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STATE AND TENDENCY OF STANDARD DISTRIBUTION APPARATUS

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1 INTRODUCTION

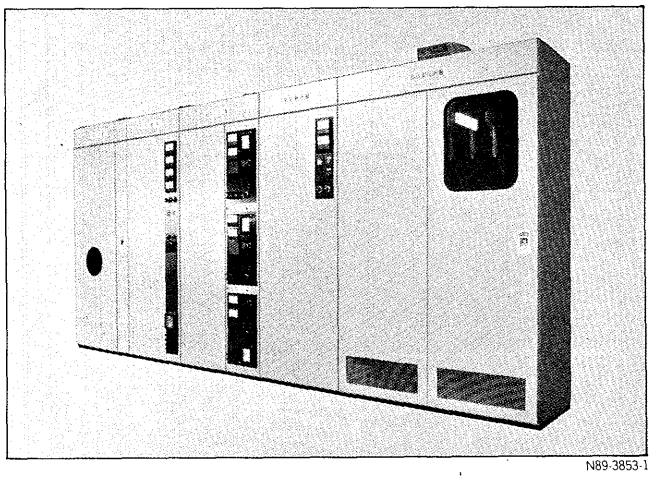
Today, electric energy is utilized as one of the most important energies from the sectors of general industries to the fields having directly to do with our daily life. The facilities that supply and sitribute this electric energy are the Distribution Apparatus and their diffusion is remarkable.

In recent years, demands are increasing for equipment of higher quality with particularly higher reliability and stability, and consequently for high-voltage (6 kV) distribution apparatus, cubicle type distribution apparatus having higher safety factor and reliability (see *Feg. 1*) are now replacing the conventional distribution apparatus of open pipeframe type that have been up to now the mainstream in these facilities, and the new type of apparatus takes up the share, in urban area, of 85% in Japan.

In such distribution equipment, many power receiving and distribution apparatus are used and also for these aparatus, equal high reliability is demanded.

The general purpose receiving and distributing equipment are machines, seen from the point of view of functioning, of opening and closing of the circuit, transforming the current and voltage and protecting the circuit. Concretely, they are switches, circuit breakers, interrupters, transformers, fuses and earth leakage circuit breakers.

Fig. 1 Thin type cubicle 6 kV receiving equipment



As well known, history of these standard distributing equipment is long and their technological progress, remarkable. In recent years, besides the improvement of their proper functions and performance, many innovations of microelectronics (ME) that have been thought up to now unrelated, are introduced to manufacturer of these quipment.

In these articles of special issue, amoung the standard type receiving and distributing equipment, those concerned with high-low voltage circuit breaker, switches and transformers namely, last products of Fuji Electric are introduced stressing on their present state and general trends.

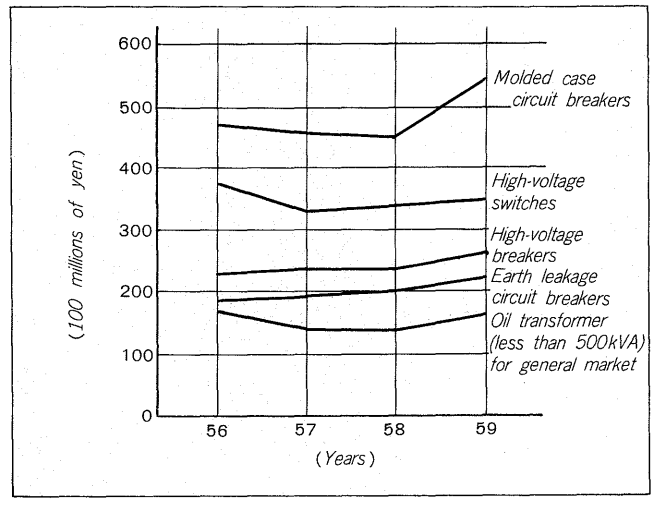
2 TRENDS AND STANDARD DISTRIBUTION APPARATUS

2.1 Market trends

As the representative standard type distribution equipment, movements in production in Japanese market in last four years of high-voltage circuit breakers, high-voltage switches, molded case circuit breakers earth leakage circuit breakers and oil transformer for current lower than 500 kVA (for general market) are shown in *Fig. 2.*

Due to the adverse influence of the slump in 1982 or

Fig. 2 Standard type main distribution equipment



thereabout, the growth has become somewhat slow, but as the general trend, we can say that it shows gradual ascent now. As for the low-voltage apparatus, the demand for earth leakage curcuit breaker is steadily growing every year, while that for molded cage circuit breakers is highly dependent on the market condition.

As for the future trends of the standard type distribution equipment, we believe that they would grow gradually in proportion more or less to the growth of development of the Japanese industries. As for the overseas market, though there are several impeding factors as high evaluation of yens, we can foresee fairly good growth in the future.

