Fuji Electric's New Global Motor Control Series

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1. Introduction

In recent years, market globalization has caused large changes in the business environment of the motor control field. The following issues have an especially large impact on customer's equipment design and purchases.

① Conformity with JIS and IEC standards
② Adoption of global specifications for electrical equipment
③ Simplification of equipment maintenance

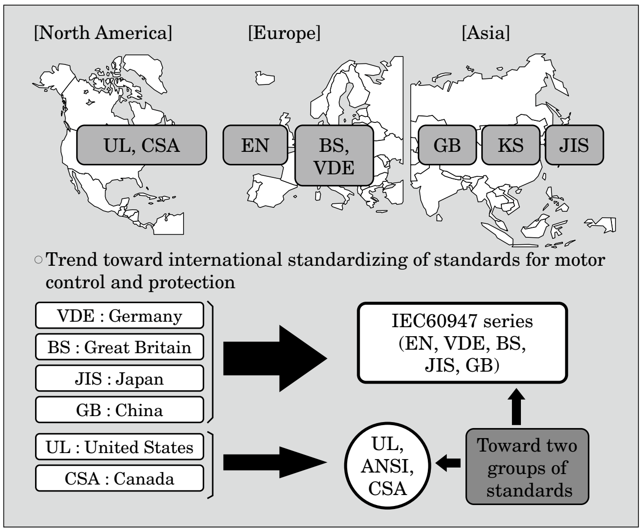
In this article we present the manual motor starter (MMS) and combination starter (combination of an MMS and a magnetic contactor (MC)), as a new motor control series that has adapted to these globalization requirements.

2. Evolution of Standards and Motor Control Methods

Throughout the world, many domestic standards for components used in electrical equipment have been adjusted to conform to IEC standards. Japan is no exception. For example, a standard that complies with the IEC60947 series has been established as JIS C 8201 for magnetic starters and motor circuit breakers. These changes affected not only equipment for industrial machines, but also equipment for ship vessels, and NK (Nippon Kaiji Kyoukai), for example, supports the new JIS C 8201-2-1 instead of the previous JIS C 8370 for circuit breakers. As we have mentioned before, the trend towards compliance with IEC standards is not limited to Japan, but exists throughout the world (Fig. 1). We are not just speaking of the European countries but also near countries in Asia. For instance, China's GB standard and South Korea's "Electric Appliance Safety Control Law" also comply with the IEC60947 series. As you can see, most of countries of the world, except UL in North America, presently have standards that comply with the IEC. This means that the globe has diverged into two systems of standards, IEC and UL.

As a result of the consistency between JIS and IEC, the method for motor control has changed (Fig. 2).

Fig.1 Trends of standards for low-voltage switches (toward two groups of standards: IEC and UL)



IEC60204-1 that relates to "Safety of machinery – Electrical equipment of machines" was established as JIS B 9960 and requires an overcurrent protective device on the line-side of a motor circuit. This means that, in Fig. 2, method B or C, in which an overcurrent protection device is provided in each motor circuit will be required instead of the previous method A.

For these new motor control methods, Fuji Electric's MMS and combination starter are ideal products that can "save space", "save wiring work", and "achieve high-level short-circuit coordination." In the following, we present the features and structure of the MMS.

3. Features of MMS and Combination Starter

The MMS is provided with the short-circuit protection function of a circuit breaker and the overload protection function of a thermal overload relay (TOR), integrated into a single compact body (Fig. 3).

Table 1 lists the main specifications of the MMS. The MMS has an AC-3 (15 kW 230 V AC, 30 kW 400 V AC) rating as a controller so it can be used for across-the-line direct motor starting. Remote switching or high frequency switching operation can be achieved by

