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Product Trends in Factory Automation System

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Mitsubishi Electric ADVANCE

Product Trends in Factory Automation System

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Precis

By providing comprehensive FA solutions backed by advanced technologies and highest quality, Mitsubishi Electric Corporation is contributing to global manufacturing and customers' satisfaction, with the aim of becoming the leading FA supplier.

This article features three topics: visualization of production information, visualization of energy, and visualization of product information. It introduces e-F@actory product lines, which can assist enterprises in reducing TCO and enhancing enterprise value, as well as some key products that underpin these product lines.

Overview

Author: *Yasuyuki Nishioka**

New era of manufacturing and ICT

The fourth industrial revolution is now underway throughout the world. Japan's manufacturing sector, which has continued to evolve uniquely, must approach ICT directly and develop clear concepts and firm strategies. Today, unfortunately two completely different types of ICT are being discussed regardless of the difference. One is ICT that is used to move things, while the other is ICT that is used to move people. While the western approach may prefer machines do all the tasks of humans, the oriental approach may prefer people and machines to work together. If so, it is necessary to construct a new explicit theory for ICT for moving people and to publicize it worldwide. Regardless of the progress of IoT, (1) not everything can be turned into data, and (2) data that cannot be linked are worthless. It is humans who define data and associate it with something. What determines the outcome of a manufacturing process may significantly depend on how humans relate to cyberspace. How will the two differing worlds of bits and atoms become united? The coming decade will be very interesting for people involved in manufacturing.

**Professor at Hosei University*

MELSEC iQ-R Series

Authors: *Yoshinobu Shimizu** and *Hirofumi Kai**

With the aim of solving various issues in manufacturing in recent years, Mitsubishi Electric has developed and released a new sequencer series called the MELSEC iQ-R series using updated architecture of previous models. This article describes the main features of the MELSEC iQ-R series which offers improved productivity, ease of maintenance, and security functions, and also describes the technologies used.

1. Features of the MELSEC iQ-R Series

1.1 Enhanced productivity

In order to shorten the production cycle, the transmission performance of the system bus has been improved to 3 Gbps from 40 Mbps of the MELSEC-Q series. As a result, the refresh time between a network module and a CPU module is reduced, with a speed of 40 times that of the Q series. In addition, the installation of a high-speed bus for exclusive use between multi-CPUs has allowed the data exchange cycle between the sequencer CPU and motion CPU to be shortened from 888 μs to 222 μs.

Table 1 shows the times taken by a CPU module to process main instructions. In order to increase the speed represented by the PC MIX value,[1] we have developed and installed an LSI circuit for sequence operation that contains control/processing technologies optimized for sequence control. Moreover, we have renewed the execution methods of the structured text (ST) language and function blocks (FBs), thus improving operational performance.

The faster processing described above shortens the production cycle of production equipment, boosting productivity.

Table 1 Main instruction speed of MELSEC iQ-R series

Series name (Model name) / Type of instruction	MELSEC iQ-R series (RnCPU)	MELSEC-Q series (QnUDHCPU)
LD instruction	0.98 ns	9.5 ns
Data transfer instruction	1.9 ns	19.0 ns
Floating-point control	9.8 ns	57.0 ns
ST language (if-instructions)	8 ns	1400 ns
PC MIX[1]	419 instructions/μs	60 instructions/μs

[1] The average number of instructions including basic instructions and data processing instructions that are executed in 1 μs. The larger the value, the faster the instructions are processed.

1.2 Enhanced ease of maintenance

In the MELSEC iQ-R series, various maintenance functions are used to assist early restoration in the event of trouble, thereby reducing downtime. Table 2 shows the new main maintenance functions of the MELSEC iQ-R series.

Table 2 Main maintenance functions of the MELSEC iQ-R series

No.	Function	Outline
1	Event history function	Displays user operation history in a list in addition to the information on error history as conventionally shown.
2	Memory dump function	Automatically saves all device data collectively in an SD card when a system failure occurs.
3	Real-time monitoring function	Displays waveform data on the current status of a device monitored in real time.
4	Label access function from external equipment	Allows access from external equipment to a device of a sequencer by variable names (labels).

In the existing MELSEC-Q series, when a user refers to a device of a sequencer (a memory area that can be configured by the user) from external equipment including a graphical operation terminal (GOT) and when changing the settings of the sequencer device, it is necessary to change the settings at the external equipment as well in order to refer to the sequencer device after changing the settings. We use a system whereby the name of a variable (label) is allocated to a reference destination device (No. 4 in Table 2) in the MELSEC iQ-R series. This means that users are freed from the process of setting a change regarding of the reference destination device on the external equipment side, thereby reducing the maintenance cost.

1.3 Enhancement of security functions

In the MELSEC iQ-R series, users can register a security key for each engineering tool, control program, and sequencer. When there is a security key mismatch between an engineering tool and sequencer, the sequencer limits browsing and editing of the control program from the engineering tool, which is helpful to prevent leakage of technology (see (1) in Fig. 1). In addition, when there is disagreement in a security key between the sequencer and control program, the sequencer prevents the control program from executing, which helps to prevent illegal copying and manufacture

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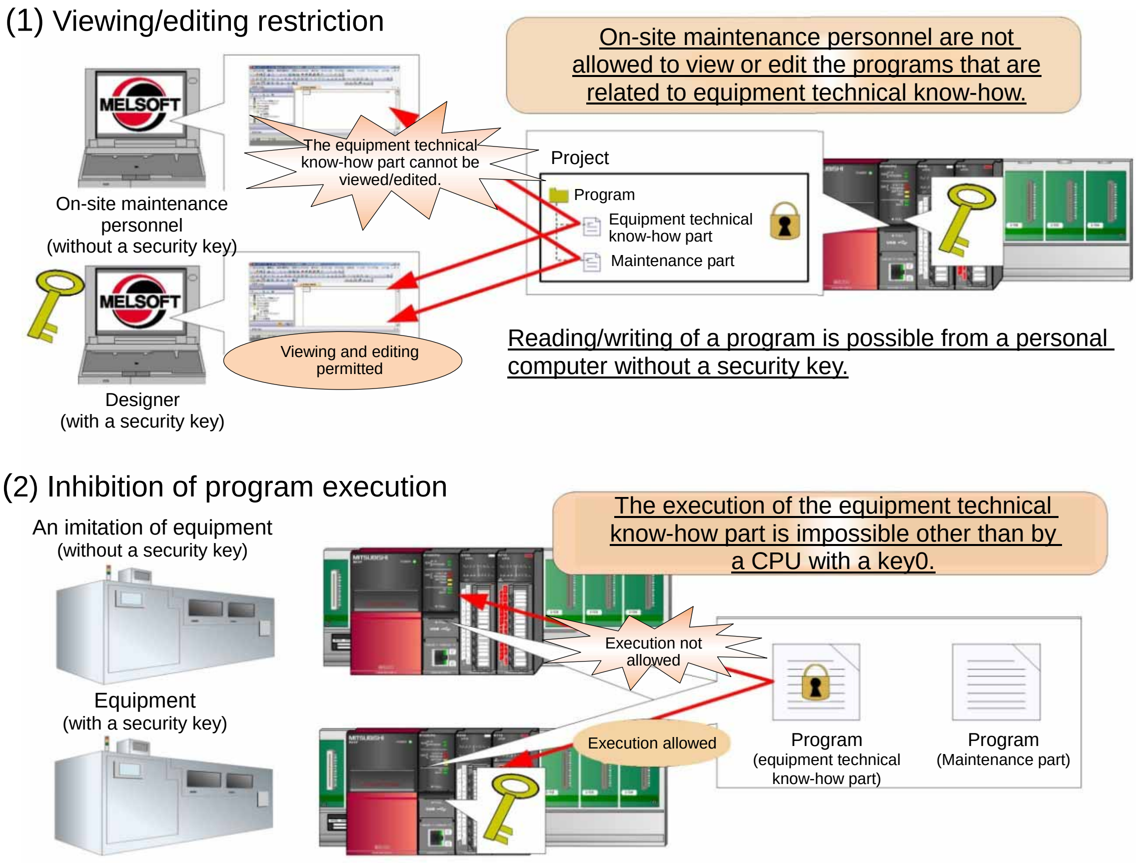

Fig. 1 Security key authentication

of counterfeits (see (2) in Fig. 1).

2. Technologies behind the Features of the MELSEC iQ-R Series

Technologies that have been used in developing the MELSEC iQ-R series are described below.

2.1 Technologies for enhancing productivity

2.1.1 Technology for enhancing the system bus performance

In order to realize the high-speed signal transmission of 3 Gbps using the configuration of transmission channels as shown in Fig. 2, restrictions regarding wiring design have been clarified based on simulated transmission channels. From this, a method of designing a substrate that supports the transmission of high-speed signals has been established.

Accurate analysis is important for simulating transmission channels. In order to improve analysis accuracy, transmission channel models with substrate via holes that are provided on an ASIC (application specific integrated circuit) package, bus connector, and base substrate have been constructed through analysis of a three-dimensional electromagnetic field (Fig. 3).

The modeled transmission parts were used in the analysis system shown in Fig. 4 to simulate transmission channels. As a result, we found the

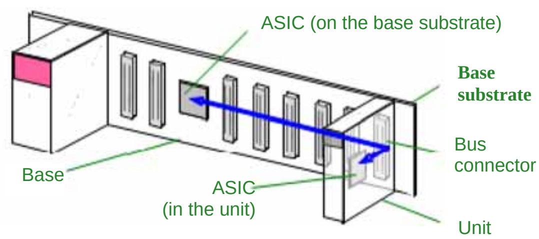

Fig. 2 Transmission line configuration of the PLC system

optimum values with respect to the extension pattern from a bus connector and pad size, via hole specifications, wire length, wire width, wiring interval, and layer composition. Our method of designing a substrate for transmission has been established by applying standardized optimum design values for high-speed transmission.

