Current Status and Future Outlook for Electric Distribution and Control Devices

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ABSTRACT

Electric distribution and control devices have greatly evolved as the indispensable elements of electrical equipment that drives industry. Fuji Electric has made various efforts with market trends in mind. We have proceeded product globalization by complying with major foreign standards and have strengthened the product capability to apply energy and environment conscious market fields through the development of high-voltage direct current equipment. For the electric distribution facilities that support advanced information system, Fuji Electric has increased the stability and reliability of power supplies while also has reduced lifecycle costs by simplifying maintenance inspections. We have also achieved the miniaturization and performance enhancement of switching devices, low-voltage circuit breakers, dedicated products intended for developing countries such as China and Asia, and power monitoring equipment.

1. Introduction

With the aim of realizing a resource-recycling society, Fuji Electric is focusing efforts on its environment and energy business, and supplying electric distribution and control devices (see Fig. 1), which have supported such business and made dramatic advances as the main constituent elements in electrical equipment that drive industry. This paper describes the changes that have occurred in the market and environment so far, and while reflecting upon Fuji Electric's history of interaction, introduces recent products and describes future efforts.

2. Market Trends and Fuji Electric's Efforts

Fuji Electric has sought to accurately grasp the changing market trends and to supply products with which can provide a large added value to the customer. The progress of the main electric distribution and control devices is shown in Fig. 2. Additionally, recent electric distribution and control equipment products are listed in Table 1.

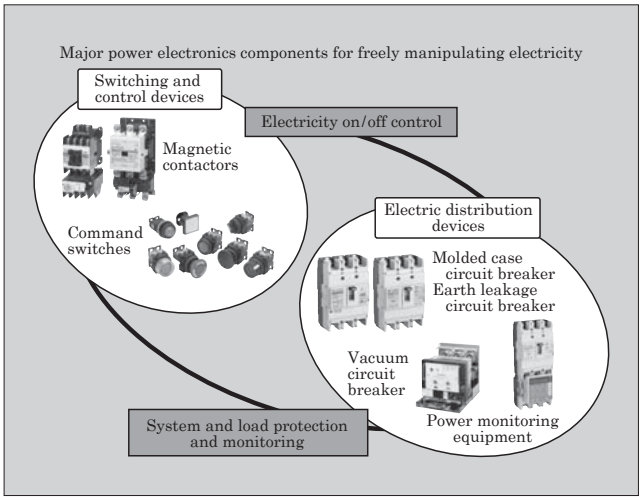

Fig.1 Fuji Electric's electric distribution and control devices

(1) Response to globalization

In 1993, the EC directive*1 was issued, and in 1995, CE marking was made mandatory. Systems for standard certification are getting strict in every nation, and in China, for example, compliance with CCC compulsory certification*2 has become essential. In recent years, with the acceleration of overseas business expansion of our customers, JIS adoption of IEC standards, and the global spreading of IEC standards, development has been pursued to make Japanese domestic standard products compliant with IEC standards. Furthermore, multi-standard products such as the "G-TWIN Breakers" for example, that support not only IEC standards, but also UL and other major overseas standards, have been developed and introduced to the market.

Additionally, for machinery and production equipment, safety requirements are increasing and various international standards have been issued, including ISO12100 "Safety of machinery–Basic concepts, general principles for design". In Japan, these standards were sequentially incorporated into JIS. In response to this safety standard and to the safety standards of the "Industrial Safety and Health Law" that was revised in 2006, Fuji Electric has strengthened its lineup of emergency stop button switches, and has provided low-voltage circuit breakers with an isolation function

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*1: EC directive: See "Explanation 1" on page 139