2.2 General trends of the apparatus

The contents of the market demands for standard type distribution equipment, though they may differ depending on the types of the equipment, are the following:

(1) High reliability of their performance

It is only natural that customers demand high reliability for the function proper to the equipment, but as for the distribution equipment, except for a few special cases, the recent Japanese products are in satisfactory technological level.

(2) High safety coefficient

In due consideration of danger when the charging unit comes to contact with human bodies or damage by arc during the breaking operation of the circuit breaker, the tendensy of course is to expect an equipment designed adopting an arc suppressing system or in a form that arcing or charging unit should not come to contact with another equipment or with human bodies. And this is the reason why the cubicle type receiving installations are high in demand.

On the other hand, for a sake of safety of use, these equipment are in an advanced stage of non-inflammability and system without oil, and products such as high-degree vacuum high-voltage circuit-breakers, mould-produced transformers, etc. are preferred and diffused widely. Also, trends are directed to maintenance-free products.

(3) Form compact and easy to use

Latest tendency for making everything small and light reflects also in the field of electric apparatus and in particular in the shape of distribution apparatus. Specially in the urban area, on account of roaring of land price, occupying space is more and more difficult to secure, and even for the cubicle type equipment, miniaturization is expected, so that now, reduced cubicle type with depth of 700mm in the size of switchboard is the standard type (See *Fig. 1*).

For distribution equipment also, the small dimensions but those which can house thin type cubicle or those of structure that can easily be mounted are demanded.

(4) Easiness in setting and operating

In case the protection system of the facility is taken into consideration, each single component apparatus should be provided with characteristics that can be coordinated globally so that they can exercise fully their function as a whole.

For example, high-voltage breakers are required to have characteristics as their overcurrent operation characteristics well compatible with those of breakers at power distributing substation and with interruption characteristics of low-voltage side wiring circuit-breakers, and recently, by incorporationg electronic type overcurrent relays, ideal characteristics are obtained.

As for ease of operation, as in case of large-dimensioned equipment whose handles are difficult to operate, they should be made easier to operate through adoption of springcharge system and others.

(5) Consideration of adaptability for export

In recent years, as for export, they are required as individual apparatus and, at the same time, as the whole of installation for export. So that distribution equipment are required to cope with such demands either directly or indirectly. That is to say, that they should conform with Standards of other countries and obtain international type approval, or still, they should be provided with compatibility and interchangeability with other products of foreign make.

Besides above, they should be of energy saving type or versatile type, having suitability for automatization, and many others can be cited as examples of that coping with the demand.

Standard type distribution equipment of Fuji Electric, in face of this situation, are the products of positive technical development such as adoption of simultaneous open-pole breaking system for wiring breakers, and of sliding induction unit, or development of electronic overcurrent relay incorporating system for vacuum circuit breakers, all of which duly introduced and adopted for the equipment; and on the other hand, using the laser transforming machines, NC machine tools and other high-technology manufacture installation, and, at the same time, preparing the latest FMS system through introduction of FA computers and highly advanced manufacturing technology as high-precision press technology, thus establishing full production system.

2.3 Normal high-voltage power receiving equipment and standard aparatus

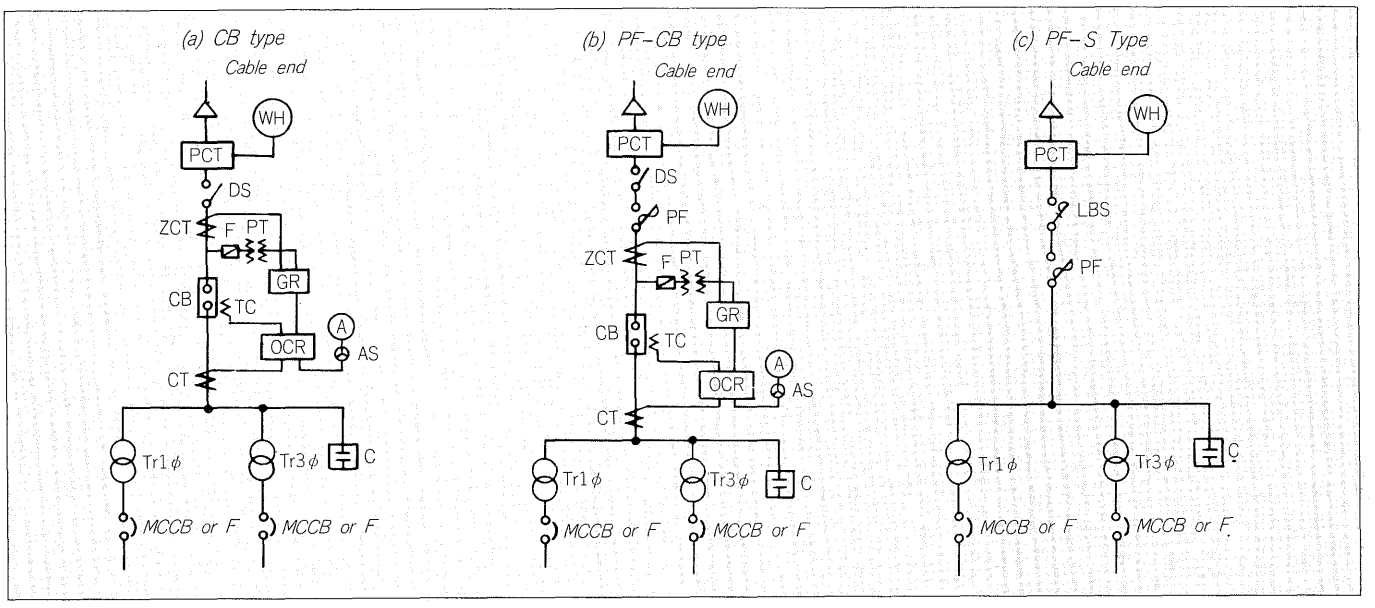
Typical block diagrams of the normal high-voltage power receiving equipment are shown in *Fig. 3.*