2.1.2 Technology for enhancing operational performance

The program branch operation using if-statements in ST language is implemented by software instructions (branch processing [JMP] instructions, etc.) in the conventional MELSEC-Q series, which increases the number of steps in programs, taking many hours to process the instructions. Moreover, pointer devices are used for the JMP instructions, which reduces the

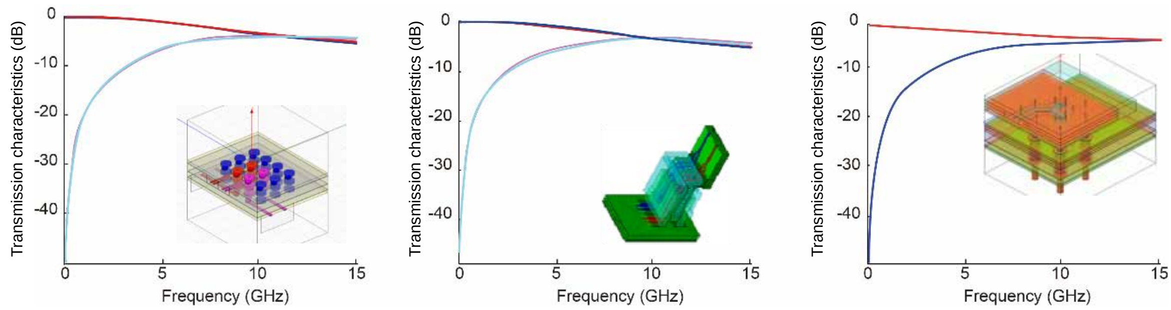

Fig. 3 Transmission characteristics (dB)

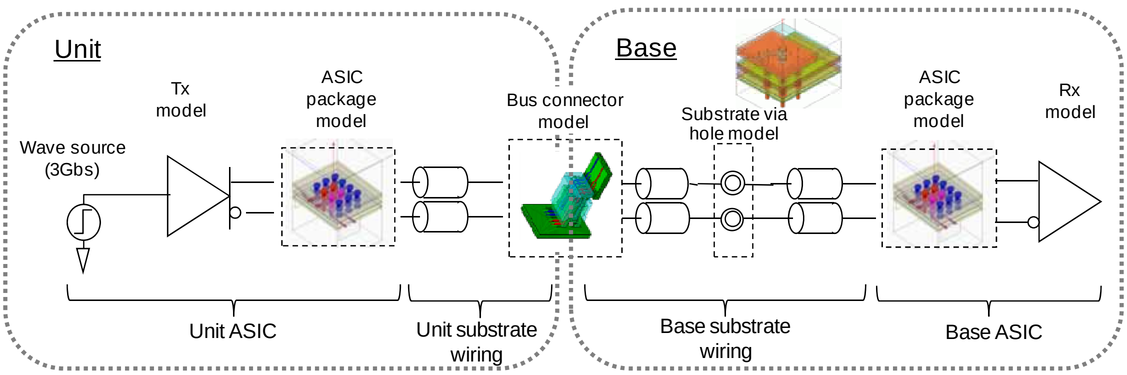

Fig. 4 Model of transmission line simulation

pointer devices that can be used by users (see (a) in Fig. 5). In the MELSEC-iQ-R series, an LSI circuit for sequence operation that has been newly developed is used to change the operation of the program branch using if-statements to be implemented by dedicated hardware instructions (if-instructions, etc.). By this change, both the number of steps in programs as well as the processing time have been significantly reduced (if-statements processing time: 175 times faster than the speed of the MELSEC-Q series). Furthermore, since the if-instructions do not use pointer devices, users can use if-statements without having to consider the number of pointer devices used (see (b) in Fig. 5).

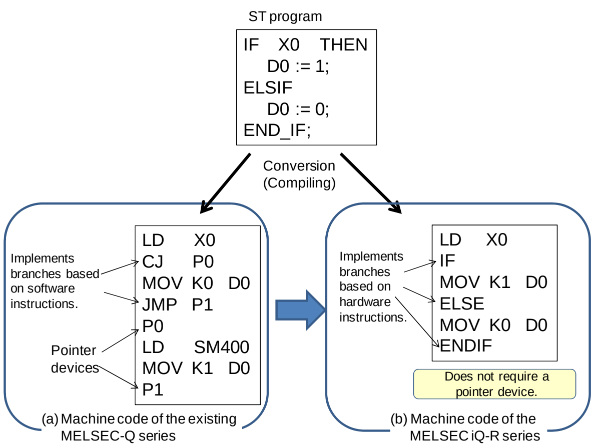

Fig. 5 Example of conversion from a ST program (if-statements) to machine code

2.2 Technology for enhancing ease of maintenance

As described in 1.2, the MELSEC iQ-R series provides a label access function from external equipment to a sequencer to improve ease of maintenance. This function consists of operation of a sequencer that returns the value of a device corresponding to a label name, in response to an inquiry using the label name (see (1) in Fig. 6). However, when using a method to search the database each time an inquiry is received takes time, and the required performance of the system may not be satisfied. Therefore, we have adopted a method in which device information obtained on the first inquiry is retained on the external equipment side, and the external equipment refers to the device information for the second and subsequent inquiries (see (2) in Fig. 6). The GOT of Mitsubishi Electric comes with this function as standard, allowing access to a sequencer using labels, thus facilitating maintenance to the same level as conventional access that uses devices in terms of performance.

2.3 Technology applied for enhancing security functions

The realization of security key authentication described in 1.3 has made it possible to register a security key not only to the sequencer main body but also to the extended SRAM cassette using a dedicated chip mounted on the extended SRAM cassette.

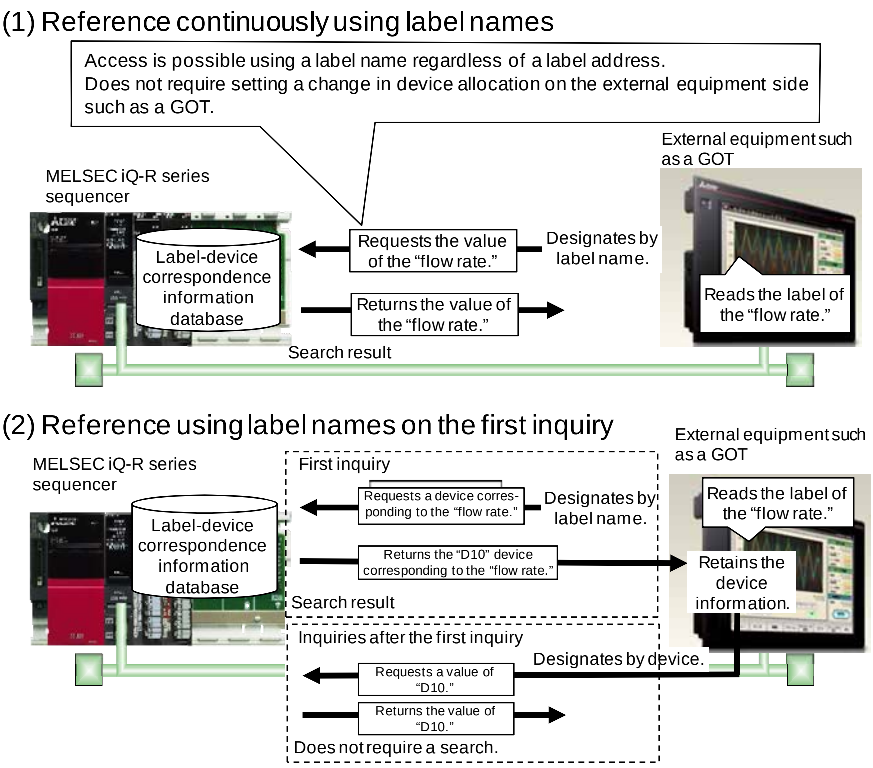

Fig. 6 Label access from external equipment

Consequently, a security key can be registered to a new sequencer by simple operations for replacing the extended SRAM cassette when a sequencer is replaced due to failure (Fig. 7). As described above, strengthening of security functions and convenience are balanced.

Fig. 7 Security key authentication with an extended SRAM cassette

3. Conclusion

This article discussed the features of the MELSEC iQ-R series and the technologies behind these features. We will continue to make innovative progress in the manufacturing industry.

Reference

(1) Hideaki Morita: Engineering Innovation and Expansion of Application Fields of Controllers for FA Use, Mitsubishi Denki Giho, 88, No. 9, 508–513 (2014)

MELSEC iQ-R Series Servo System Controller

Authors: *Hiroyuki Ono** and *Tomonori Ando**

The latest motion CPU module (RnMTCPU) and simple motion module (RD77MSn) have been developed as additions to our servo system controllers in the MELSEC iQ-R series, delivering 1.8 times the speed of conventional Q series units and even higher functionality. These units can provide solutions for enhancing productivity when used in combination with the MELSERVO J4 servo amplifier series and engineering software of GX Works3 and MT Works2.

1. Background

We offer two types of servo system controller: motion CPU modules for large-scale systems and simple motion modules for medium- to small-scale systems (Fig. 1).

The motion CPU module is our unique multi-CPU system in combination with a PLC CPU module. The loads of motion control and sequence control are distributed to CPU modules, thereby balancing the stable sequence control and high-precision/ high-response motion control. In addition, by upgrading software, users can benefit from newly added functions.