*2: CCC compulsory certification: See "Explanation 2" on page 139

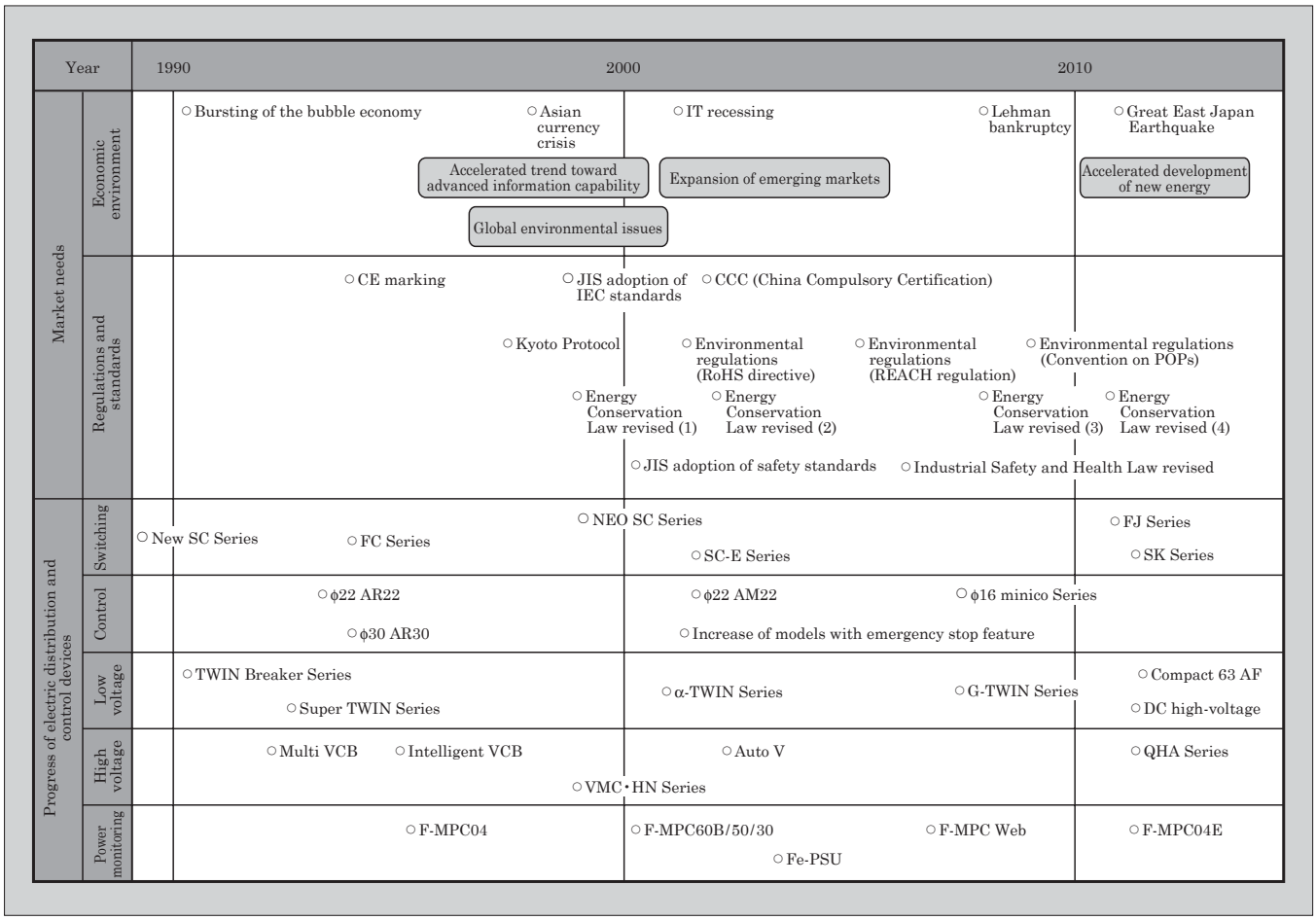

Fig.2 Progress of electric distribution and control devices

Table 1 New electric distribution and control devices products in recent years

Market needs	Equipment group	New products
Globalization	Switching devices	"SK Series" of mini contactors and thermal relays
	Control devices	"Minico Series" of ϕ16 command switches
	Low-voltage circuit breakers	125 to 800 AF "G-TWIN Series"
		Compact 32 to 63 AF low-voltage circuit breakers
For emerging markets	Switching devices	"FJ Series" of mini contactors
Energy and environment	Low-voltage circuit breakers	High-voltage DC breakers
	Power monitoring equipment	"F-MPC04E" single-circuit AC power monitoring unit
Advanced information capability	Low-voltage circuit breakers	Low-voltage circuit breakers for IDC
	Power monitoring equipment	"F-MPC Igr" Igr insulation monitoring device
	High-voltage equipment	"QHA Series" of digital protective relays for high-voltage electric distribution
		Vacuum circuit breakers for dry-air sealed-type cubicles

as a standard to meet the requirements of standards for supply-disconnecting devices. With the "SC Series" (SC-03 to SC-N16) electromagnetic contactor, safety standards were met by providing, as a standard function, positive opening mechanism contacts (positively-driven contacts) and safety opening function contacts (mirror contacts).

(2) Response to market expansion in emerging economies

China's market liberalization has proceeded since 1990, and China has evolved from the "world's factory" to the world's largest market. In the future, China and other Asian nations will continue to grow, and investment in public infrastructure is increasing. Moreover, with the recent appreciation of the Japanese yen, the Japanese manufacturing industry's export business tends to shift to local production in this region. To ensure a competitive advantage in this market for customers who have expanded into this region, Fuji Electric is establishing an optimized product lineup to meet a low-price level in this region.