The lead-in systems are available in three types, depending on the type of main breaker equipment, namely, CB type using breakers as such as vacuum breakers, PF-CB type reinforcing the capacity of comparatively low-interrupting capacity breakers with current limiting fuses, and PF-S type which is a combination of current limiting fuse and switch. At present, CB types are used mainly for large-capacity installation and PF-S type for medium and small capacity installation.

As for transformers, generally three-phase transformers of 6 kV for primary side, 200V or 400V for secondary side, and single phase transformers with 100V on secondary side are used in Japan.

As standard type receiving and distributing equipment in the high-voltage system, we can cite high-voltage breaker,

Fig. 3 Example of block diagram of high-voltage distribution equipment



high-voltage interrupter, power fuse, high-voltage load switch, capacitor, measuring instrument, relays and transformer. While, for low-voltage system equipment, we can cite molded case circuit breaker, low-voltage current limiting fuse, earth leakage circuit breaker and electromagnetic switch.

In the following, description is made on the recent situation and trends of each group of equipment and apparatus.

3 STATE AND TENDENCY OF HIGH-VOLTAGE DISTRIBUTION EQUIPMENT

3.1 High-voltage main circuit breaker

Main circuit breakers used for high-voltage receiving and distributing installation are high-voltage circuit breakers, power fuse and high-voltage air load switch (See *Fig. 3*).

Circuit breakers are provided with merits of long useful life of switching, ease of rethrowing-in, adjustability of operational characteristics, steadiness in small current interruption, freedom from phase failure, etc. so that they have been used for comparatively larger-type installations.

However, in recent years, LBF with striker in which mechanical tripping system is adopted has been developed even for PF-S, so that a remarkable improvement in small-current interruption performance and freedom from phase failure are obtained and their operational safety is enhanced and they have become easier to be adopted.

On the other hand, in CBs also, by incorporating OCR into CB, a new type of CBs are being developed that require no separate OCRs and CTs. The comparative list of outlines of each machine is given in *Table 1*.

3.2 High-voltage breaker

The high-voltage breakers are available in the following types:

(1) Oil circuit breaker
  (a) Minimum oil circuit breaker
  (b) Tank type oil breaker
(2) Oilless circuit breaker
  (a) Vacuum circuit breaker
  (b) Magnetic circuit breaker
  (c) SF_6 circuit breaker

Recently, the demands are for non-inflammability; so that oilless breakers are winning popularity.

However, as for the minimum oil circuit breakers, though they contain oil, they enjoy stable demand for having little oil volume, possibility of stacking up with many units abundance in availability of types, excellent interrupting characteristics, etc.

To make breakers oilless is a worldwide tendency and it is a wide known fact that the mainstream of the high-voltage circuit breakers are the vacuum circuit-breakers (VCB). Besides their incombustibility, the vacuum circuit-breakers has many other merits such as compactness in size, lightness in weight, save resource and save energy properties, and high reliability, thus explaining their popularity.