Furthermore, the simple motion module makes it possible to conduct position control, synchronous control, and speed and torque direct control from a PLC CPU module. This feature, which helps users to easily perform sophisticated motion control, is highly valued in the market.

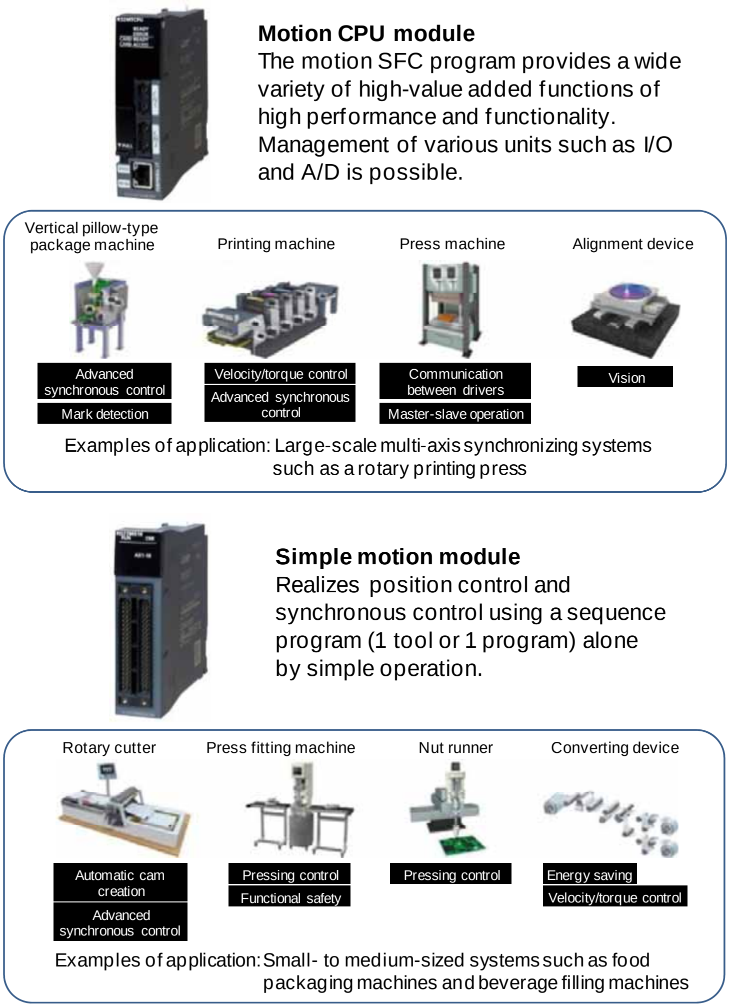

Fig. 1 Types and uses of servo system controllers

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This article describes how we are working to meet the following emerging market demands.

(1) Improvement of the responsiveness in motion operation processing and a large increase of the control data
(2) Increase in the speed and volume of data exchange between units
(3) Standardization and packaging of application programs
(4) Improvement of the ease of debugging without using an actual machine or personal computer

2. Hardware

2.1 Improvement of basic performance thanks to the newly developed SoC

The faster processing core of the newly developed system-on-chip (SoC) allowed us to speed up the motion operation cycle to 1.8 times that of the conventional Q series motion CPU modules. In addition, by building a communication control part that supports the SSCNET III/H servo network within the SoC, fewer components are needed. Furthermore, designed to minimize heat generation, these units are naturally air-cooled, eliminating the need for heat sinks and fans.

2.2 Increased bus speed and countermeasures against noise

The speed of data exchange between units has been successfully increased to 40 times that of the Q series by setting the transmission speed of the system bus to 3 Gbps. Moreover, the speed of the synchronous communication bus for exclusive use between multi-CPUs has been quadrupled. Furthermore, the use of a clock synchronizing between the units allows a large-scale motion synchronizing system to be built using multiple units.

In this hardware design, we have employed a front-loading hardware design simulating the electric plane resonances of substrate patterns, etc. to balance the mitigation of spurious emission and influence of external noise, with high-speed operation.

2.3 Improvement of other functions

Ferroelectric random access memory (FRAM) is used as non-volatile memory, eliminating the conventional need for a battery for retaining power in the event of a power failure in order to protect important information such as the original data of a machine, thus simplifying maintenance. In addition, the dot matrix display in the motion CPU modules greatly improves the visibility of the states of the unit. Moreover, the SD memory card slot allows large volumes of data to be handled.

3. Software

3.1 Strengthening the linkage between units

For the linkage between conventional CPU modules, it has been necessary to write a positioning program in a motion CPU module in advance, making programming cumbersome and inflexible. However, the faster system bus allows direct instructions to be given by a PLC CPU module, which facilitates programming using function blocks (FBs).

3.2 Advanced synchronous control

All series of servo system controllers of Mitsubishi Electric come with a function called “advanced synchronous control”, which allows mechanical elements such as gears, clutches, and cams to be electronically controlled with a simple operation (Fig. 2). In the MELSEC iQ-R series, by using the improved CPU performance, the dynamic creation of complicated cam patterns, which previously had to be created off-line (only on engineering software), can now be done at a CPU module, enabling the cam pattern to be finely adjusted using a human machine interface (HMI)

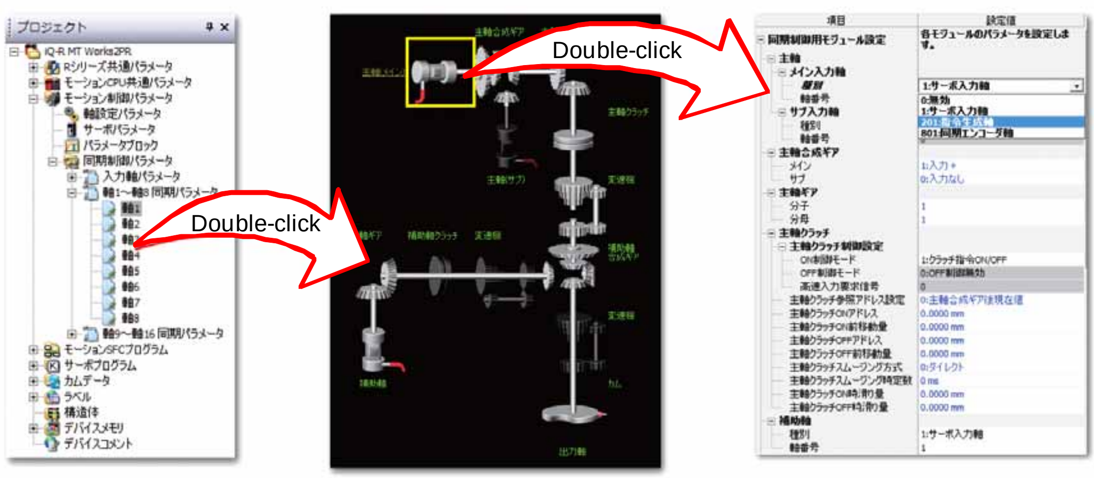

Fig. 2 Advanced synchronous control

such as a touch panel. In addition, as cam patterns can be read and written using SD memory cards, a wider variety of production recipes can be stored simultaneously ready for use.

3.3 Add-on functions

The frequently used special functions that were previously supported using customized software have been modularized and a system has been built to provide users with these modularized special functions as add-on functions. The combination of add-on functions in accordance with the devices used makes it possible to provide various control solutions (application packages). Table 1 shows examples of such functions.

Table 1 Example of add-on functions

Target device	Packaged add-on functions
Gantry control	Tandem operation, vibration suppression filter, interference check
Printing machine	Tension control, mark detection, multi-axis distributed synchronization
Carrier robot	Coordinate conversion, interference check

3.4 RAS (reliability, availability, and serviceability) enhancement

RAS has been greatly enhanced by strengthening the logging functions compared to the conventional series. For example, in addition to the event logging common to the MELSEC iQ-R series (change in power source conditions, security-related information, etc.), the communication status of the SSCNET III/H servo network, the reason for a request to restore to the original state, etc. are recorded in a CPU module in an integrated manner. The recorded information can be used for detecting the causes of troubles.

Furthermore, as it is possible to accumulate the data sampling results in an SD memory card, waveforms can be captured when a trouble occurs at the production site without engineering software. In addition, data can be backed up and restored using SD memory cards and programs can be updated, thus shortening the downtime for CPU module replacement. Moreover, in terms of reliability, the tolerance to software errors and the durable cycle life of memory elements have been improved by applying error-correcting codes (ECCs) to the memories inside the units, managing the frequency of rewriting flash memory, and dispersing used sectors.

4. Engineering Software

4.1 Enhancement of the linkage between engineering software programs

The engineering software linkage between the PLC, simple motion module, and servo amplifier is enhanced, allowing various operations to be implemented by GX Works3 alone including programming, parameter setting, debugging, servo tuning, etc. In addition, the linkage between the simulators of the PLC and simple motion module has been established, allowing drive control simulation without a servo amplifier or servo motor. This reduces the startup man-hours at the worksite (Fig. 3).