(3) Response to energy and environmental tendency

Interest in preserving and improving the local environment increased in the latter half of the 1990s, and attention has focused on eco-products, energy savings

and new energy. In accordance with a framework for action based on the "Kyoto Protocol" adopted at the Third Conference of the Parties to the United Nations (COP3) Framework Convention on Climate Change in 1997, the Japanese "Law Concerning the Rational Use of Energy" (Energy Conservation Law) was repeatedly revised, and the coverage of regulation was expanded from large-scale businesses to small-scale businesses. For power monitoring devices, Fuji Electric has responded to the strengthened regulations thus far with a model change of its "F-MPC Series" and an expansion of product lineup. Additionally, ever since the Great East Japan Earthquake, renewable energy usage has been expanding and awareness of energy savings and conservation has been increasing more than ever. For general residential buildings, the model of energy savings called eco-house through the use of direct current (DC) has been attracting attention. In the information and communication field, 400 V DC-class equipment is under consideration primarily for use at data centers.

In the expanded usage of renewable energy, photovoltaic power has been attracting attention. For photovoltaic power generating facilities to be used at mega-solar plants, improved efficiency of energy utilization and the use of higher voltages above 1,000 V DC to reduce the cost of power generation are being advanced worldwide. Fuji Electric increased the voltage of its "G-TWIN Series" DC circuit breakers (and switches) that were released in 2007. Responding to requests for even higher voltage, Fuji Electric is intensifying its efforts for DC high-voltage products (750 V DC, 1,000 V DC)

(4) Response to advanced information capability

As of the mid-1990s, the Internet and PCs started to become popular, and society had arrived at an advanced information age. At high-voltage electric distribution facilities, in order to prevent service loss in advanced information systems, the power supply stability and reliability must be improved, and these requests have become increasingly severe in recent years. Products such as the multi VCB and Auto V that aim for a compact size, lighter weight and more advanced functionality had been developed thus far; moreover, in order to reduce the lifecycle cost (LCC) further, high-voltage breakers are being developed in response to requests for longer intervals of periodic maintenance and inspection, a reduced number of inspection items, and preventative maintenance.

Moreover, in order to minimize the spillover effect when power supply trouble occurs, the protective relay used is required to provide reliable operation and protective coordination, and to facilitate the installation and the usage of equipment through reducing the burden of daily inspections and so on.

Additionally, as a result of the expanded usage of distributed power sources such as photovoltaic power, products that support grid-connection have become necessary. Based on such market trends, Fuji Electric has developed new protective relay products.

At data centers, semiconductor factories and the like, 24-hour non-stop operation is required and reliability is especially critical. The ability to configure highly reliable electric distribution and feed systems in a small space and with energy savings is getting increasingly important at not only plants and manufacturing facilities, but also at office buildings and commercial facilities, and in response, Fuji Electric is expanding its lineup of low-voltage breakers and power monitoring equipment for this field.

3. Efforts for Miniaturization and Performance Improvement of Switching Devices, Control Devices and Low-Voltage Circuit Breakers

In response to requests for the globalization of switching devices, control devices and low-voltage circuit breakers, Fuji Electric has continued to develop products that lead the industry while realizing smaller size, increased performance and improved ease of use through enhanced wiring and the like. Figure 3 shows the trend in downsizing for the example of low-voltage circuit breakers. The latest model of the 100 AF class of low-voltage breakers has been miniaturized to 63% the size of the TWIN Breakers of the 1990s, while achieving higher performance.

3.1 Switching devices

Fuji Electric began manufacturing and selling switching devices, such as magnetic contactors for starting and stopping electric motors and thermal relays for overload protection, for the first time in Japan in 1954, and has driven the industry as the Japan's top brand capable of responding quickly to market needs and customer needs. Fuji Electric's total production volume is approaching 300 million units. Figure 4 shows the historical changes thus far.