In the high-voltage receiving facilities, it is important to have a high reliability in power supply, for that, it is necessary to take care of avoiding occurrence of propagating accidents. Traditionally, the high-voltage circuit breakers themselves were not provided with line failure detective function and by combining them with separate set transformers and relays, they constituted main breaker equipment. Then, in order to eliminate the possibility of lowering reliability due to this, high-voltage automatic circuit breakers incorporating current transformer, relays in one body of the circuit breaker are rapidly being diffused. *Fig. 4* shows the outer view of the high-voltage automatic vacuum circuit breaker (Auto V). This circuit breaker combines through-type small current transformer (CT) with electronic overcurrent relay (OCR), making themselves

Table 1 Comparison of main breakers CB and PF-S

Item \ Machine type	CB		PF + S		Remarks
	General type	Auto V (VCB with OCR)	General type	LBS (*with Striker PF-S)	
Connection and interruption of short-circuit current	○	○	○	○	
Short-circuit failure detection	X	○	○	○	X Another OCR required
Useful switching life	○	○	△	△	
Small over current interruption	○	○	△	○	△ All-domain fuse only possible
Circuit openning	X	X	○	○	X Another operator required
Operational characteristic modification	—	○	△	△	△ Change fuse — No characteristics
Reclosing	○	○	△	△	△ Electromagnetic operation possible
Countermeasures for phase failure	○	○	X	○	

○: Possible △: Partially possible X: Needs another apparatus

Fig. 4 OCR-incorporated vacuum circuit breaker (Auto V)

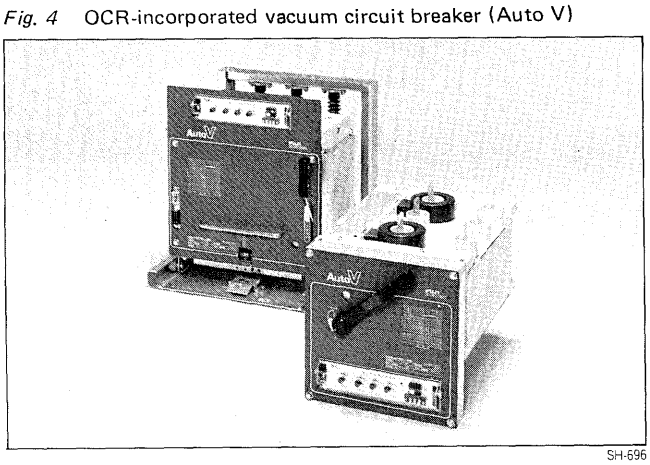
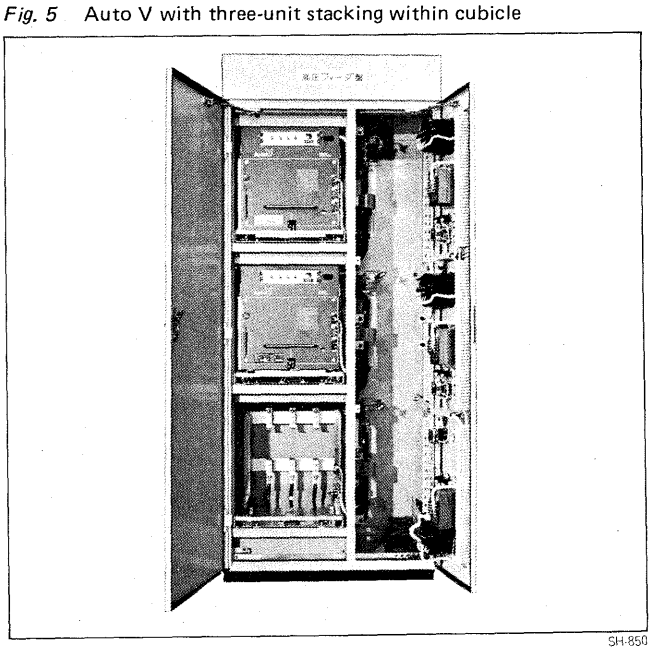


Fig. 5 Auto V with three-unit stacking within cubicle



compact and high-reliability high-voltage automatic circuit breakers. The main features are the following.

(1) Incorporated electronic OCRs have characteristics which are suitable for cordination between power source side and load side equipment and are possible to adjust freely.

(2) Power source for electronic circuits as OCR are provided from the CT secondary side, so that no operating current is needed at all.

(3) As CT is provided with overcurrent constant and overload withstanding characteristics sufficiently compatible among themselves, there is no need for checking individual aptitude.

(4) They are compact in size and economic.

Fig. 5 shows an example of thin-type cubicle with three Auto V's stacked.

3.3 Air load-break switch with fuse

The air load-switch with fuse is a solid-structure switch combining high-voltage current limiting fuse with high-voltage air load break switch, and each component taking up partial charge, that is, the current limiting fuse interrupting short-circuit current and load switch, switching the load current, in order to enhance the cost performance.

Up to now, in case a fuse was used, there had been produced an interruption of that phase, that is, so called phase loss of state occurred. This was demerit of using the fuse, but thanks to development of mechanical striker tripping system, this problem was solved, consequently the present-day function of the air load switch with fuse is very close to that of circuit breaker. *Fig. 6* shows an example of outer views (LBF).