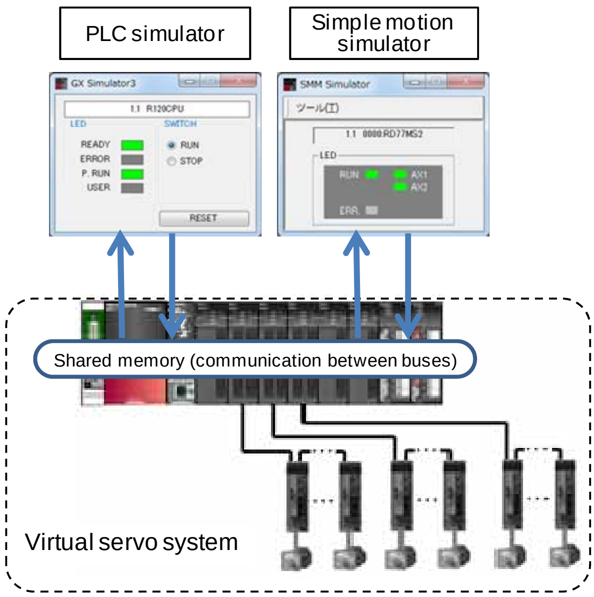

Fig. 3 Simulator linkage

5. Conclusion

To meet the demand for more sophisticated manufacturing and to make full use of the total power of our FA products, servo system controllers are increasingly becoming the core of our control equipment. We will continue to play a leading role in the development of servo system controllers.

FA Integrated Engineering Software "MELSOFT iQ Works Version 2"

Authors: *Yuzuru Tone** and *Shunsaku Takeuchi**

In the field of factory automation (FA), there is demand for making engineering work more efficient in all aspects of the life cycle of a product from system design, to use and maintenance. In response, we have developed and released FA integrated engineering software called MELSOFT iQ Works Version 2 (hereafter, "iQ Works V2"). iQ Works V2 enables data to be managed from MELSOFT Navigator (hereafter, "Navigator"), which is system management software, and from other engineering software each for a PLC and motion controller in an integrated manner, thus helping customers to reduce TCO. This article explains the characteristic functions of iQ Works.

1. System Configuration Setting

iQ Works V2 sets up system configurations including a module connection configuration of a PLC and motion controller and a network connection configuration. This process is conducted using two configuration diagrams, namely, the network configuration diagram and the module configuration diagram. The system designer can set up a virtual system configuration prior to constructing the real one. By using the system configuration checking function of Navigator, the system designer can desk-check errors such as those related to connections, connections exceeding the upper limit, and insufficient power supply capacity.

Furthermore, from a PLC and other modules on a configuration diagram, start-up of individual engineering software and interaction between parameter settings can be operated.

In addition, a configuration diagram can be automatically generated using Navigator, which communicates with a PLC (Fig. 1). This eliminates the re-setting process in software which is conventionally done manually by the system designer when a change is made in the real system configuration.

2. Parameter Setting

Parameters must be set for each module, including a PLC and motion controller. These parameters are set using engineering software for each module.

In order to streamline the parameter setting, iQ Works V2 provides a parameter batch setting function from Navigator to individual engineering software ((1) in Fig. 2) as well as a parameter import function from individual engineering software to Navigator ((2) in Fig. 2).

The parameter batch setting function from Navigator to individual engineering software is used for parameters for communication settings, etc., which are determined in an integrated manner for the system as a whole. Parameters are set in Navigator such that there is no inconsistency throughout the system and then these parameters can be set to individual engineering software in the system at once. This function helps prevent setting errors and also eliminates the trouble of manually input parameters to each engineering software.

The parameter import function from individual engineering software to Navigator is used when changing the parameters at the stage of equipment

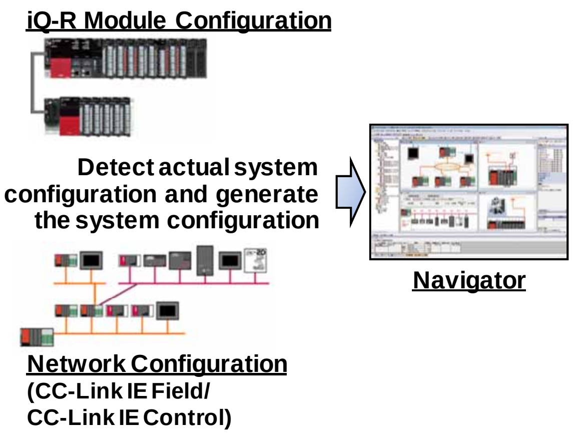

Fig. 1 System configuration

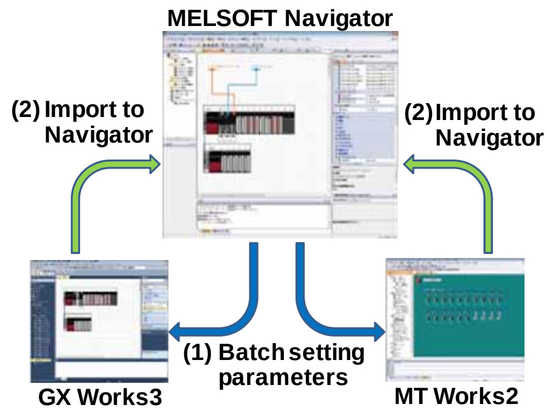

Fig. 2 Parameter setting

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start-up. After parameters are changed in the each engineering software, the change is imported to Navigator, thus preventing inconsistencies of data between engineering software in the system.

Moreover, iQ Works V2 has a function for interacting with partner-made software as part of the interaction between engineering software used for parameter setting.

3. Interaction with System Label

With iQ Works V2, it is possible to arbitrarily name (or "label") the memory address of a PLC, etc. which can be used in common among the PLC, motion controller, and GOT. This shared label is called a "system label." The use of a system label allows the system designer to carry out the design without considering memory addresses.

System labels are collectively managed in the system label database of Navigator. The system label database comprehensively manages system label names and system address allocation information. Individual engineering software can use system labels by accessing the system label database. Moreover, when an address that is allocated to a system label is changed, consistency among engineering softwares in the system is maintained by the change notification function. By using system labels for preparing programs and screens of the GOT, the workload for the system designer as well as setting errors are greatly reduced.

According to existing iQ Works, the GOT accesses a PLC using addresses as shown in Fig. 3 (a). Therefore, if a change is made to an address that is allocated to a system label, it has been necessary to enter the address information after the change to the GOT.

In order to skip this step, iQ Works V2 includes a function that allows devices to communicate with each other using label names alone as shown in Fig. 3 (b): when the GOT accesses the memory of a PLC, the system label names are exclusively used. Accordingly, when a change is made to an address that is allocated to a system label of a PLC, it is not necessary to apply the change in address to the GOT, thus further reducing the man-hours required for system maintenance.

4. Interaction with a Simulator

iQ Works V2 is provided with an environment for simulating devices that configure a system. A system designer can desk-check the operation of a program before assembling the real equipment, thereby reducing the programming man-hours. When a system is configured by combining multiple devices, a simulator of each device can interact with other ones (Fig. 4).

In order to simulate a real system, each simulator must pass and receive control information (input/output signals and control data to be used for positioning control and sequential control) at a timing similar to the actual system. With iQ Works V2, control information is exchanged such that each simulator can operate at a timing similar to the actual system by time sharing control of simulators.

5. Conclusion

The functions of iQ Works V2 described here help make life cycle engineering in a large-scale system more efficient, thus reducing TCO at enterprises. These functions will also help achieve the e-F@ctory concept, i.e., visualization of production information, visualization of energy, and visualization of safety, promoted by Mitsubishi Electric Corporation.

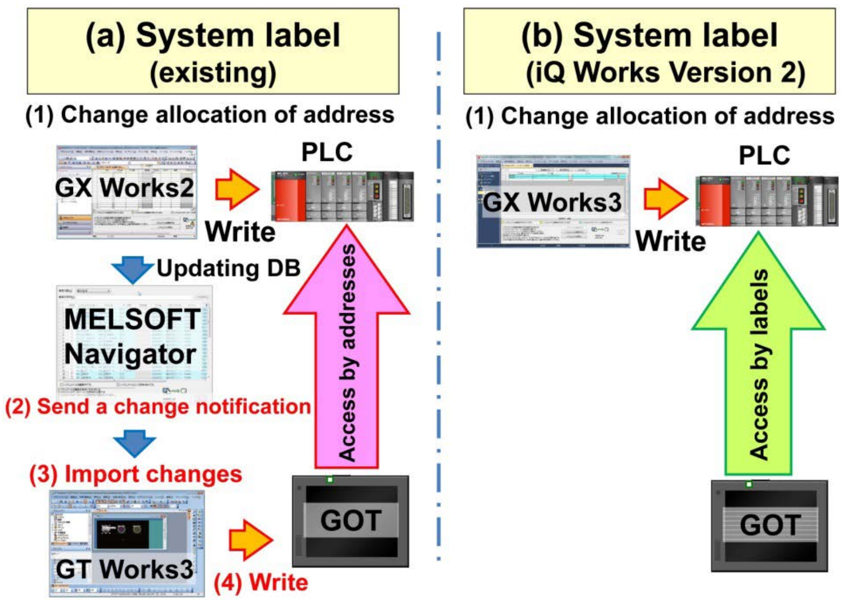

Fig. 3 System label

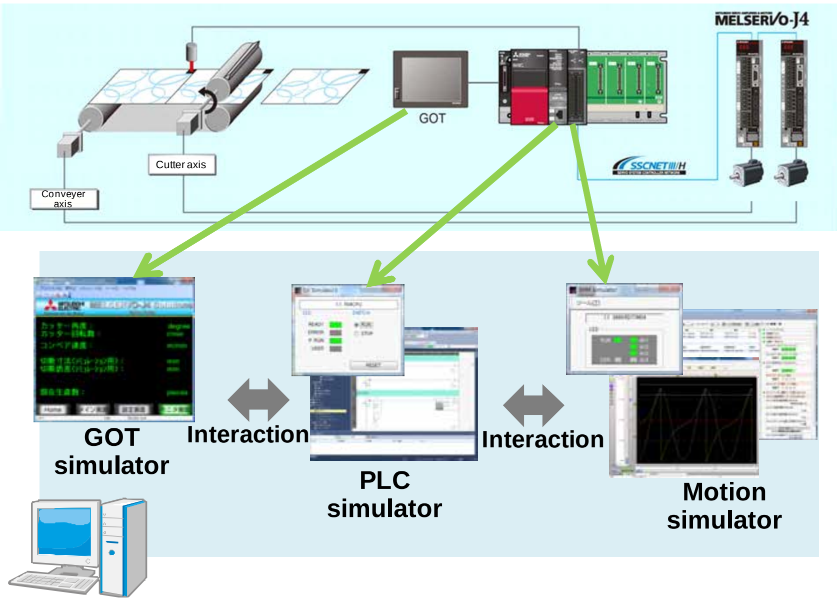

Fig. 4 Interaction simulation

6. Reference

(1) Shuichi Tanaka, et al: FA Integrated Engineering Software "MELSOFT iQ Works Version 2," Mitsubishi Denki Giho 89, No. 4, 223-226 (2015)

The Brand-new Model of CNC, M800/M80 Series

Author: *Kotaro Nagaoka**

In response to demands in machining for boosting productivity, Mitsubishi Electric has developed the M800/M80 series, the latest series of computerized numerical controllers (CNCs). The M800/M80 series not only ensure high productivity through overwhelmingly superior performance, but also provide excellent usability and flexibility, and thus innovatively add value to any machine shop.

