Present Status and Prospects for Controllers

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1. Introduction

Now we are just at the entrance of the 21st century, remarkable progress in data communication is dramatically changing our social and economic structures.

Similarly, in the fields of factory automation (FA) and process automation (PA), progress in information processing, field such as open technology, multi-vendor supply, network technology, and multimedia technology, typically represented by personal computer systems, is advancing the fields of machine control and production line control. As the result, the appropriate state of so-called controllers is also greatly changing.

This paper examines changes in production systems caused by the flow of this information revolution or digital revolution and describes conditions of future controllers.

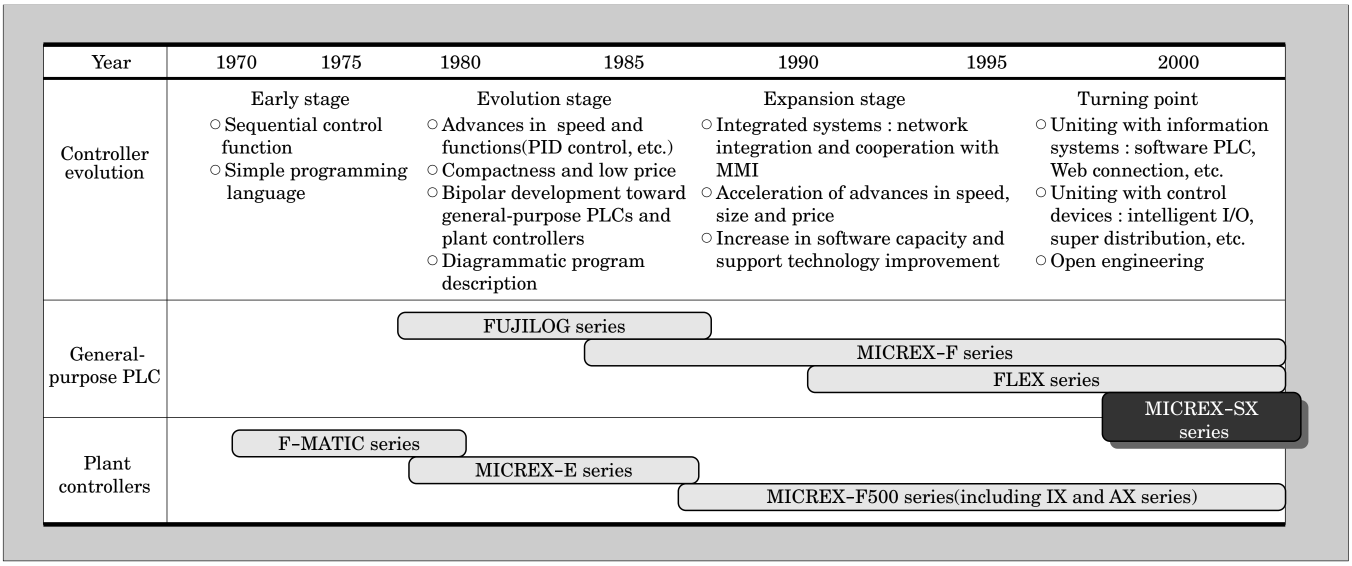
2. Developments and Present Status of Controllers

In 1968, General Motors in the USA presented requirements for industrial control equipment, and in response, several US companies announced products the following year, introducing the programmable controller (PLC). Since then, the PLC has rapidly grown with advances in semiconductor device technology and microprocessors, and has established its position as an indispensable component for control systems.

The relation between controller evolution and Fuji Electric's products is shown in Fig. 1. In its early stage, the controller aimed to replace the wired logic of relay control panels with software and had basic functions for sequential control (logic operation, timer, and counter) with several hundred I/O points. In Japan, controllers with 500 I/O points and a program capacity of 4k words were commercialized and were mainly and selectively used to replace relay panels in large plants.

Late in the 1970s, controller function and performance was rapidly advanced due to the advent of microprocessors, entering an era of full-scale development. Functions such as arithmetic operations, data processing, and proportional, integral and derivative (PID) control were realized in the upper-class controllers, as was high-speed processing. Because of these advances in high-speed processing and data processing

Fig.1 Controller evolution and Fuji Electric's products



function, the controllers were used for the online positioning and tension control of precision steel rolling mills and process instrumentation PID control. In addition to use as relay panel replacements, they were also widely used as plant controllers.