The mechanical striker tripping system is a system with which the switch is interrupted mechanically by utilizing fusion indicator at the time of fuse operation. Thanks to this system, not only prevention of loss of phase operation can be avoided but also in case of fuse not having all-domain interrupting characteristics, by fusing indicator of the fuse, the load switch effectuates the interrupting operation in the small current domain, so that the small current interrupting characteristics have become secure. *Fig. 7*

Fig. 6 DF-S type circuit breaker with striker (L Schalter)

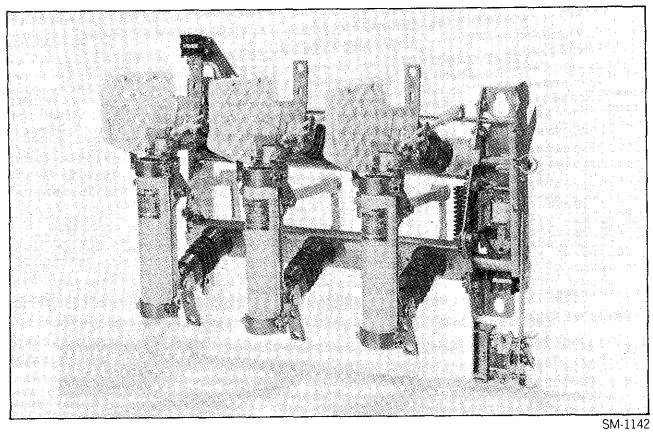
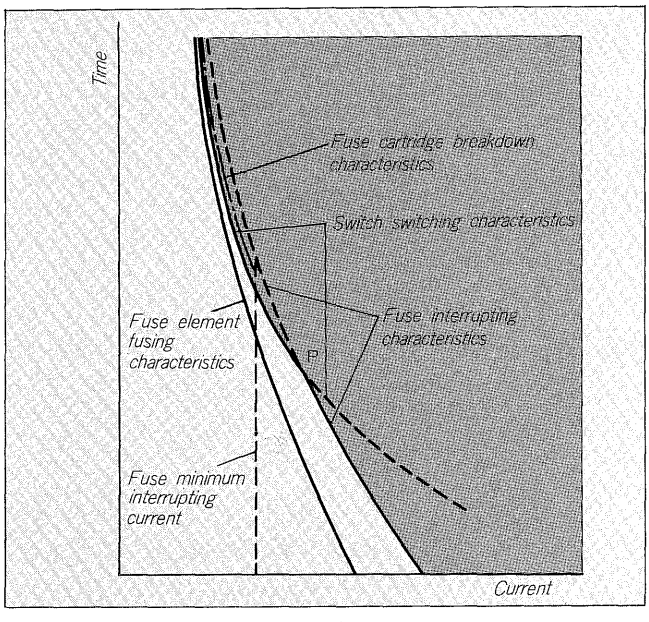


Fig. 7 Operating characteristics of fuse load switch with striker



shows the related characteristics. The diagram shows that in the larger current side from the intersection (P) of operating characteristics between fuse and switch, it is fuse that carries out an interruption and on the contrary, in the smaller current side, it is the switch that does that operation.

It is presumed that from now on for the PF-S type Main circuit breakers, this type of mechanical striker system would become a mainstream.

The current limiting fuse is excellent in interrupting characteristics during short circuit current and its passing I^2t is also small, so that it would be effective for protection of capacitors.

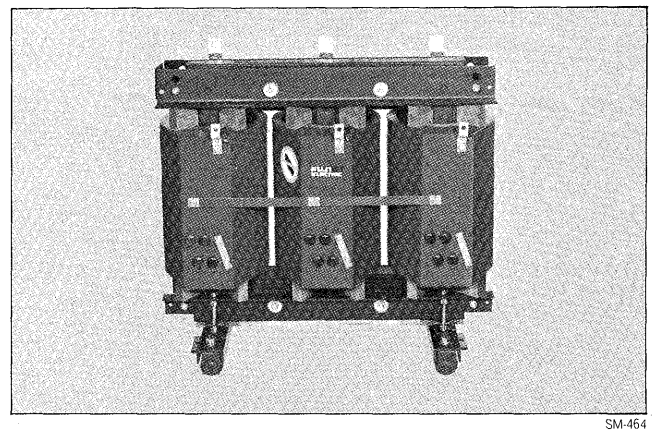
3.4 Transformer

Roughly speaking, the transformers for distribution can be classified into two categories: one is oil transformers and another, dry-type transformers. Oil transformers are widely used traditionally, and the dry types are safe from the point of view of prevention of fires, so that they are often used for indoor electric installations.

Table 2 Classification of distributing transformers

Classification	Types of transformer	Place of installation		Incombustibility	Maintenance
		Outdoors	Indoors		
Oil-filled	Oil (general mineral oil) transformer	○	○	×	○
	Silicone oil transformer	○	○	○	△
	Synthetic insulating oil transformer	○	○	△	△
Dry type	Varnish impregnated transformer	×	○	○	×
	Mould transformer	×	○	○	◎
	SF_6 gas insulated transformer	○	○	○	△

Fig. 8 Mould transformer three-phase 100 kVA (FM-84)



Classification and application as well as outlines of characteristics of each transformer are indicated in *Table 2*.