1. Introduction

Machine tools are used in the manufacturing of a wide variety of products such as electronics, automobiles, aircraft, and medical instruments. The machine tool market is generally growing amid fluctuating capital investment. In addition, with the rapid spread of various machine tools in emerging countries especially in Asia, the range of the machine tool market is expanding. Accordingly, in addition to enhancing productivity and securing safety and reliability that have been required for a CNC, which controls machine tools, new needs are arising including usability that allows unskilled persons to easily operate the tools, and coordination with factory automation and production management systems in line with the progress in information technology, networks and the IoT.

The M800/M80 CNC series were developed to meet these diverse market needs. The new CNC series, which inherits and improves on the high productivity and customizability of the M700V/M70V series, innovatively adds value to manufacturers through enhanced usability and coordination with the FA integrated solution called e-F@ctory, proposed by Mitsubishi Electric.

Introduced below are the features and versatile functions of the M800/M80 series.

2. Overview of the M800/M80 Series

2.1 Model lineup

Figure 1 shows the lineup of the M800/M80 series. The features of each series are as follows.

(1) M800W series

A premier model with expandability and flexibility

(2) M800S series

A high-grade model for high-speed, high-precision, and high-grade machining and simultaneous multi-part processing using lathes

(3) M80 series

A standard model that balances high productivity and usability

(1) M800W series (2) M800S series (3) M80 series

Fig. 1 Lineup of the M800/M80 series

Table 1 shows a comparison of these series.

Table 1 Comparison of the M800/M80 series

Series	(1) M800W	(2) M800S	(3) M80
Type	Separate type (The display separated from the CNC body)	Panel-in type (The display built in the CNC body)	
Display OS	Windows[1] 8	Real-time OS	
Display size	19-inch/15-inch	15-inch/ 10.4-inch	15-inch/ 10.4-inch/ 8.4-inch
Processing program capacity	270 kBPM[2]		135 kBPM[2]

[1] Windows is a trademark or registered trademark of Microsoft Corporation (U.S.) in the U.S. and other countries.

[2] kBPM: kiloblock per minute

2.2 Features of the M800/M80 series

2.2.1 Ground-breaking high-speed processing

The M800/M80 series come with a unique CPU developed by Mitsubishi Electric specifically for CNCs. This dedicated CPU has revolutionary processing capacity for programs including those of PLCs, and allows high-speed processing of fine segment programs and large-scale ladder programs (an increase of 1.6 times from M700V). Moreover, the optical communication speed between the control unit and drive unit in the CNC is also increased, thereby greatly improving the performance of the system as a whole,

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and increasing the manufacturing speed and precision to raise productivity.

2.2.2 Advanced design

The M800/M80 series also come with a newly designed display and keyboard that make the screen easier to use even for unskilled persons and also improve overall operability. A flat shape with premium accents for the touch-panel display enhances operability. Furthermore, the vertical 19-inch display of the M800W series comes with a dual-screen display panel which splits the screen into upper and lower parts, with the lower screen being customizable by manufacturers. This enables manufacturers to tailor operations to its own style (Fig. 2).

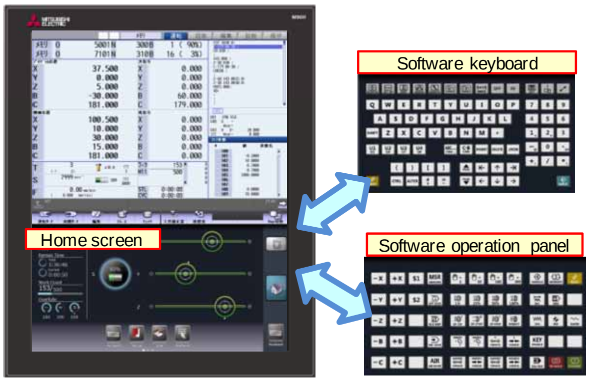
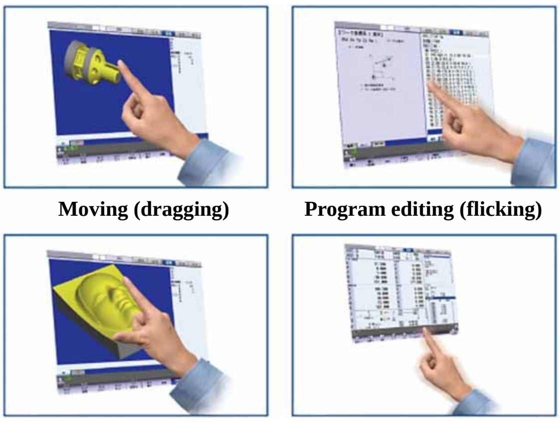


Fig. 2 Multi-screen design of 19-inch display panel

2.2.3 Capacitance touch panel

All displays of 10.4 inches or larger come with a touch panel. The capacitance touch panels offer longer life and enable operation through intuitive gestures on the multi-touch interface (Fig. 3). The touch panels are resistant to damage from chips, water, cutting oil, etc., using clear glass that is resistant to damage and impact for surface protection.



Moving (dragging) **Program editing (flicking)**

Zooming (pinching) **Menu turning** (flicking)

Fig. 3 Intuitive operation using touchscreen display panel

3. Wealth of Functions of the M800/M80 Series

3.1 Functions for lathe operation

With improved functions for milling, the M800/M80 series can control the processing of complicated odd-shaped parts. The models in these series also have various functions for controlling a multi-axis and multi-part system, shortening cycle time and enhancing productivity. Furthermore, the expansion of interactive functions through program editing for synchronization in a multi-part system, interactive cycle insertion, and 3D graphic checking allows complicated processing in a simple and efficient manner.

3.2 Functions for machining centers

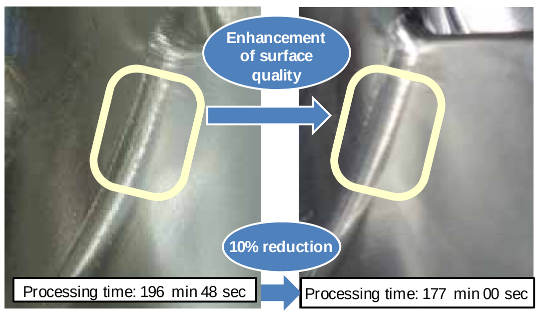
The M800/M80 series come with the SSS-4G (Super Smooth Surface-4th Generation) control, which is an upgraded version of the SSS control which is a unique high-speed, high-precision and high-quality processing control function of Mitsubishi Electric, for operation using machining centers.

In addition, to make the processing more rapid, more precise, smoother, and simpler than the conventional SSS control, the following functions have been improved:

- To shorten production cycles through optimum acceleration and deceleration adjusted to the characteristics of each axis (more rapid)
- To operate a tool while smoothly suppressing the vibration even when passing a corner at high speed (more precise; smoother)
- To adjust parameters in an understandable and simple manner by designating allowable errors (amount of tolerance) (simpler)

Figure 4 shows the effects of SSS-4G control.

(a) Appearance of a test workpiece



(b) Comparison of enlarged images (left: M700V; right: M800)

Fig. 4 Effects of the SSS-4G control of M800 CNC

3.3 Solution for innovative manufacturing

Solutions are needed that make full use of FA and IT technologies for helping customers to improve processes and reduce the total cost, including all manufacturing processes of development, production, and maintenance, and thus provide better manufacturing than competitors. In response, we propose an FA integrated solution, e-F@ctory. The following functions can be provided by the M800/M80 series as a part of e-F@ctory.

(1) MES interface function

When processing is completed and an alarm is issued, the CNC autonomously transmits data in SQL statements to the database in a production management system.

(2) EcoMonitorLight connection

Visualizes the power consumed by the entire machining equipment by directly connecting with a power consumption monitor of Mitsubishi Electric.

(3) Support for numerous field networks

Supports CC-Link and PROFIBUS-DP[3], and enables a wide variety of peripheral devices to be connected.

4. Conclusion

This paper has introduced the latest M800/M80 series in the CNC lineup, and the main functions. We will continue to develop products that meet diversifying manufacturing needs.

[3] PROFIBUS is a trademark or registered trademark of PROFIBUS User Organization.