In 1988, Fuji Electric developed the "New SC Series" of 2.2 to 4 kW small-capacity magnetic contac-

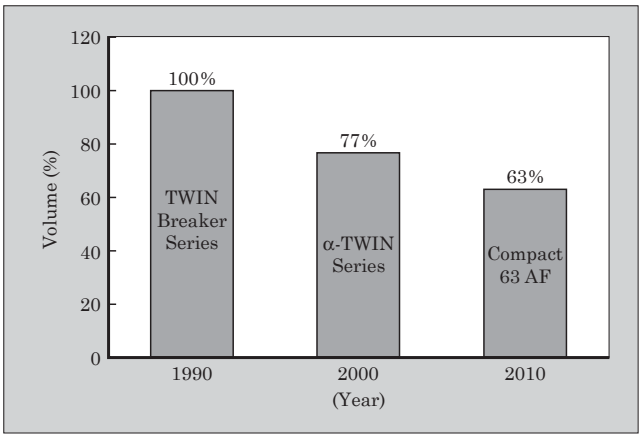

Fig.3 Miniaturization of low-voltage circuit breakers

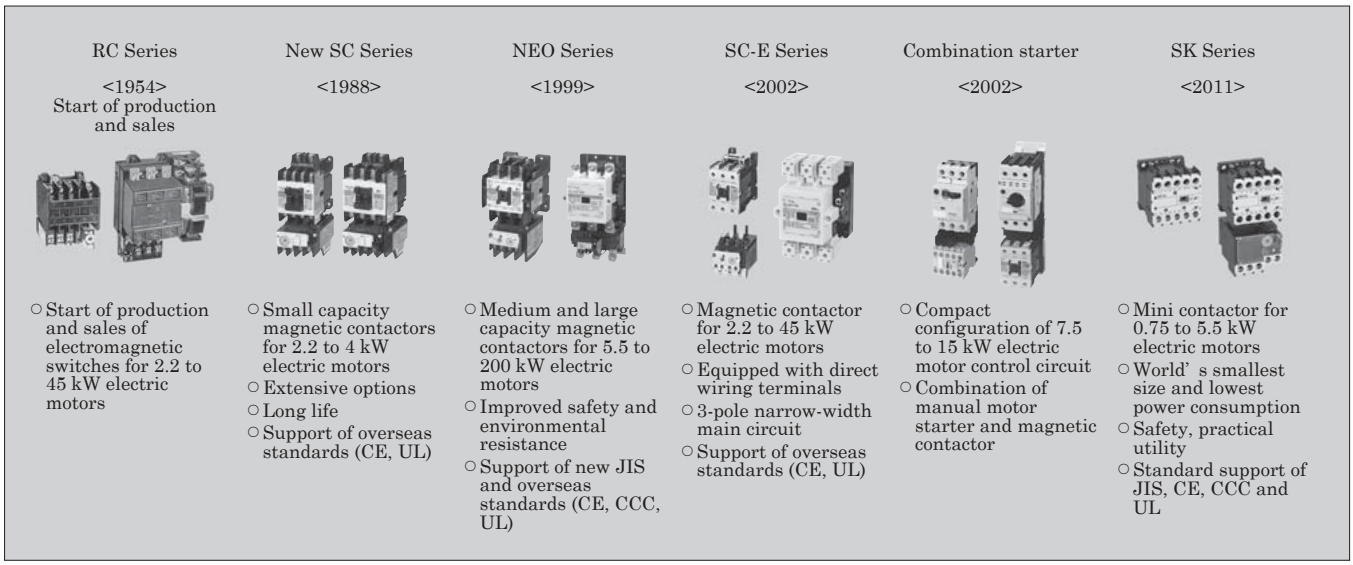

Fig.4 History of Fuji Electric's switching devices

tors for electric motors, featuring extensive options, a long service life, and certification of international standards (CE, UL).

In 1999, Fuji Electric developed the "NEO SC Series" of 5.5 to 200 kW large-capacity magnetic contactors that complied with safety standards, environmental regulations, the new JIS and international standards (CE, UL and CCC).

In 2002, Fuji Electric developed and launched the "SC-E Series" as a product for the global market, featuring small-size de facto width of 45 mm for the global-market direct wire connection terminals, a 3-pole main circuit, modularization, linked contacts available, and compact size. Additionally, Fuji Electric developed a manual motor starter (MMS) featuring advanced motor circuit protection that compactly integrates a molded case circuit breaker and a thermal relay. The MMS features a high level of short-circuit protective coordination and a busbar system that enables a reduction in wiring work. Additionally, ease of use has been improved with a combination starter that combines an MMS and a magnetic contactor.

In this manner, by responding globalization with conformance to overseas standards, and specifications, and proposing the safety with linked contacts, advanced combination of a molded case circuit breaker, magnetic contactor and thermal relay, and the use of a busbar system or the like to reduce wiring work, Fuji Electric has advanced switching devices while anticipating global trends.