On the other hand, the downsizing and price reduction of small-scale controllers were accelerated, and demands for controllers with only a sequential control function rapidly increased, mainly for use in the machine control systems of the assembly and machining industry. Fuji Electric's small-size controllers, including the FUJILOG series, were widely marketed to users who would purchase the controller and develop programs by themselves. Thus a category of general-purpose PLCs, different from plant controllers, was created.

In the middle of the 1980s, when application specific ICs (ASICs) were put to practical use, the advance in functions and downsizing of controllers accelerated even more. It was the most active expansion period up to 1995. The application of plant controllers spread to various fields. This resulted in systems whose characteristics were developed for specific applications such as instrumentation distributed control systems (DCSs) and high-speed, high-reliability power generator control. At the same time, with the trend toward total systemization such as network integration and man-machine interface (MMI) cooperation, software increased in quantity, and software engineering support technology appeared as an important factor.

Advancing the general-purpose PLC to smaller size and lower price, while the installed functions became similar to the plant controller. While the general-purpose PLC evolved to offer remote I/O, to link drive control such as servos and inverters, and to connect with personal computers, its small size, low price, and advanced functions were the impetus behind a transition in controllers for the 21st century.

3. Changes in Production Systems

To consider appropriate conditions for controllers at this transition point, we will examine changes of the production systems in which controllers are utilized.

3.1 Changes in enterprise production activities

The manufacturing industry has recently shown various changes and seems to be at a major turning point. As a backdrop, changes have been observed in enterprise environments. Enterprises, whether willingly or not, have been fighting off tough international competition and are powerfully promoting various innovations to maintain and strengthen their competitiveness and ability to survive.

3.1.1 Measures for globalization

The rapid development of information and communication has completely eliminated national boundaries. Enterprises in the midst of tough international competition desperately push for globalization as an essential strategy. Such measures aim to expand sales in foreign markets and to aggressively promote overseas production while keeping an eye on production cost reduction, component procurement, and commodity logistics. Organic connections between overseas production bases and existing domestic production systems, that is, measures to increase the competitive advantage through so-called global scale production and logistic systems, are promoted irrespective of the enterprise scale.

3.1.2 Reduction in the total cost of ownership (TCO)

Cost competitiveness, the first requirement to beat the competition, is essential for survival. Reducing total costs, including all phases of production, is always a high priority. Consequently, enterprises are constantly promoting innovation in production systems.

(1) Construction of non-redundant production systems

In a period of high economic growth, manufacturing facilities were permitted to include some degree of redundancy, and in fact, redundancy intended for future modification was required. Today, however, for the purpose of thorough rationalization and improved efficiency, a system with a higher degree of freedom is under study. In this system, "a production system with neither excess nor deficiency, and well suited for the purpose of production is introduced and put into operation." "If there is any change in the production goal, the system can be quickly reconstructed at minimum cost and put into operation."

(2) Reduction in system construction cost

To effectively utilize the increased degree of freedom to reduce cost, systems and components that do not depend on the specifications of specific equipment manufacturers are under development. Under such circumstances, systems could be constructed by freely selecting and combining components, irrespective of the vendor, to minimize costs.

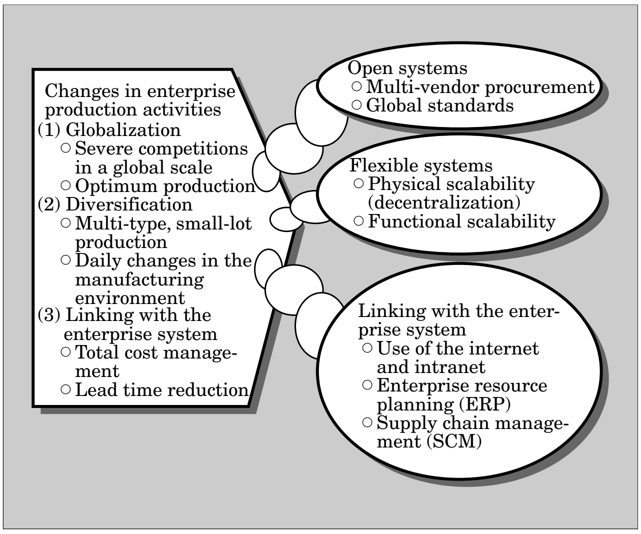
(3) Reduction in engineering cost

The cost of software production and maintenance after operation starts as a percentage of the total cost of a production system rises each year due to increasingly sophisticated systems. There is fear that this trend will result in a crisis. Enterprises continue to innovate software production methods and investigate outsourcing, including the outsourcing of maintenance.