Cutting-edge Technology with Fiber Laser Processing Machine

Authors: *Naoki Miyamoto** and *Takayuki Hirano**

Along with an increase in the output power of fiber laser oscillators, in the market of sheet-metal laser processing systems in recent years, the range of plate/sheet thickness that can be cut by fiber laser processing systems is expanding. In order to meet market needs, we have released a new fiber laser processing system, the ML3015NX-F40 (hereafter, "NX-F40") with a 4-kW oscillator mounted, developed with the concepts of (1) high speed, (2) ecology, and (3) high quality. Figure 1 shows the external appearance of the system.

Fig. 1 New fiber laser processing system NX-F40

1. Concept of the NX-F40 Fiber Laser Processing System

1.1 High speed

Since the wavelength of a fiber laser beam is shorter than that of a CO_2 laser beam, fiber laser beams have a high absorption rate to metal and good focusing properties. In addition, increased output has made it possible to process even medium-thickness plates at high speed. The NX-F40 comes with a new processing head that has been developed to use an optical system to make the best use of these advantages of fiber laser beams. The new processing head achieves three times faster processing of a 1 mm-thick stainless steel sheet than CO_2 laser processing systems, such as by our previous model, ML3015NX-F (hereafter, "NX-F") with a 2.5-kW fiber laser oscillator. In addition, the new model exhibits high machining performance relative to its output when processing medium-thickness plates as shown in Fig. 2.

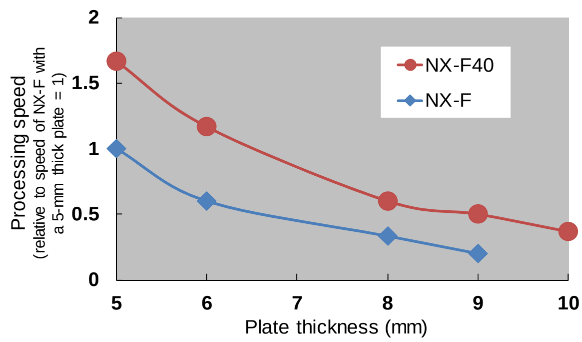


Fig. 2 Comparison of stainless steel (SUS304) processing speeds

1.2 Ecology

The main factor to be considered in the operating cost of a laser processing system is power consumption. Equipped with a low-loss NC made by Mitsubishi Electric, drive devices, and a fiber laser oscillator with excellent oscillating efficiency, the NX-F40 uses about 60% less power, as shown in Fig. 3, than the ML3015NX-45CF-R (hereafter, "NX-45CF-R"), which is a CO_2 laser processing system with an equivalent output. Furthermore, the NX-F40 features an eco mode that reduces standby power consumption, based on a technique for stopping unnecessary purge gas when a

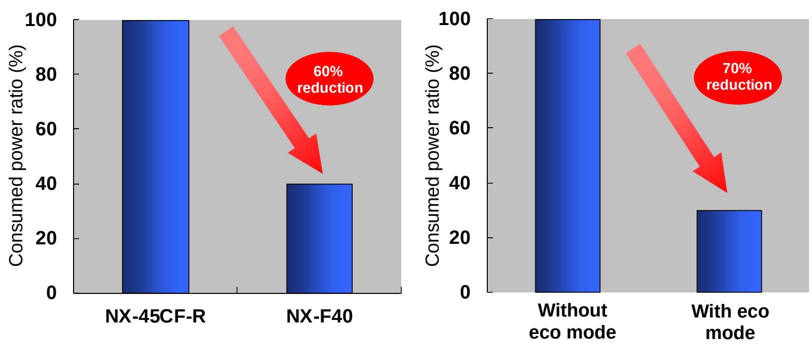


Fig. 3 Reduction in power consumption of NX-F40

*Nagoya Works

processing system is at rest and for shutting down the oscillator, cooling device, and other devices in a phased manner. This mode reduces power consumption by 70% compared with not using eco mode. Moreover, the operation of devices in the system, from shutdown to return of power, is smooth without degrading work efficiency. Thus, the laser processing system is environment friendly.

1.3 High quality

The NX-F40 has an output control function to perform machine processing to manufacture high-quality products in a stable manner, achieving laser output stability of ±1%. This is based on a technique for stabilizing the laser output at high speed by using a microcomputer. This technique reduces dross (deposits) that develops on the reverse side of workpieces during high-speed processing. In addition, the processing head has been newly developed to make full use of 4-kW output.

2. Examples of Processing by NX-F40

When first released to the market, fiber laser processing systems were characterized by high-speed cutting, micro-fabrication of sheets, and high-reflection material processing based on the excellent convergence attributable to its wavelength. However, the increase of oscillator output and rapid progress in processing technology deliver performance close to that of CO_2 laser processing systems when processing not only sheets but also plates. The latest processing technologies are outlined below.

2.1 Increase in maximum plate thickness that can be processed

The NX-F40 has expanded the range of plate/sheet thickness that can be cut, thanks to the increased oscillator output power and improved optical system. Table 1 shows a comparison between the NX-F and NX-F40 regarding the cutting ability by type of material. The maximum cutting ability exhibited by the NX-F40 was with 22 mm-thick plate of mild steel and stainless steel, and 18 mm-thick plate of aluminum alloy. This shows that the maximum plate thickness that can be processed is increased by about 30% compared with the NX-F, and an increase of about 25% compared with CO_2 laser processing systems with equivalent output.

2.2 Increase in plate thickness that can be processed by F-CUT

For the previous NX-F model, we realized laser processing system technology that allowed any forms to be made by cutting with maximum productivity, including F-CUT developed to perform processing without shaft halt to exploit the focusing and absorptivity properties of fiber laser beams, and software for processing path optimization (FRG) to make full use of the effect of F-CUT. The thickness limit that can be processed by F-CUT has been increased from 2.0 mm to 3.0 mm in the NX-F40, thanks to an increase in output. Figure 4 shows an example of processing by F-CUT. The time required to process a 3-mm thick plate has been reduced by 52% compared with the NX-F.

2.3 Improvement of cutting surface quality

It is widely known that cutting mild steel using oxygen may cause a change in the cutting phenomenon at a threshold processing speed of around 2 m/min. At a cutting speed of 2 m/min or below, the energy of oxidation reactions (combustion) of iron is a major factor causing the melting of base material, requiring oxygen to be supplied at a sufficient flow rate. On the other hand, at a cutting speed exceeding 2 m/min, it is laser output that significantly contributes to melting of base material. This often causes streaks formed by periodic oxidation reactions (combustion) to become less noticeable, thereby reducing the roughness of the cut surface. Table 2 compares the surface of a 9-mm thick mild steel plate cut by the NX-F40 with that cut by the NX-45CF-R. The

Table 1 Comparison of cutting performance by material

Processing system	Material	Assist gas	Plate thickness (mm) 2 4 6 8 10 12 14 16 18 20 22 24
NX-F	Mild steel	Oxygen	
	Stainless steel	Nitrogen	
	Aluminum alloy	Nitrogen	
	Copper	Oxygen	
	Brass	Nitrogen	
NX-F40	Mild steel	Oxygen	
	Stainless steel	Nitrogen	
	Aluminum alloy	Nitrogen	
	Copper	Oxygen	
	Brass	Nitrogen	

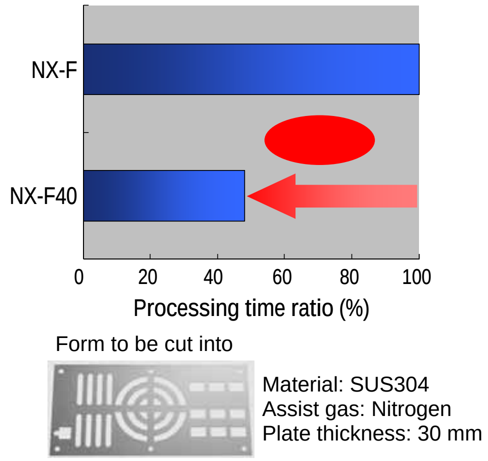


Fig. 4 Reduction in processing time by F-CUT

Table 2 Comparison of quality of cut surface

Model	Fiber laser (NX-F40)	CO_2 laser (NX-45CF-R)
Cut surface		
Surface roughness (μm)	25	30
Processing speed (mm/min)	2,100	2,100

processing speed of the NX-F40 is about 150% that of the NX-F thanks to the increased output power of the oscillator and the use of a newly developed processing head. As a result, the roughness of the cut surface has been significantly reduced, obtaining a cutting surface quality equivalent to that using the NX-45CF-R.

2.4 Shortening of processing time by new piercing technology

When processing mild steel plates (excluding thin material regarded as sheets), the time required for piercing (drilling at the starting point) accounts a large proportion of the total processing time. Therefore, a high peak piercing device has been newly mounted on the NX-F40. High peak piercing is piercing technology that makes use of the suppression of burning by a powerful side blow and the high responsiveness of the oscillator. Figure 5 compares the piercing abilities with mild steel plates of thicknesses up to 19 mm. As a result of efforts to drastically shorten the piercing time for each plate thickness, with the 19-mm thick plate, the time was reduced by 73% compared with the conventional piercing time.