General trends for transformers are towards incombustibility, miniaturization, alleviation, enhancement of functioning, energy saving, etc.

Mould transformer (*Fig. 8*) is structured that the winding parts are moulded with epoxy resine, and is excellent in insulating properties and moisture proofing properties, and easy for maintenance and inspection, large resistance to overload for short time, small in size, light in weight, low noise, energy saving and many other excellent properties. This transformer will be the mainstream of transformers in future.

Fuji Electric, first developer of full practical mould transformer in Japan having an abundant experience in commercializing this type of transformers under the name of "Moltora", has now prepared many series of products, and further in order to diffuse them, developed new products "Compact Moltora" emphasizing their economomicity to be commercialized. This product is a mould transformer, since it is small in size, suitable also for thin-type cubicle. Also, low-voltage mould transformer for low-voltage system is serialized. (For the details, see the separate article "Fuji Electric low-voltage mould transformer light and compact with high reliability.)

4 LOW-VOLTAGE DISTRIBUTION APPARATUS: STATES AND TRENDS

4.1 Low-voltage apparatus and general trends

As low-voltage distribution apparatus, there are in the line of our products, molded case circuit breaker (MCCB), fuse and earth leakage circuit breaker (ELCB), as well as, though they may be classified otherwise, magnetic motor starter (MS), circuit protector (CP), or PCT and relays. *Fig. 9* shows an outer view of the molded case circuit breaker motor starter (Fuji Auto-breaker).

In low-voltage distribution apparatus, there are many apparatus that have a long history, and by late fifties the fundamental types have been completed and by late sixties diversification of the machines as miniaturization and serialization of the machines were initialized. As the trends of seventies, electronization of each type of machine and enhancement of their function were devised, and for coping with the export problem, conformation with foreign standards such as UL, as well as IEC, NEMA and CSA was studied and now there are many products that have been type approved overseas.

As for protection of short circuit of low-voltage circuit, together with enlargement of capacity in low-voltage system in late 60's, current limiting fuses having large interrupting capacity suitable for this, and MCCB having a function of interrupting repeatedly overcurrent and switching capability are used in happy combination supplementing insufficiency of one another. At present, the mainstream is the MCCB; and taking advantage of current limiting fuse's high protective capacity during the interruption of large current, they are widely used in the large capacity mains and semiconductor circuit protection as well as control circuits.

4.2 Electronization of low voltage apparatus

For coping with the present day trends of electronization of all machines, there are two methods that can be considered, namely, the case in which the machine itself should be electronized and another, provide means of adapting the equipment to electronic equipment or electronic circuits.

As for the electronization of the equipment themselves, MCCB and ECLB are already electronized. Electronization of MCCB concerns mainly detection of overcurrent whose function has been entrusted, up to now, to electromagnetic coil or bimetal that has been switched over to CT and electronic circuit, and with this, supplementary functions such as adjustment of characteristics, reducing of operational fluctuation or detection of phase defects can be added. As for electronization of ELCB, it mainly consists in electronization and making IC's of zerophase current component detecting circuit on the secondary side of zero phase transformer (ZCT).

For magnetic motor starter, a super magnet system, which is DC magnet incorporating electronic control circuit was developed (See *Fig. 10*). With this system, excitation loss was reduced to less than 1/2 of what it used to be, and no damage to the contact nor burning of coil were produced even when there were abnormal variation in control voltage. This really is an epoch making system that can be operable either on AC or DC. The principle of operation is shown in *Fig. 11*.

For the contactor of magnetic motor starter also, solidification was devised and solid state contactor (SSC) using thyristor was also developed. (See *Fig. 12*.)

Then, as distribution apparatus aiming at adaptability to electronic devices and circuits, there are semiconductor protecting fuses and circuit protectors for electronic circuit.

Among the short circuit protective breakers, the current limiting fuses have the highest current limiting characteristic so that as the passage I^2t (A^2s) also is low, they are the most suitable protector for protecting short circuit of semiconductors which are susceptible to thermal intensity (See *Fig. 13*.)