3.1.3 Pursuit of total efficiency improvement

Needless to say, the recent market environment has greatly changed. The former method to efficiently mass-produce a few types of products has passed. The current method has changed to the production of many types of products in small lots. Daily changes in the production environment, such as order size, specifications, and the date of delivery, are normal. Such market environments exert a bad influence on enter-

Fig.2 Changes in production systems



prises, increasing the lead-time as well as increasing the total stock. As a countermeasure, enterprises are working to improve total efficiency by linking the enterprise information system to the production system online, and integrating the management of order entry, component procurement, and commodity shipment.

3.2 Desired production systems

What type of production systems will meet these demands for production innovation? Figure 2 shows required changes in production systems.

3.2.1 Open systems

The various components and networks of a production systems are all required to have open specifications. Open specifications means that "specifications for basic functions and operation procedures are open to the public and standardized, and this standardization is maintained among vendors such that users can freely select devices to construct systems." The current personal computer is a typical example.

Open specifications will release users from the monopoly of vendors and allow them to procure necessary functions and performance from arbitrary vendors anywhere in the world.

3.2.2 Unified engineering

As described above, the sophistication of production systems increases engineering cost. Improved software production efficiency is the main countermeasure to this problem. It is important that the software design method be universal, irrespective of equipment type and geographic region, and must comply with international standards.

From this point of view, the IEC standard for controller programming language [IEC61131-3 (formerly standard IEC1131-3 1993)] is worth special mention for a core component of production systems. This standard was established to unify program description methods and further standardize programming procedures based on software technology. Adopting this standard, we can expect the natural componentization and reuse of software, and a rapid improvement in software productivity.

3.2.3 Flexible systems

Flexible architecture systems that can satisfy requirements for constructing efficient systems suitable for production purposes and quickly reconstructing them to meet production modification are desired. A system with flexible architecture "has physical and functional scalability as well as high-speed processing and sufficient processing capacity." This phrase is important for the configuration of controllers as they prepare to change for the next generation.

3.2.4 Information technology (IT) connection

Previously, production systems were isolated from the enterprise information systems directly connected to enterprise management. However, when facing the tough competition mentioned above, to meet suddenly changing market needs, production systems linked in real-time to the management activities, or in other words production systems that can be connected to IT, are desired.

By linking production systems in real-time with enterprise resource planning (ERP) and supply chain management (SCM) systems through the intranet or other IT, a sufficient output can be maintained and it is possible to flexibly meet production schedule changes such as the date of delivery and quantity. Based on production system information, systems will gradually develop toward management strategic planning.

4. Controller Requirements

As production changes, controllers, the major components of production systems, are facing a turning point toward the 21st century. The keywords of object technology, decentralization, and open systems are required elements for this transition. These requirements, including those already actualized, are examined below.

4.1 Adequate control performance

There are high expectations for control performance, a basic controller requirement, with respect to both processing speed and software capacity. One goal is to achieve a processing speed with a 1ms control cycle. In a program with several ten thousand steps, the execution cycle for an instruction should be less than 50ns, and therefore, 10ns can be expected as a tentative goal.

With regard to software capacity (program step quantity), the transition from hardware processing to software processing has been advanced by progress in application technology such as software componentization. A software capacity of 100k steps will be required.

4.2 Degree of freedom in system construction

With conventional controllers, the selection of controller type determined the scale of the system and performance, and the system was constructed only by supplying the required number of I/O points. However, components must be supplied so that users can freely construct their own systems. Future trends are described below, key points of which will be physical and functional decentralization.

(1) Open I/O

There is already a trend for the I/O to be decentralized and connected by networks. A de facto standard for I/O connecting networks accelerates the flow of diffusion, and I/O modules will soon be available from multi-vendors.