In recent years, market needs have increased for further miniaturization of control panel size, higher safety function including electric shock protection, more frequent use of a DC control power supply, etc. In response, Fuji Electric developed the "SK Series" mini contactors and the "TK12" thermal relays that, while realizing the world's smallest size, are truly global-compliant and conform to all standards in Japan and overseas.

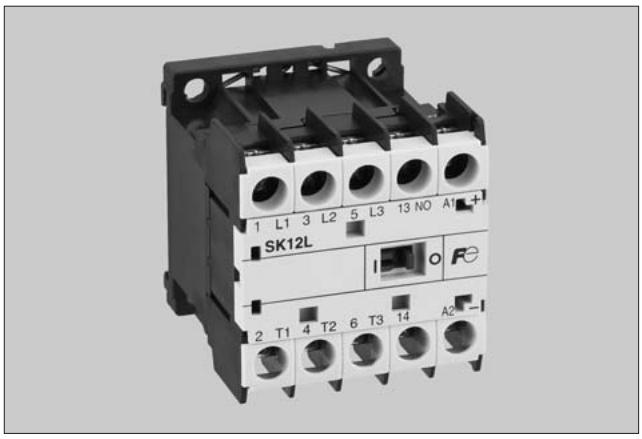

Fig.5 "SK Series" mini contactor

(1) "SK Series" mini contactors

The SK Series, the world's smallest mini contactors, also realize the world's smallest class of low power consumption (86% compared to existing models) for motor control applications of 2 kW and below. This series is also equipped with safety features such as electric shock protection and mirror contacts, and conforms to the world's major standards (JIS, IEC, CCC, UL and TÜV) as a standard product feature.

Figure 5 shows the appearance of an SK Series mini contactor, and its features are listed below.

(a) World's smallest mini contactor
- ○ Dimensions: W45×H48×D49 (mm)
- ○ Same external dimensions of both AC control products and DC control products

(b) Low power consumption
- ○ 86% compared with existing model (low-power DC coil 1.2 W)

(c) Extensive lineup
- ○ 3 ratings: 6, 9 and 12 A
- ○ Control coil: AC, DC and low-power types

(d) Extensive options
- ○ Additional auxiliary contact unit (2 poles, 4 poles)
- ○ Coil surge absorber unit
- ○ Interlock unit
- ○ Connection module (MMS combination)

(e) Improved safety function and easier use
- ○ Standard provision of detachable terminal cover (IP20)
- ○ Provided with mirror contact function
- ○ Short-circuit current rating (SCCR): 480 V AC 50 kA
- ○ UL rated 480 V AC 5HP
- ○ IEC rated 480 V AC 12 A (AC3)

(f) Standard products are certified for the world's major standards
- ○ JIS, IEC, GB (CCC), UL and TÜV

(2) "TK" of thermal relays

The TK12, while realizing improved wiring and safety, also achieves a significantly smaller size than previously in the combination with a magnetic contactor. To improve safety function, a protective element is provided for each phase to realize specifications that enable open phase protection. To improve wiring while realizing a compact size, a terminal layout was adopted whereby the main circuit terminals and auxiliary terminals are arranged in a parallel configuration so that the main circuit and the auxiliary circuit wires do not interfere with one another at the time of wiring. Figure 6 shows the appearance of a TK Series thermal relay, and its features are listed below.

(a) Improved safety
- ○ 2E thermal relay with overload and open phase protection in a standard product

(b) Miniaturization
- ○ 87% size of existing model in combination with magnetic contactor (installation area), 55% by volume
- ○ Dimensions: W45×H97.5×D55 (mm)

(c) Improved wiring capability
- ○ Round-type crimped terminals can be connected
- ○ Wire lead-out capability from secondary side of magnetic contactor
- ○ No interference from main circuit and auxiliary circuit wires by employing parallel terminal layout when performing wiring work

(3) Combination starter

Fuji Electric has established a lineup of combination starters that combine an MMS and a magnetic contactor (see Fig. 7).

As a manual switch for electric motors, the MMS is sometimes used by itself; however, it is more often used in combination with a magnetic contactor in general. An MMS provide high current-limiting capability, such combination therefore can contribute to higher short-circuit current rating (SCCR). Since the combination starter couples an MMS and a magnetic contactor with dedicated wiring components, it streamlines the wiring work and reduces space.

3.2 Low-voltage circuit breakers

Since 1968, Fuji Electric has been manufacturing and selling low-voltage circuit breakers (molded case circuit breakers and earth leakage circuit breakers) that provide line protection and electric shock protection, and for over 40 years has been developing products that anticipate the needs of the market. Figure 8 shows the historical changes thus far.