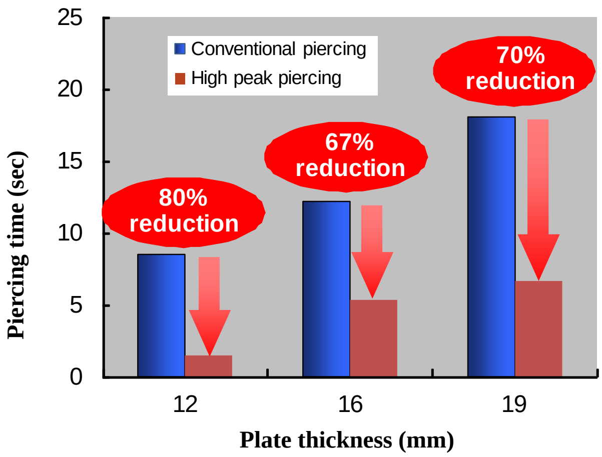
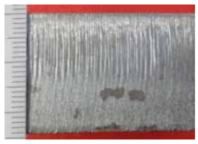
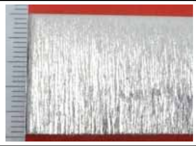


Fig. 5 Comparison of piercing performance by thickness

2.5 Technology for cutting thicker plates

Although there has been rapid progress in plate cutting technology using fiber laser processing systems, the processing quality of fiber laser processing systems of all manufacturers has not yet reached the level of existing CO_2 laser processing systems. Table 3 shows examples of various plates processed using the NX-F40. In order to realize a system for high-quality processing of a wide range of thickness from sheets to plates using a fiber laser processing machine, the NX-F40 comes with an optimized optical system embodying technologies we have created during 30 years of developing CO_2 laser processing systems as well as an optimized assist gas flow. This enables high-quality cutting of a 25-mm thick mild steel plate using oxygen, and of 25-mm thick stainless steel and aluminum alloy plates using nitrogen.

Table 3 Examples of plates cut by NX-F40

Material	Plate thickness (mm)	Sample cut	Cut surface
SS400	25		
SUS304	25		
A5052	25		

3. Conclusion

The technology of laser processing systems has progressed greatly compared to that of other machine tools, and such technology improvement is expected to continue. As a comprehensive laser processing system manufacturer, we will strive to meet users' needs which are becoming increasingly sophisticated and diverse, improve the performance of laser processing systems and actively respond to a wide range of needs in various fields of manufacturing.

Expansion of Circuit Breaker and Switch Lineup for Photovoltaics Market

Authors: *Shigeki Koumoto** and *Shinya Watanabe***

With the increasing concern about global warming and in the wake of the Great East Japan Earthquake, power generating systems that use renewable energy have been spreading in recent years. Among such systems, the use of large-scale megawatt class photovoltaic power systems (“PV systems”) has expanded alongside changes in laws and subsidy systems for feed-in tariffs in July 2012 by the national government and local municipalities in Japan and advances in the performance of solar panels.

This article describes the characteristics of the newly-developed circuit breaker and switch that have already been released in the PV market to enhance our lineup, and explains the direct current interruption technology used in the new products. The new circuit breaker and switch can be used in high-voltage direct current equipment of 750 V DC to 1,000 V DC classes for which there is strong demand for megawatt-class PV systems.

1. Characteristics of the High-Voltage Direct Current Circuit Breaker and Switch

Tables 1 and 2 show the specifications of the circuit breaker and switch that have been developed for high-voltage direct current circuits. This time, we developed three series of new models that can be used in high-voltage circuits of 750 to 1,000 V DC. These series are ideal for PV systems as shown in the schematic view of Fig. 1. The features of each series are described below.

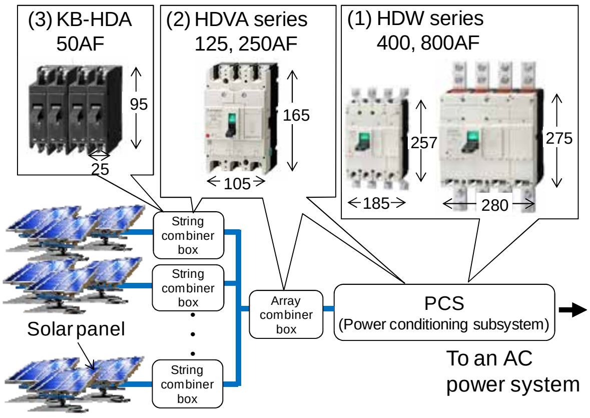
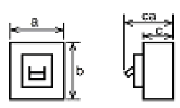


Fig. 1 Application to the PV system

(1) HDW circuit breaker series applicable to 750 to 1,000 V DC

This series can be used at 750 to 1,000 V DC, which is best suited to a large-capacity power conditioning subsystem (PCS), and consists of two models, NF400-HDW (maximum rated current: 400 A)

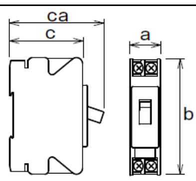
Table 1 Product specifications (circuit-breaker)

Type name			NF125-HDVA		NF250-HDVA		NF400-HDW		NF800-HDW	
Rated current Rated ambient temperature		A DC 40°C	50, 60, 75, 100	125	125, 150, 175, 200, 225	250	250, 300, 350, 400		500, 600 ,630, 700, 800	
Number of poles			3		3		3	4	3	4
Rated insulation voltage Ui		V	800		800		800	1000	800	1000
Rated short-circuit breaking capacity (kA)	JIS C 8201-2-1 Ann.1 JIS C 8201-2-1 Ann.2[1] IEC 60947-2 EN 60947-2 GB14048.2 (Icu/Ics)	1000 V DC	–	–	–	–	–	10/5	–	10/5
		750 V DC	–	–	–	–	10/10	10/10	10/10	10/10
		600 V DC	–	–	–	–	–	–	–	–
		400 V DC	–	–	–	–	–	–	–	–
	JIS C 8201-2-1 Ann.2 (Icu)	750 V DC	10		10		–	–	–	–
		600 V DC	–	–	–	–	–	–	–	–
Number of operating cycles		Without current	10,000	8,000	8,000	8,000	5,000		3,000	
		With current	1,500	1,000	1,000	1,000	1,000		500	
Rated impulse withstand voltage Uimp		kV	8							
Reverse connection			Possible							
Overall dimensions (mm)		a	105				140	185	210	280
		b	165				257		275	
		c	68				109		109	
		ca	92				161		161	

[1] The product applicable to 1,000 V DC is Ann. 1 only.

*Fukuyama Works **Advanced Technology R&D Center

Table 2 Product specifications (switch)

<table>
<tr><th colspan="3">Type name</th><th>KB-HDA</th></tr>
<tr><td colspan="3">Rated current A DC
Rated ambient temperature 40°C</td><td>15</td></tr>
<tr><td colspan="3">Number of poles</td><td>2</td></tr>
<tr><td colspan="3">Rated insulation voltage Ui V</td><td>800</td></tr>
<tr><td colspan="3">Rated voltage Ue V DC</td><td>750</td></tr>
<tr><td colspan="2" rowspan="2">Utilization category
JIS C 8201-3</td><td>750V DC</td><td>DC-21B</td></tr>
<tr><td>400V DC</td><td>DC-22A</td></tr>
<tr><td rowspan="8">Making and breaking capacity
JIS C 8201-3</td><td rowspan="4">750V DC</td><td>Making current</td><td>22.5</td></tr>
<tr><td>Breaking current</td><td>22.5</td></tr>
<tr><td>Time constant</td><td>1</td></tr>
<tr><td>Number of operating cycles</td><td>5</td></tr>
<tr><td rowspan="4">400V DC</td><td>Making current</td><td>60</td></tr>
<tr><td>Breaking current</td><td>60</td></tr>
<tr><td>Time constant</td><td>2.5</td></tr>
<tr><td>Number of operating cycles</td><td>5</td></tr>
<tr><td colspan="2" rowspan="3">Short-circuit current strength
JIS C 8201-3</td><td rowspan="2">Rated short time withstand current Icw A DC
s</td><td>180</td></tr>
<tr><td>1</td></tr>
<tr><td>Short-circuit making capacity Icm A DC</td><td>180</td></tr>
<tr><td rowspan="4">Number of operating cycles</td><td rowspan="2">750V DC</td><td>Without current</td><td>2,000</td></tr>
<tr><td>With current</td><td>300</td></tr>
<tr><td rowspan="2">400V DC</td><td>Without current</td><td>10,000</td></tr>
<tr><td>With current</td><td>1,500</td></tr>
<tr><td colspan="3">Rated impulse withstand voltage Uimp kV</td><td>6</td></tr>
<tr><td colspan="3">Reverse connection</td><td>Possible</td></tr>
<tr><td colspan="3">Polarity</td><td>Pole L: N(-)
Pole R: P(+)</td></tr>
<tr><td rowspan="4">Overall dimensions (mm)</td><td rowspan="4"></td><td>a</td><td>25</td></tr>
<tr><td>b</td><td>95</td></tr>
<tr><td>c</td><td>60</td></tr>
<tr><td>ca</td><td>77</td></tr>
</table>

and NF800-HDW (maximum rated current: 800 A). The 3-pole models can be used in 750 V DC circuits; the 4-pole types in 1,000 V DC circuits. The HDW circuit breakers allow reverse connection, which improves workability and reduces wiring.

To perform current interruption under such high voltages, the HDW circuit breakers are able to extend arcs without use of permanent magnets in the current interruption part, as described in the next section.

(2) HDVA circuit breaker series applicable to 750 V DC

For the NF125-HDVA and NF250-HDVA circuit breakers that are best suited to string combiner boxes, array combiner boxes, and small PCSs, we revised the arrangement of permanent magnets and splitter plates in previous models, thereby improving breaking performance. The 3-pole HDVA circuit breakers can be used at 750 V DC like the existing lineup of HDV series for 600 V DC. The standardization of external forms in accordance with the number of poles has enhanced workability and wiring efficiency.

(3) KB-HDA switch applicable to 750 V DC

This is a switch best suited to string combiner boxes in which each circuit of a solar cell string is made and broken, and that have wiring collectively held, and is added to the lineup that includes the existing KB-HD, which is applicable to open circuit voltages up to 600 V DC. The KB-HDA has been downsized to 25 mm in width and 95 mm in vertical length with the external form interchangeable with the KB-HD. This compact KB-HDA helps reduce the size of the string combiner box.