Fig.2 Motor control method comparison

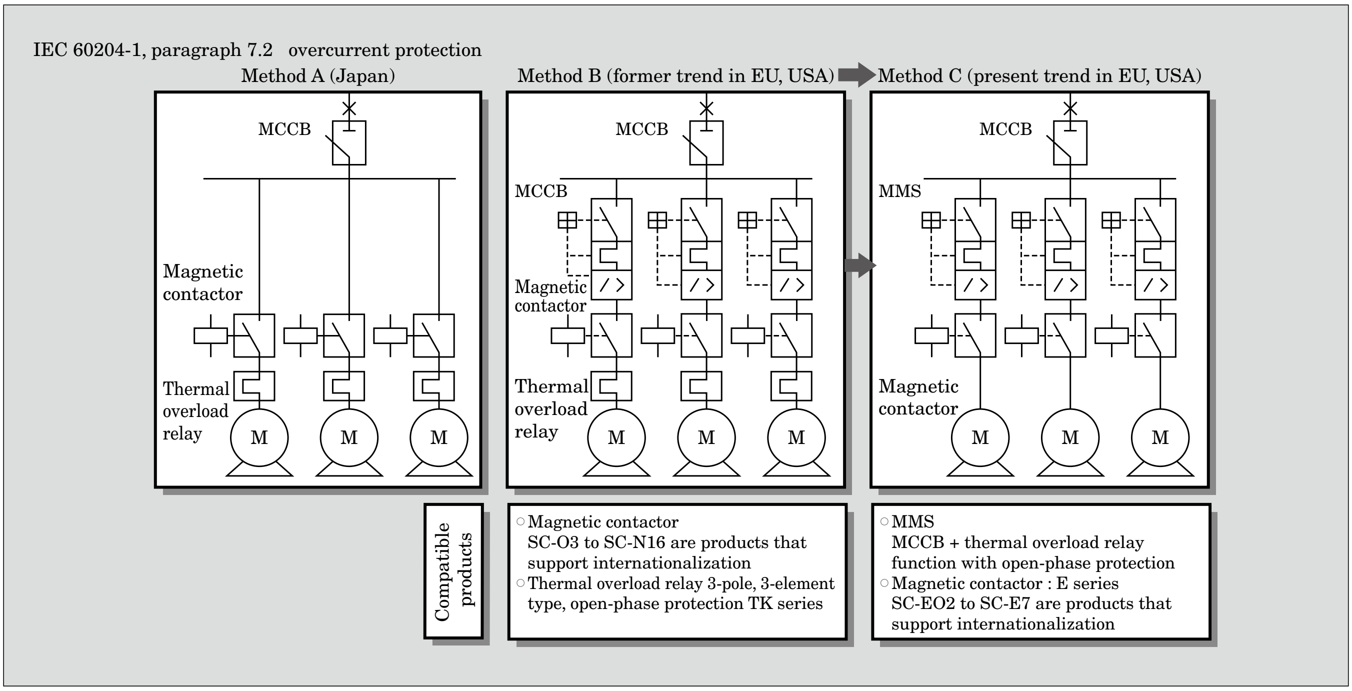
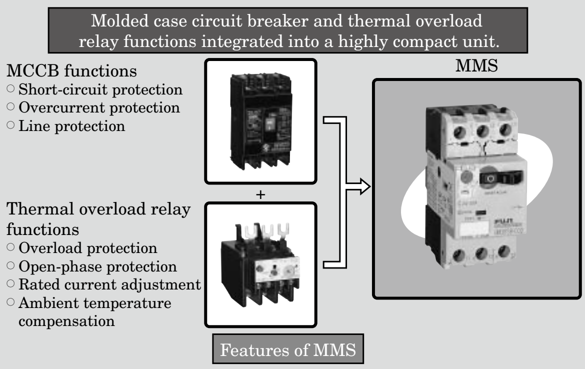
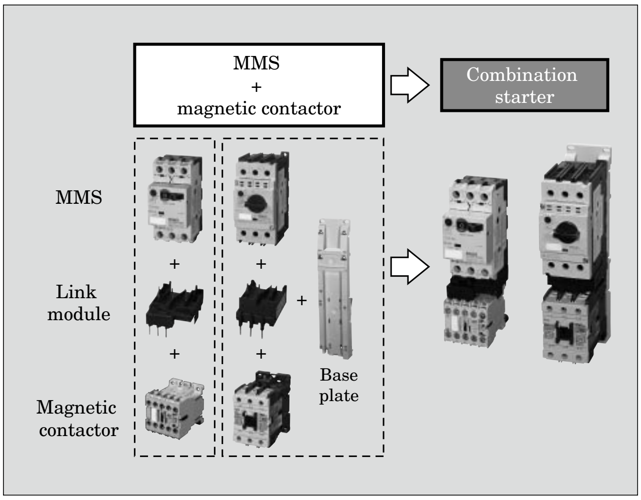


