on Microsoft® Office (Excel®, Word®, Visio®, etc.), format, various lists and so forth.
- Preparation of document rule to simplify the coding work for software from document

(2) Data coordinating function within document

- A function that preserves data produced in producing a list or a functional specification in a common database for sharing and

*5 MELSEC is a registered trademark of Mitsubishi Electric Corp.
*6 TECNICE is the merchandise of Nippon Steel & Sumikin Texeng. Co., Ltd. (Trademark in Japan under application)

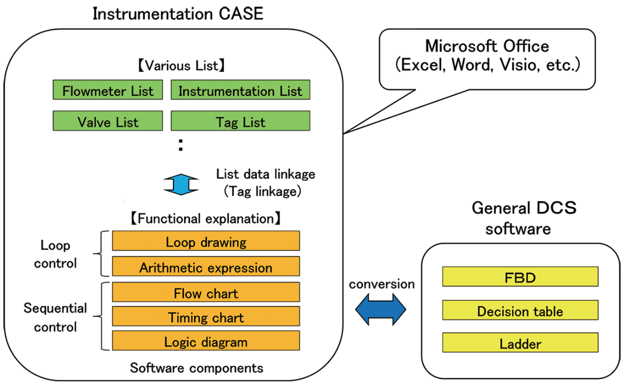


Fig. 16 Conceptual diagram of instrumentation CASE based on general DCS

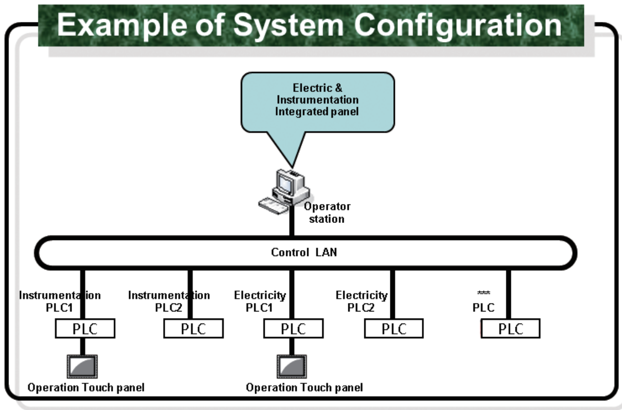


Fig. 17 Example of general DCS system configuration

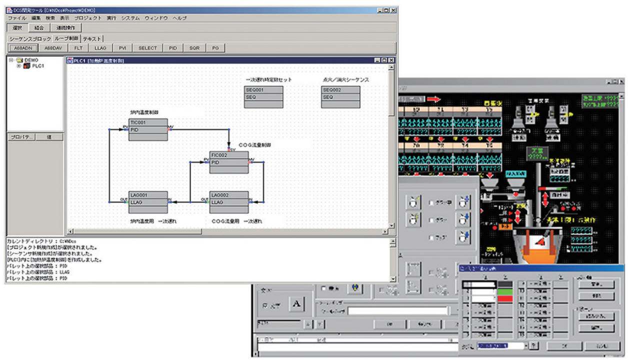


Fig. 18 Example of monitor and control tool

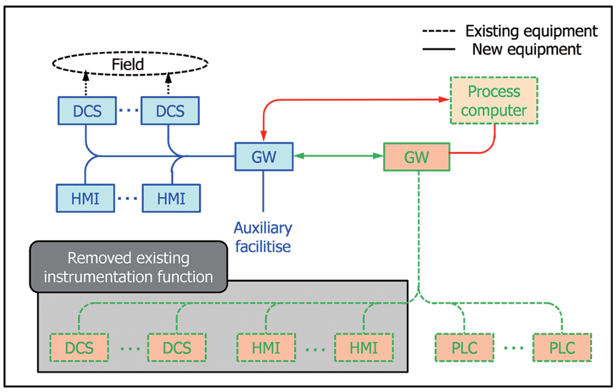


Fig. 19 Outline diagram of updated DCS system for Kashima Works No.2 continuous annealing furnace

that calls for data with tag linkage for use in creating either a list or a functional specification

(3) Coordinating function of document and open DCS
- A function of exporting a tag and relevant necessary data extracted from the document to be incorporated into open DCS software

4.3 Outline and example of application of open DCS (TECNICE)

Figure 17 shows an example of the system configuration of an open DCS (TECNICE), the features of which are described hereunder.

(1) Realization of a low cost system with the development of a monitoring and control tool
- With the developed tool, reduction of cost, flexible correspondence to request, and construction of a system with high software-development capability are enabled (**Fig. 18**).

(2) Open-system-oriented software technology with the employment of general OS
- With the use of the Windows system as a platform, utilization of various general packages (Excel, etc.) is enabled and appropriate software operation is made possible.
- Expansion of system is easy by means of general network (Ethernet).

(3) Integrated EIC type system
- Integration with general PLC in the electrical field is easy, and sharing and integration in operation monitoring are particularly simple.

Next, as a specific application example, the case of renewal of DCS in the Kashima Works No.2 continuous annealing furnace line is introduced. In the existing line, an EI-integrated system based on DCS supplied by a heavy electric machinery manufacturer was used, the DCS part of which was renewed to TECNICE. The major subject of this project was to realize the system configuration that is capable of coordinating with the existing system. The system configuration after the renewal is shown in **Fig. 19**.[14] To construct a network between the existing system and the newly installed DCS, a gateway (GW) was installed. A gateway was also installed on the existing system and the coordination was realized by connecting the gateways with general I/F. This coordinating method was realized because the open DCS has a wide variety of compatibility with I/F, which is a great advantage of the open DCS. As there are various types of general DCS and so many types of combinations, for the construction of highly reliable systems, broad knowledge and device-combining technology are essential.

Application has been expanded to other facilities in steel works such as pulverized coal injection equipment, secondary refining furnace, continuous hot-dip galvanizing line, continuous pickling line, large section mill reheating furnace, etc.

TECNICE is applicable up to middle-scale systems. Presently, a study is in progress for application to large-scale systems. In addition, in the large-scale systems, as higher reliability is required, redundancy of the MMI･network will also be studied.

Furthermore, to fully utilize the advantages of affinity with other systems and the large capacity high-speed data processing performance of open systems, connection to various IoT devices will also studied as required.

5. Conclusion

Conventionally, application of open systems to the iron and steel process control was difficult on account of stringent requirements; however, thanks to the previous long-term development efforts, now the following merits are enjoyed.

(1) Revolution in system construction work and engineering work
- Reduction in cost and achievement of standardization by building competitive situations through bulk purchase at the purchasing stage
- Prevention of leakage of knowhow by means of in-house development of all application software
- Securing system reliability based on users' own liability for system integration technology and accumulation of knowhow

(2) Revolution in maintenance work
- Improvement of maintenance efficiency with unified system specification
- Establishment of maintenance support system and promotion of maintenance education

(3) Support of affiliated family company
- Support for strengthening the price competitiveness for the sales of the NS SEMI SYSTEM in the market
- Support for stable operation by supplying various software development tools and problem analysis means

We will continue to collect information from the rapidly progressing open system technologies, including the state-of-the-art IT technologies, and conduct test and evaluation thereof. We are determined to continue the development of technologies to compensate for system deficiencies and/or to apply to the stringent iron and steel process control, and make efforts to construct control systems that can contribute to corporate needs immediately.

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