(2) Multi-CPU

The CPU for controllers has become smaller and less expensive due to progress in semiconductor and control technologies. Multi-CPU systems that meet the needs of different applications by increasing or reducing the number of CPUs are gradually becoming more popular and will be the mainstream someday. Multi-CPU distributed control capable of localizing appropriate sections of application functions can rapidly improve the system robustness.

(3) Intelligent I/O

Intelligent I/O is another form of the multi-CPU system, the so-called functional distribution of CPUs. Intelligent I/O uses I/O and simple software to process functionally complete blocks at their process ends and will become an important element in the future. A future topic for intelligent I/O is the modeling of flexible communication between distributed applications, such as servomotor control.

4.3 Open engineering

Although controller programming had the common basic technique of ladder diagram description, manufacturers continued their own vendor-specific guidelines. Recently, however, the international standard IEC61131-3 has gradually come into general use. This can standardize not only program descriptions but also design methods. In particular, the method of software componentization is expected to promote object-oriented technology.

In any case, it will be necessary to provide an open engineering environment in compliance with this standard.

In addition, it is desired to coordinate controllers with the "C" and "Java"* general-purpose languages to apply the increasing capability of information processing engineers to control, and to practically apply technology-oriented programming (auto-programming) as a tool to maximally utilize the control know-how of shop-floor engineers.

*Java: A registered trademark of Sun Microsystems, Inc. USA

4.4 Personal computer controllers

Due to advances in personal computer performance, there is a new trend toward utilizing personal computers formerly used for production management in lower-level control such as sequential control. This trend was accelerated by the open module architecture controller (OMAC) proposed by US automobile manufacturers. The idea is to install control, monitoring, and engineering functions on a single personal computer. The control part consists of software logic (software PLC) and is attracting attention as a new genre.

Many vendors have introduced software PLCs. Detailed service such as coordination with hardware PLCs and ease in connecting I/O units will become necessary conditions. Since a personal computer is the operating environment, the development of a "Java PLC", for example, is expected.

4.5 Information network controllers

The trend of production systems toward real-time connection to ERP and SCM systems through the intranet, an IT, so as to be incorporated into an enterprise information system is described above. It is necessary for controllers at this transition point to have a "flexible architecture", typically represented by open and distributed systems, as well as be connected to an upper-level information system through the IT. The first step will be the installation of network adapters in controllers, which provide Web server and remote message transmission by electronic mail to display the control status through internet or intranet. In the near future, control servers with the same distributed object capability as the information system will be installed in controllers, and the enterprise information system will freely download execution orders to controllers. Therefore, an ideal enterprise manufacturing system will be realized in which the operation of information and control systems is seamlessly linked.

5. Fuji Electric's Activities

Ever since the first controllers were developed, Fuji Electric has supplied control systems to the fields of FA and PA. These control systems have had good results with many users. The controllers facing the transition to the next generation of production systems, particularly those controllers oriented to open systems, could not be realized without partially modifying the characteristics of our own controllers, which posed a difficult problem to Fuji Electric. To continue to be a reliable system vendor in the 21st century, Fuji Electric decided to introduce the new-generation integrated controller MICREX-SX series as shown in Fig.1. The MICREX-SX control systems are oriented to open systems, distributed system and object technologies.

The goal of this series is to realize, as much as possible, the following future controller requirements.

(1) Integration of peripheral modules such as controllers and MMI
(2) Distributed placement of small modules by means of the serial bus
(3) Adoption of the IEC standard language and integrated support system with personal computers
(4) Realization of super high-speed processing (20ns) and multi-CPU
(5) Aggressive utilization of software modules
(6) Systematization inclusive of the software PLC
(7) Compatibility with de facto standard networks

The above list is also the goals for Fuji Electric's controllers 10 years from now. In the future, Fuji Electric will develop "flexible architecture", decentralization, and linking with IT.

6. Conclusion

Revolutions in production systems and controller requirements to meet them have been described.

In the future, controllers will unite with the upper-level information system through linking personal computers and IT, while super distributed systems toward integration with the control object will be developed. Fuji Electric will make efforts to go ahead of the times to continue to be a reliable control system vendor. We would appreciate it if users and parties concerned would give us guidance and support.