Fig.3 Configuration and features of MMS



Compact size	57 % reduction in required mounting space compared to MCCB + thermal overload relay
Large breaking capacity	400 V AC (32 A rating) 25 kA (standard model) 50 kA (high performance model)
Short-circuit protective coordination	IEC 60947-4-1 type 1, 2
Reduction in wiring work	50 % reduction in required wiring work for MMS + magnetic contactor instead of MCCB + magnetic contactor + thermal overload relay
Standards	Japanese standards : JIS C 8201-1, JIS C 8201-2-1, JIS C 8201-4-1, Electrical appliance and material safety law Overseas standards : IEC60947-1, IEC60947-2, IEC60947-4-1, UL508, CSA C22.2 No.14, China GB

Fig.4 Appearance of combination starter



combining the MMS with a magnetic contactor to make a combination starter. Figure 4 shows the external appearance of the combination starter. The combination starter is provided with many functions, such as short-circuit protection, overload protection and switching, and can therefore be easily applied to electrical equipment having motor circuits that require IEC60204-1 or JIS B 9960 conformance.

One of the most important features of the MMS and combination starter is that they provide excellent current limiting performance during a short-circuit. This current limiting characteristic has made the MMS capable of reaching short-circuit breaking levels as high as 230 V AC 100 kA and 415 V AC 50 kA (type BM3RH). In the following, we will describe the basic structure of the MMS short-circuit interrupting section.

4. Short-circuit Interrupting

The main feature of the short-circuit interrupting section is the 2-point contact opening structure (double-break mechanism), shown in Fig. 5, that reduces the