Also, there are circuit protectors that are used both as protector of various electronic devices beginning with latest computers or protection of control circuit and as power

Fig. 9 Molded case circuit breaker (FAB)

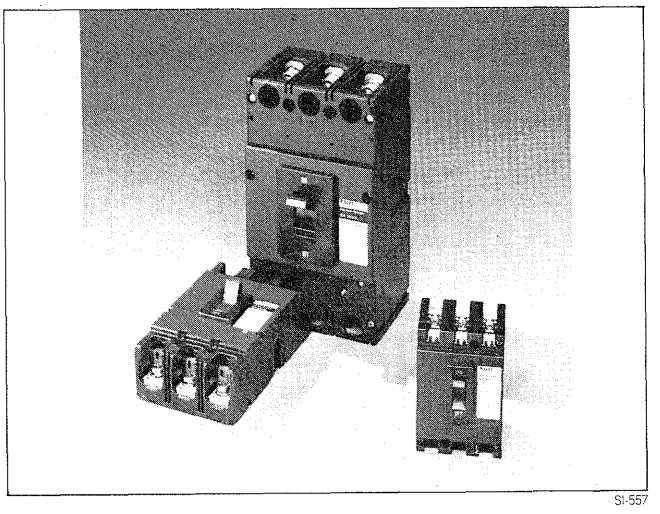


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Fig. 10 Electromagnetic switch (new SC type)

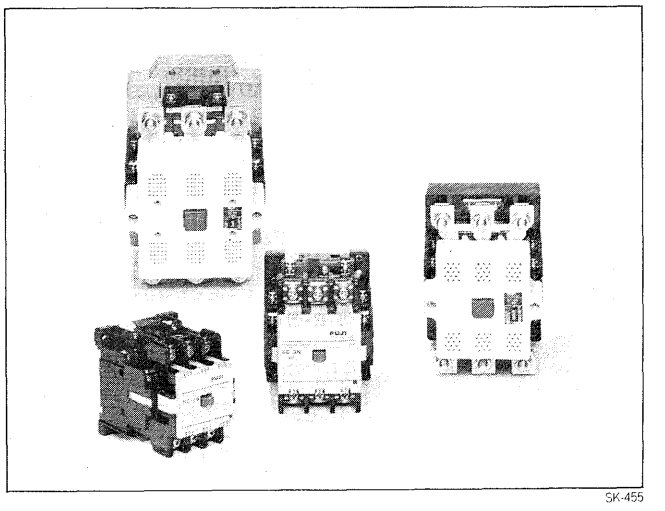

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Fig. 11 Principle and circuit composition of new SC type

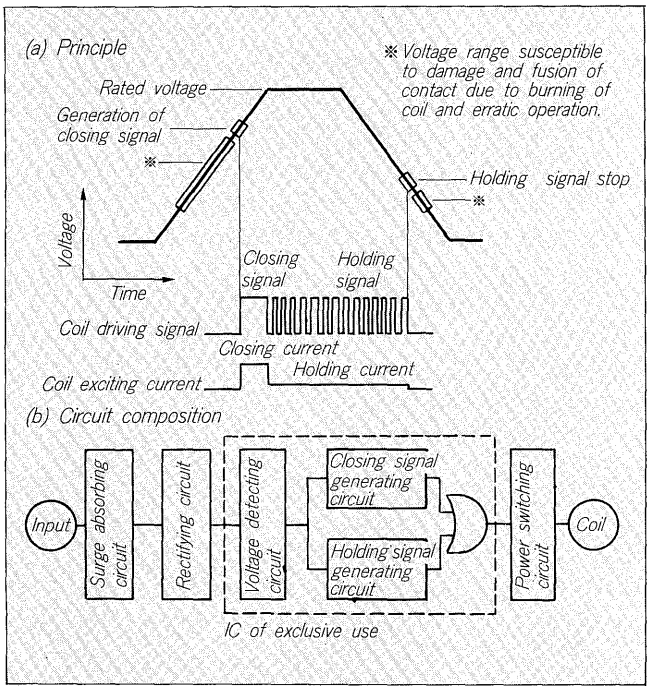
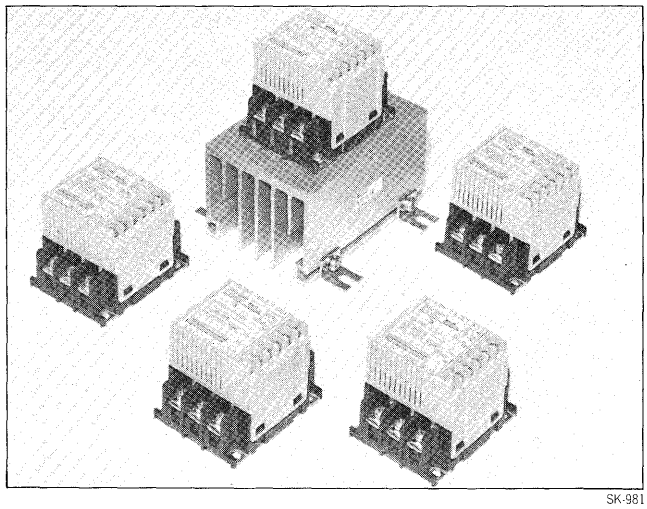


Fig. 12 Solid state contactor



supply switching. There are various types in contact composition and various operational characteristics are available. Their outer views are shown in *Fig. 14*.