In 1990, the 30 to 225 AF "TWIN Breaker Series" was developed and was well accepted as the industry's first "TWIN" feature model which means both molded case circuit breakers and earth leakage circuit breakers having the same external size. At present, such uniform size concept has been established as the de facto standard in the Japanese market. Also, unified basic dimensions among frames, higher breaking capacity, advancing miniaturization, and more expansion of options and derivative products have been provided.

In 1992, expanding the TWIN Breaker development concept to larger capacities, the 400 to 800 AF capacity "Super TWIN Series" was developed. With

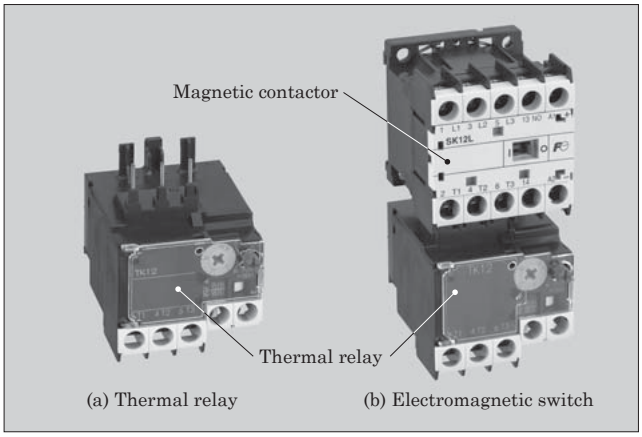

Fig.6 "TK12" thermal relay and magnetic contactor

Fig.7 Combination starter

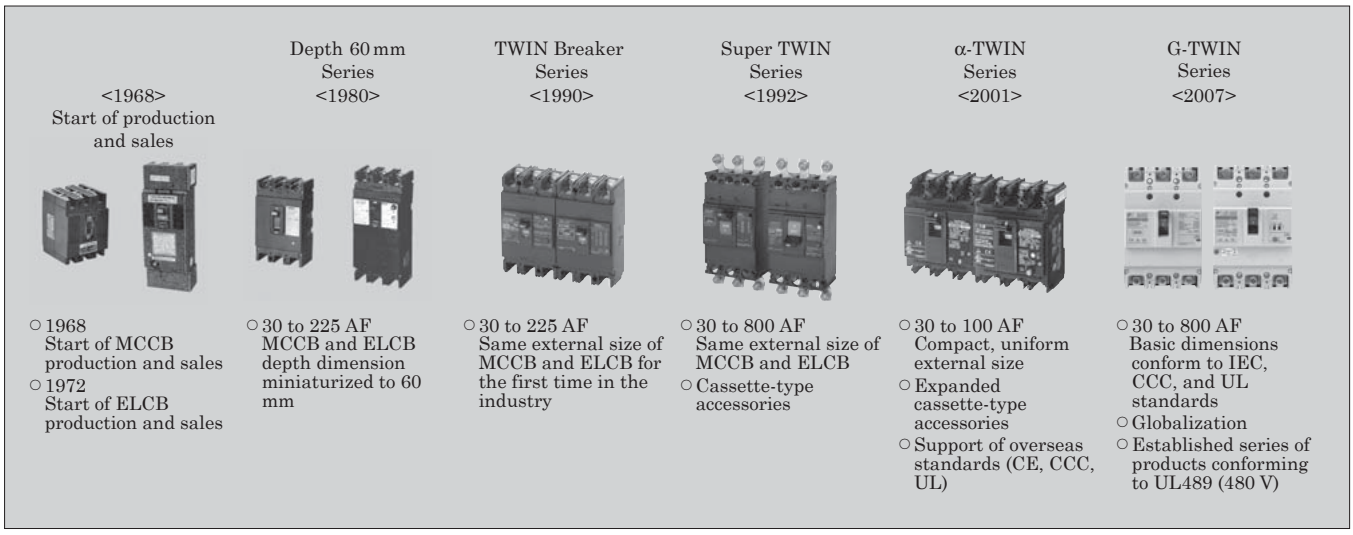

Fig.8 History of Fuji Electric's low-voltage circuit breakers

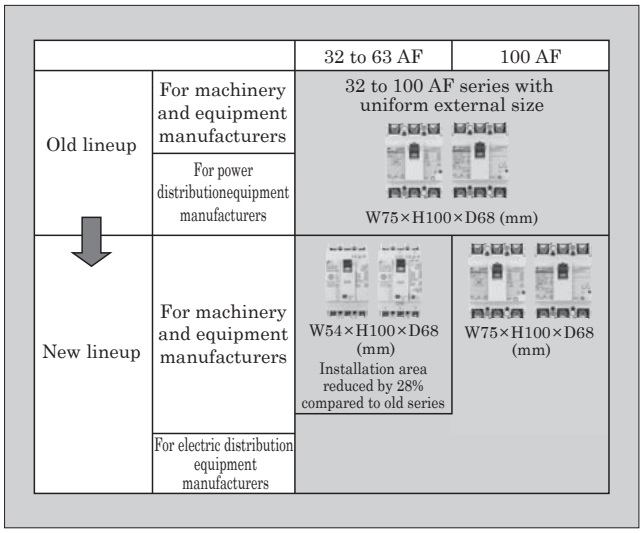

Fig.9 New and old lineups of 100 AF and below low-voltage circuit breakers

Fig.10 32 to 63 AF compact low-voltage circuit breakers

this Super TWIN Series, internal accessories could be installed by the customers themselves.

In 2001, the 32 to 100 AF "α-TWIN Series" was developed, featuring the industry's smallest uniform size, high breaking capacity, compact size, safety features such as an isolation function, and certified compliance with overseas standards (CE, CCC and UL).

In 2007, the 125 to 800 AF "G-TWIN Series" was developed. In basic dimensions it conforms to major overseas standards such as IEC, CCC and UL. Moreover, through providing a series of devices that conform to UL 489 (480 VAC), complying with IEC specifications for earth leakage circuit breakers (standard 3-phase applicable, withstand voltage test switch), unifying the internal accessories and complying with environmental regulations, truly global products have been developed.

In this manner, Fuji Electric has proposed the concept of a compact and uniform size, and has responded to a wide range of market needs for machinery and equipment, control panels, electric distribution switchgears and the like. The α-TWIN Breakers are small-size products from 32 to 100 AF, and are used in a wide range of fields (see Fig. 9).

In recent years, as in the case of switching devices, small size and enough safety feature, including electric shock protection, is required of low-voltage circuit breakers. Although there exist machinery, equipment and control panel applications that seek smaller size, there are also electric distribution applications with equipment with uniform external sizes to standardize, power distribution panels, and therefore the market environment is getting polarized in terms of the functions required of low-voltage circuit breakers. For this reason, Fuji Electric developed 32 to 63 AF compact low-voltage circuit breakers for machinery, equipment and control panel applications (see Fig. 10).