Table 1 MMS specifications

<table>
<tr><td colspan="2">Frame A</td><td colspan="8">32</td><td colspan="4">63</td></tr>
<tr><td colspan="2">Type</td><td colspan="4">BM3RSB (standard model)
BM3RSR (standard model)</td><td colspan="4">BM3RHB (high performance model)
BM3RHR (high performance model)</td><td colspan="4">BM3VHB
(high performance model)</td></tr>
<tr><td colspan="2">Number of poles</td><td colspan="4">3</td><td colspan="4">3</td><td colspan="4">3</td></tr>
<tr><td colspan="2">Handle type</td><td colspan="4">Rocker</td><td colspan="4">Rotating handle</td><td colspan="4">Rotating handle</td></tr>
<tr><td colspan="2">Rated current (A)</td><td colspan="4">0.16 to 32</td><td colspan="4">0.16 to 32</td><td colspan="4">10 to 63</td></tr>
<tr><td colspan="2">Rated insulation voltage U_i (V) /
Rated impulse withstand voltage U_{imp} (kV)</td><td colspan="4">AC690/6</td><td colspan="4">AC690/6</td><td colspan="4">AC1,000/8</td></tr>
<tr><td rowspan="2">Utilization category</td><td>IEC60947-2,
JIS C 8201-2</td><td colspan="4">Cat.A</td><td colspan="4">Cat.A</td><td colspan="4">Cat.A</td></tr>
<tr><td>IEC60947-4-1,
JIS C 8201-4-1</td><td colspan="4">AC-3</td><td colspan="4">AC-3</td><td colspan="4">AC-3</td></tr>
<tr><td>UL standard category</td><td>UL508, UL508E</td><td colspan="4">Suitable for Group Installation</td><td colspan="4">Suitable for Group Installation</td><td colspan="4">Suitable for Group Installation</td></tr>
<tr><td colspan="2">Overload protection,
open-phase protection</td><td colspan="4">Yes</td><td colspan="4">Yes</td><td colspan="4">Yes</td></tr>
<tr><td colspan="2">Instantaneous tripping characteristic</td><td colspan="4">13 × I_E max.</td><td colspan="4">13 × I_E max.</td><td colspan="4">13 × I_E max.</td></tr>
<tr><td rowspan="2">Durability</td><td>Mechanical durability
(No. of cycles)</td><td colspan="4">100,000 : I_n = 0.16 to 25 A
70,000 : I_n = 32 A</td><td colspan="4">100,000 : I_n = 0.16 to 25 A
70,000 : I_n = 32 A</td><td colspan="4">50,000</td></tr>
<tr><td>Electrical durability
(No. of cycles)</td><td colspan="4">100,000 : I_n = 0.16 to 25 A
70,000 : I_n = 32 A</td><td colspan="4">100,000 : I_n = 0.16 to 25 A
70,000 : I_n = 32 A</td><td colspan="4">25,000</td></tr>
<tr><td rowspan="14">Rated breaking capacity
I_{cu}(kA)
IEC60947-2
JIS C 8201-2</td><td>Rated current I_e (A)</td><td>240 V</td><td>415 V</td><td>460 V</td><td>690 V</td><td>240 V</td><td>415 V</td><td>460 V</td><td>690 V</td><td>240 V</td><td>415 V</td><td>460 V</td><td>690 V</td></tr>
<tr><td>Less than 1.6</td><td rowspan="7">100</td><td rowspan="5">100</td><td rowspan="3">100</td><td>100</td><td rowspan="10">100</td><td rowspan="6">100</td><td rowspan="4">100</td><td>100</td><td colspan="4" rowspan="4">—</td></tr>
<tr><td>1.6 to 2.5</td><td rowspan="9">3</td><td rowspan="2">8</td></tr>
<tr><td>2.5 to 4.0</td></tr>
<tr><td>4.0 to 6.3</td><td>50</td><td rowspan="3">6</td></tr>
<tr><td>6.3 to 10</td><td>15</td><td rowspan="2">50</td><td rowspan="9">100</td><td rowspan="2">100</td><td rowspan="4">50</td><td rowspan="2">6</td></tr>
<tr><td>9 to 13</td><td>50</td><td rowspan="5">10</td></tr>
<tr><td>11 to 16</td><td rowspan="4">25</td><td rowspan="4">50</td><td rowspan="4">35</td><td rowspan="4">4</td><td rowspan="7">50</td><td rowspan="7">5</td></tr>
<tr><td>14 to 20</td><td rowspan="3">50</td></tr>
<tr><td>19 to 25</td><td rowspan="5">35</td></tr>
<tr><td>24 to 32</td></tr>
<tr><td>28 to 40</td><td colspan="4" rowspan="3">—</td><td colspan="4" rowspan="3">—</td></tr>
<tr><td>35 to 50</td></tr>
<tr><td>45 to 63</td></tr>
<tr><td>External dimensions (mm)</td><td>W × H × D</td><td colspan="4">45 × 90 × 68</td><td colspan="4">45 × 90 × 79</td><td colspan="4">55 × 110 × 96</td></tr>
</table>

amount of let-through energy during the breaking of a short-circuit current. This is a result of joint development using the switching technology of an MC and the breaking technology of an MCCB. The double-break mechanism has a very efficient structure for driving the electrical arc, and enables a reduction in contact wear and also minimizes the short-circuit let-through I^2t. Below, we will present the basic principles of MMS short-circuit current breaking.

When there is a short-circuit current, the moving conductor will receive an electromagnetic repulsive force due to the parallel currents flowing in opposite directions in the fixed conductor and the moving conductor. The moving conductor is accelerated further by the magnetic field of the magnetic yoke mounted on the arc moving plate, which leads to instantaneous opening of the contacts. After the contacts have fully opened, a driving force will be applied by the magnetic force generated at the fixed contact and the current flowing through the electrical arc. Because of this force, the arc will be driven into the arc plates and extinguished immediately.

During the driving and extinguishing process it is very important to maintain a stable contact distance between the fixed and moving contacts. The MMS has a pushbar located directly above the moving contact that transmits the movement of the plunger placed in the instantaneous tripping coil. This plunger activates as soon as it detects a short-circuit current that will force the opening of the contacts via the pushbar. The advantage of this mechanism is that it can detect and also open the contacts at the same time, and thus helps to break the short-circuit current before the current rises. Furthermore, this mechanism can forcibly keep