4.3 Enhancement of equipment functions and their diversification

Together with introduction of many new high technologies, their electronization, integration of circuits and microcomputerization, diversification of functions of low voltage distribution apparatus is devised.

For example, for MCCB, in particular, breakers of large capacity incorporating microcomputer (Power Breaker), many functions such as ground detection, operation display, operation check, possibility of changing rating and others are added, and inspite of these, these breakers have

Fig. 13 Semiconductor protecting fuses

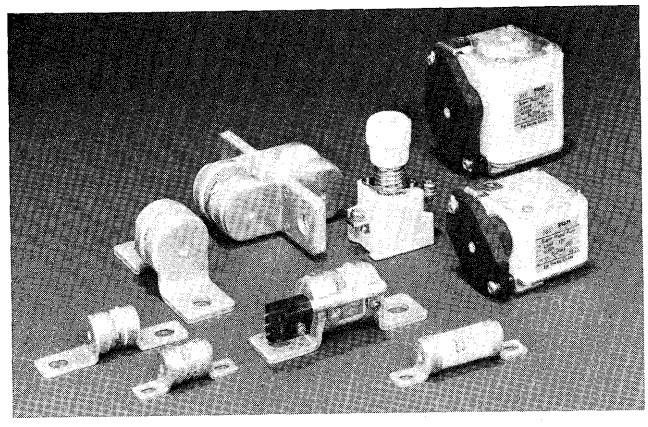
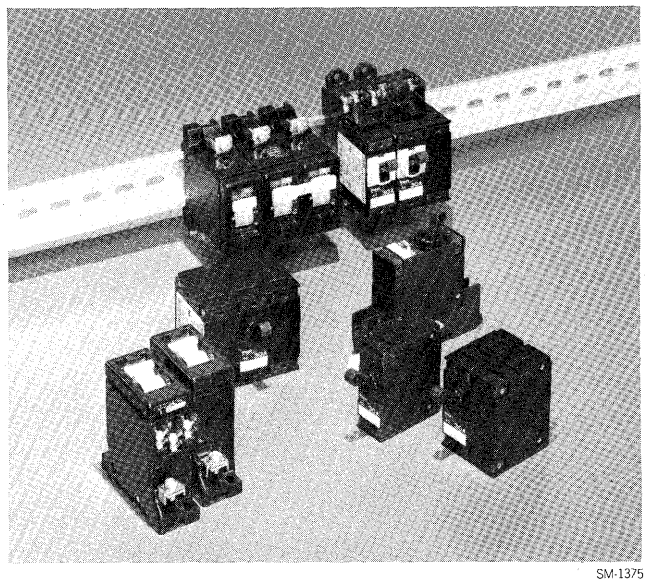


Fig. 14 Circuit protector



become very easy to handle. (For the details, see the separate article "Multi function type low voltage circuit breaker for mains "Power Breaker" by microcomputer control")

Also Fuji Electric has developed as a new interruption system, "Simultaneous open polar interruption system" (Fuji Electric's patent) as well as a new circuit breaker (Arc space free breaker) having high interruption capacity, high current limiting characteristics and arc suppressing capability.

We have further presented to the market new products of standard practice, that is, structure of dimensions for MCCB and ELB, which have compatibility with DIN, so that they can be mounted on 38 mm DIN rail, and those having a uniformed height of 60 mm, so that the new products are all very easy to manipulate.

5 SUMMARY

This report outlined the present state and trends of

recent standard type receiving and distributing apparatus.

The distributing equipment their importance in the social activities is everyday increasing. And the technological development of this field also, beginning with introduction of microelectronic technology, to hybridation of functions, diversification, enhancement of functions, as well as development of new interruption principle and enhancement of function through introduction of new materials, is remarkable.

In this article dediated to standard type distributing equipment, on the background of this situation, we have described the outlined of the representative machine types that have been developed recently. Fuji Electric is determined to continue endeavoring for research for developing new technology coping with the needs of market, and we ask our users and readers their continuous favors and instructions.

TOPICS

FUJI's Participation in HANNOVER MESS'86

For the first time FUJI ELECTRIC participated in HANNOVER Fair in which it enjoyed a high reputation.

Under the title "Optical Technology and Pattern Recognition" FUJI exhibited a variety of FA (Factory Automation) components which incorporate its advanced optical and microcomputer technology. These include optical field instrumentation systems (FFI system), automatic apearance inspection devices (FUJI Multi-Window), linear image sensors, photoelectric switches and programmable controllers (MICREX-F).

Among the visitors of over 500,000 of the "Fair of Fairs" 10,000 key personnels visited the 2108 FUJI Stand which enhanced interrest in advanced technical products to meet the FA requirements.