The compact 32 to 63 AF low-voltage circuit breakers, while achieving the industry's smallest size, also realize high breaking performance, an extensive variety of available accessories, safety protection of the terminals and compliance with the major overseas standards (JIS, IEC, CCC, UL, TÜV), and have the fol-

lowing features.

(1) Product external size
  ○ External size of 3-pole product: Industry's smallest width of 54 mm
  ○ Small installed footprint: 72% compared to existing models
(2) Breaking capacity
  ○ 1.5 times existing models
  ○ I_{cs} = 100%×I_{cu} (AC200 V system)
(3) Terminal area
  ○ IP20 standard compliance
(4) Accessories
  ○ Extensive variations of internal accessories
  ○ Extensive accessory functions such as side by side mounting
(5) Two types of mounting, with screws or a DIN rail
(6) Conformance to various overseas standards; two types of lineups are provided to fit the application
  ○ Standards: JIS, IEC, CCC, TÜV
  ○ Global: JIS, IEC, CCC, TÜV, UL489
(7) Standard compliance with various environmental regulations including the RoHS directive*3

4. Dedicated Products for Emerging Country Markets

As for switching device, low-voltage circuit breaker and control devices, the trend toward the JIS adoption of IEC standards has advanced in Japan, and the mainstream of products are having the same specifications for Japan and overseas. As for the crimped terminal connections that are commonly used in Japan, however, because of the different method used overseas based on an industrial tradition of direct wire connections, Fuji Electric's electromagnetic switch lineup includes the SC-E Series for use in overseas markets and that supports direct wire connections, so as to be compatible with any market in the world.

In emerging economies such as China and other Asian countries, for important safety related circuits used in equipment for export or in elevators, the same high quality, long switching life, and conformance to major overseas standards as in Japan are sought; however, these are not always required in equipment for local use.

For this reason, as dedicated products for local equipment, the "FJ Series" that conforms to local standards was developed and launched in China in April 2011.

In the future, while monitoring overseas markets and customer trends, Fuji Electric plans to expand its lineup of dedicated products for overseas market following such contactors.

*3: RoHS directive: EU (European Union) directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment

5. Fuji Electric's Efforts Involving Power Monitoring Equipment

The Japanese Energy Conservation Law was revised in 2010, and with the expansion of energy management obligations to factories, offices, stores and other small businesses, further simplifications of the energy management tasks is requested.