Fig.5 Internal structure of MMS

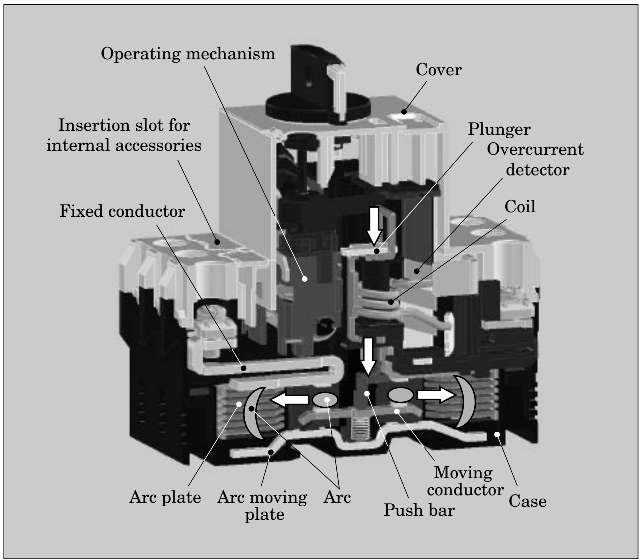
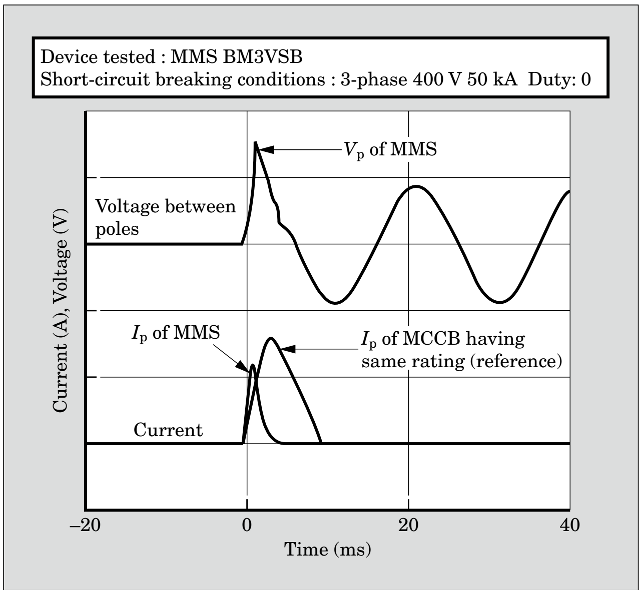


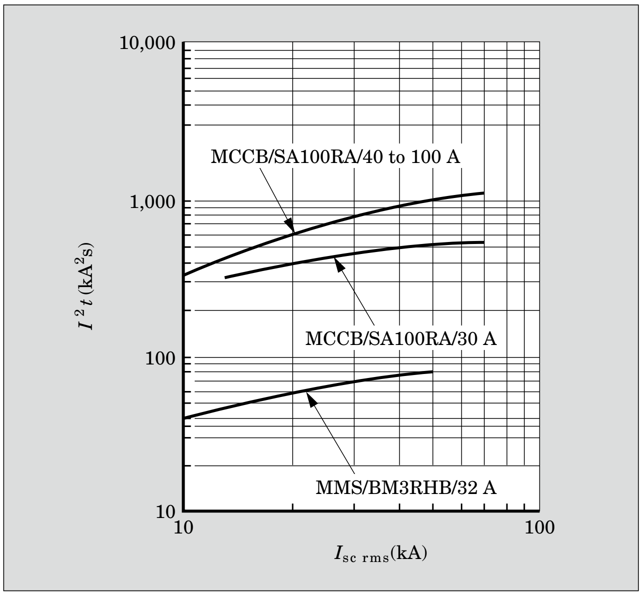
Fig.6 Oscillogram of short-circuit breaking



open the contacts as long as there is a short-circuit current. This feature will maintain the moving contact at a stable position during the current breaking process.

Because of the high current limiting performance, the MMS can break a short-circuit much more quickly than an MCCB. Figure 6 is an oscillogram at 400 V/50 kA, comparing an MMS and MCCB during the breaking of an arc. The overall breaking time with an MMS is only 3 ms (compared to 10 ms with an MCCB) and the current peak (I_p) is limited to 75 % (12 kA). Due to this short breaking time and the small peak value of current, the short-circuit let-through energy (I^2t) during a short-circuit will also be very small. This means that the impact of heat energy on load-side components (such as the MC) of the MMS is also limited to a small value. Figure 7 compares the I^2t values of Fuji Electric's MMS and MCCB. The I^2t of the MMS

Fig.7 Short-circuit let-through I^2t (compared to MCCB)



is less than 1/5th that of the MCCB.