2. High-Voltage Direct Current Interruption Technology for the Circuit Breaker and Switch for PV Systems

2.1 High-voltage direct current interruption technology for the circuit breaker for large-capacity power conditioning subsystems

For the direct current circuit breakers in the HDW series that are mounted on PCSs, there is a need for direct current interruption technology that can handle a wide current range from small current to fault current of more than several kiloamperes. In order to ensure good breaking performance covering such a wide range of current, it is effective to use a method in which an arc generated during interruption is compressed into splitter plates that are configured by arranging U-shaped steel plates to split the arc and make it disappear.

When developing this series, we improved the insulation cover that protects the splitter plates and fixed electrode from the arc, enabling these direct current circuit breakers to be used at 1,000 V DC. The details of the improvement are described below.

To increase the applicable voltage, it is important to increase the number of splitter plates used; more than 10 splitter plates are required for a circuit breaker for 1,000 V DC.

In order to make sure that all of the more than 10 splitter plates in this series are used, 10 splitter plates are arranged between fixed and movable electrodes where the division of an arc surely takes place as shown in Fig. 2, and 5 additional plates are arranged near the tip of the movable electrode.

Figures 3 (a) and (b) shows the splitter plates and insulation cover with the improved structure respectively; the items with "*" in the figure are improved from the previous models. The arranged splitter plates have a slit for pulling an arc and are designed such that the electromagnetic force acting on the arc is enhanced, while exhaust configurations are provided at the back of the splitter plates (as shown in the right of Fig. 2). Thanks to these slit and exhaust configurations, the electromagnetic force that pulls the arc into the back of the splitter plates is strengthened, and also the division of the arc is promoted due to the negative pressure generated against the arc pulled.

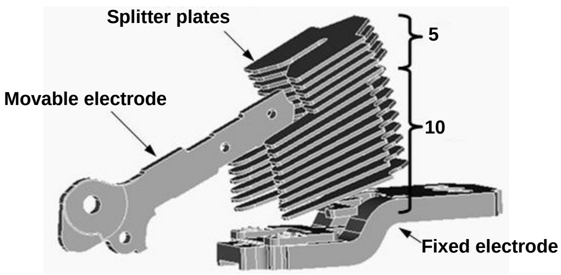
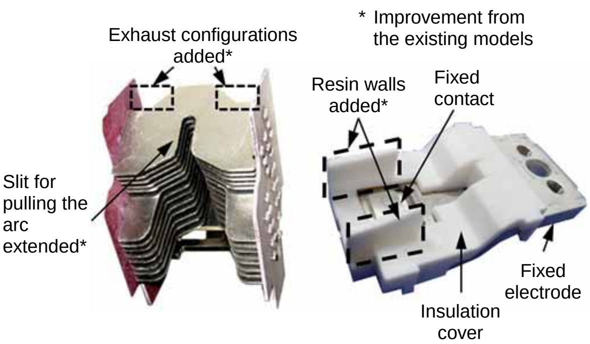


Fig. 2 Arrangement of splitter plates in an arc-extinguishing device



(a) Splitter plates (b) Insulation cover

Fig. 3 Improved structure of the arc extension and drive control

Meanwhile, the insulation cover has resin walls such that the space between fixed and movable contacts is sandwiched by the walls. These resin walls are designed to eject insulating ablation gases using thermal reaction with the arc. At the same time as the gas flow that pushes the arc toward the splitter plates is created, the decrease in dielectric strength of air between the contacts can be suppressed. Therefore, the arc that has been once pulled into the splitter plates can be prevented from causing dielectric breakdown between the contacts.

Figure 4 shows images taken during observation of the arc behavior under current interruption using the improved structure. After the improvement, it became easier to pull the arc into the splitter plates, thereby realizing highly reliable interruption over a wide range of current from a few amperes to 10 kiloamperes in a 1,000 V DC circuit.

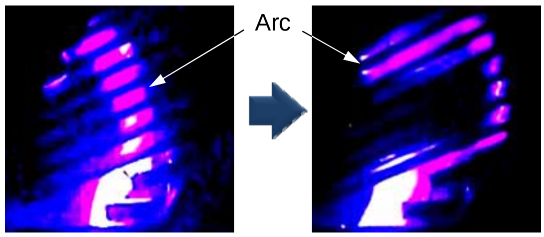


Fig. 4 Observed arc image before and after using the improved structure

2.2 High-voltage direct current interruption technology for the switch for string combiner boxes

Each string combiner box in a PV system has switches for making and breaking input solar cell strings. As it is necessary to arrange several dozen switches simultaneously in a string combiner box that has many input strings, a compact, space-saving switch that allows reverse connection is desired. To meet this market need, we have developed a high-voltage direct current interruption technology named ARC SWEEPER (a winner of the 2015 R&D 100 Awards sponsored by US R&D Magazine Corporation), which allows arc extension control independent of the direction of current, thus achieving the industry's smallest direct current switch that allows reverse connection. During development of the KB-HDA, we made further improvements to ARC SWEEPER, which made it possible to raise the voltage ceiling of our direct current switch to 750 V DC. The details of the improvements are described below.

Figure 5 shows the internal structure of the KB-HDA direct current switch featuring the new technology. An insulation cover is arranged in an arc extinction space, and an iron core bar (attraction bar) for controlling magnets and magnetic fluxes is mounted inside the insulation cover. When an arc is generated

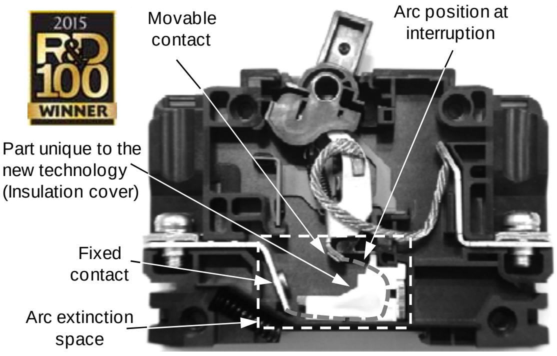


Fig. 5 Internal structure of KB-HDA

between the contacts under the current interruption, the leakage fluxes that are released from the attraction bar interact with the arc regardless of the current direction, and the arc extends along the attraction bar.

Figure 6 shows the attraction bar and insulation cover that are used in the product for 750 V DC (KB-HDA). The portions with dotted lines in this figure indicate the shapes of the attraction bar and insulation cover that are used in the product for 600 V DC (KB-HD). For the product for 750 V DC, the tip of the attraction bar protrudes, with a shape that adjoins the shape of the protrusion to the space between the contacts. The electromagnetic forces acting on the arc are strengthened by this protrusion at the start of the current interruption, thereby making it possible to pull the arc to the side face of the insulation cover more rapidly.

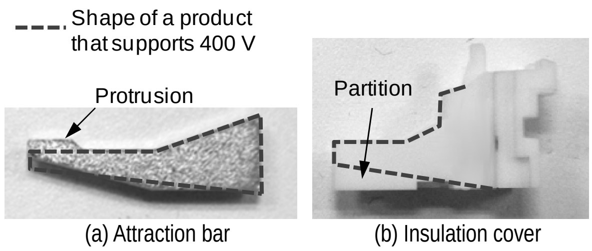


Fig. 6 Improved point of new technology

Meanwhile, regarding the insulation cover, the lower portion of the cover has been extended, and a partition for separating the space on both sides of the cover (the back and front when facing Fig. 6) has been added. This partition suppresses the spread of high-temperature gas (conductive gas) that is generated around the arc, and makes it possible to retain the arc in an extended state in a stable manner.

Figure 7 is an example of comparison of the breaking performance in a direct current circuit (750 V DC; 20 A) between a switch with our new technology and that employing a conventional method (large magnets arranged in the vicinity of contacts, thereby extinguishing the arc by an arc extension effect made using magnets alone). The comparison of the arc

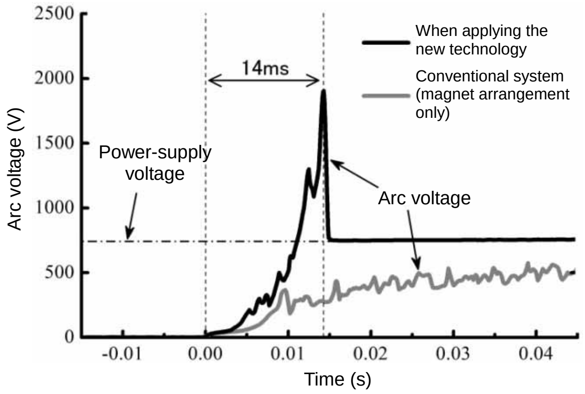


Fig. 7 Comparison of breaking performance of the new technology and conventional method

voltage measured in these two cases revealed that although the switch of the conventional method performed adequately at arc voltages up to about 500 V, it was unable to raise the arc voltage higher than the power supply voltage, resulting in inability to interrupt current.

On the other hand, the arc voltage of the switch using the new technology exceeded the power supply voltage approximately 0.01 second after the start of interruption, and the current was completely interrupted in about 0.014 seconds.

As described above, the improved technology has led to a switch that can used for 750 V DC circuits, which has been difficult to achieve using conventional methods.

3. Conclusion

This article described the characteristics of high-voltage direct current circuit breakers and switches for the PV market as well as the direct current interruption technology of these new models. We will continue to develop products that meet the needs of users, striving to increase the number of models and applications, and to expand the applicable voltage range.

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