In response to this need, the DIN rail-mounting type "F-MPC04E" single-circuit AC power monitoring equipment was developed and the F-MPC Series lineup was expanded. Since the display was provided as an option, the volume was reduced by 1/2 compared to the existing "F-MPC04S" panel-mounted type. In addition to the RS-485 communication function provided as a standard feature, the MODBUS/RTU protocol as well as the standard protocols of the "F-MPC Series" power monitoring systems is also supported to enhance compatibility.

Additionally, the PowerLogic Series (manufactured by Schneider Electric in France) is able to monitor power quality, and is provided with a function for preventing equipment trouble before it arises and a function for facilitating an early resolution in the event of trouble. Fuji Electric's lineup of power monitoring devices has been expanded with the PowerLogic series, together with the F-MPC Series (see Fig. 11).

Furthermore, in addition to the need for energy savings, there are also electrical safety-related needs for automating equipment inspections and extending the interval between periodic inspections mainly at data centers, semiconductor manufacturing plants and other places of businesses where a system shutdown would not be acceptable because of its severe loss.

To meet these needs, continuous monitoring of the current leakage by a method that is not affected by the capacitive element to ground and the harmonic wave element of the cable is needed.

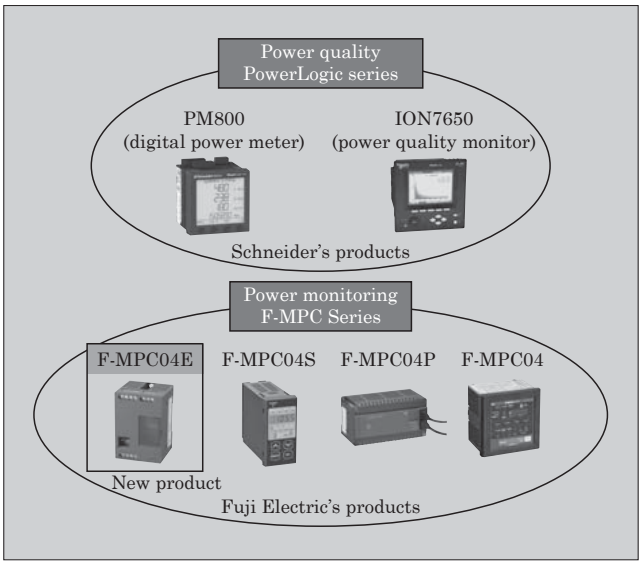

Fig.11 Lineup of power monitoring devices

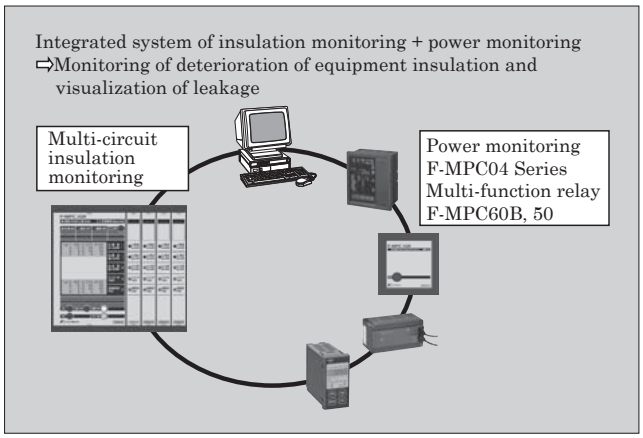

Fig.12 Power monitoring and insulation monitoring in the same system

To realize this in a way that is applicable regardless of the phase and wiring scheme, Fuji Electric has developed an Igr insulation monitoring equipment that can detect insulation deterioration without being affected by imbalance of the capacitive element to ground among phases. A lineup of integrated measurement equipment for 4 circuit and 8 circuit applications, selectable according to the system size has been established, and these equipment can easily be connected to F-MPC Series devices through a RS-485 communication interface, so that power monitoring and insulation monitoring can be linked and managed in the same system, using the same protocol (see Fig. 12).

6. Postscript

Amidst the trend of advancing globalization, society and the marketplace are changing rapidly, and the ability of agile response is needed. Fuji Electric's mission is to sense changes in the market and the evolution of technology with a keen perceptiveness while looking ahead to the future, and to provide products in a timely manner through technology development with concentrating intelligence while continuously responding to the needs of the customers.

Through continuing to provide equipment and services that meet the diverse needs of the customers, Fuji Electric aims to become a "best partner" for society and industry.

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