From the above we can say that the combination starter is an ideal component for large short-circuit breaking applications such as motor control centers.

5. Short Circuit Co-ordination Between MMS and MC

With globalization, the electrical equipment of a domestic customer may be installed in various countries throughout the world, and the demand for simplified maintenance is increasing. For example, there is a demand for electrical equipment that is able to quickly restore the power supply of manufacturing facilities for minimum stoppage time following a short-circuit accident. To fulfill this requirement, motor control components must comply with the IEC60947-4-1 standard for "type 2" short-circuit co-ordination.

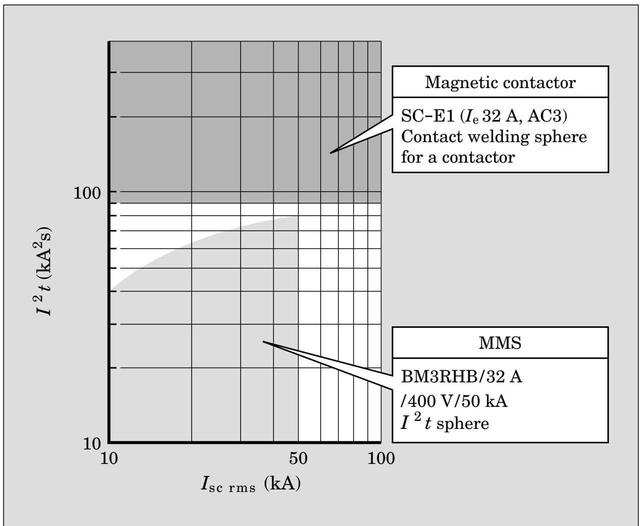
In the IEC60947-4-1 standard, there are two types of protection levels defined as "type 1" and "type 2" for the short-circuit co-ordination between short-circuit protective devices (fuses or MCCB) and the MC. "Type 1" protection level allows the MC to sustain damage and require partial or complete replacement for further service (contacts are allowed to be welded), after a short-circuit accident. On the other hand, "type 2" protection level must provide continuous service, without requiring replacement or sustaining damage except for light welding of the MC contacts.

Fuji Electric's combination starter series is capable of "type 2" performance up to 400 V 18.5 kW. (See Table 2.) Previously, it had been difficult to achieve "type 2" performance using an MCCB, because the short-circuit let-through I^2t was quite large during a short-circuit. But because the MMS has a very small short-circuit let-through I^2t, the combination starter can achieve short-circuit co-ordination even with a 50 kA (400 V)

Table 2 Combination starter series

AC400 V	BM3R + SC-M	BM3R + SC-E02 to E05	BM3R + SC-E1	BM3V + SC-E1, E2, E2S
External appearance				
Type 1	0.06 to 4 kW 0.23 to 9 A	0.06 to 11 kW 0.23 to 22 A	15 kW 30 A	18.5 to 22 kW 37 to 48 A
Type 2	0.06 to 1.1 kW 0.23 to 2.5 A	0.06 to 7.5 kW 0.23 to 16 A	11 kW 22 A	15 to 18.5 kW 30 to 37 A

Fig.8 Relation between MMS I^2t performance and the contact-welding sphere of a magnetic contactor



circuit. Figure 8 shows a comparison of the short-circuit let-through I^2t of the MMS and the contact-welding sphere of the MC at 400 V 50 kA. The maximum I^2t of the MMS is about 80 kA^{2}s, and is smaller than the limit value of 90 kA^{2}s of the MC. This performance is the result of applying Fuji Electric's unique breaking technology presented in section 4. This excellent performance can be used to contribute to improved maintenance capability in global equipment.

Previously, "type 2" performance was a requirement of the IEC standard but was not included in the old JIS standard. This requirement has been introduced, however, for the new JIS C 8021-4-1 standard that is mostly compatible with the IEC. As a result, the demand for "type 2" performance is increasing. We can say that Fuji Electric's combination starters are a product series that has anticipated important needs in advance.

Fig.9 Combination starter system

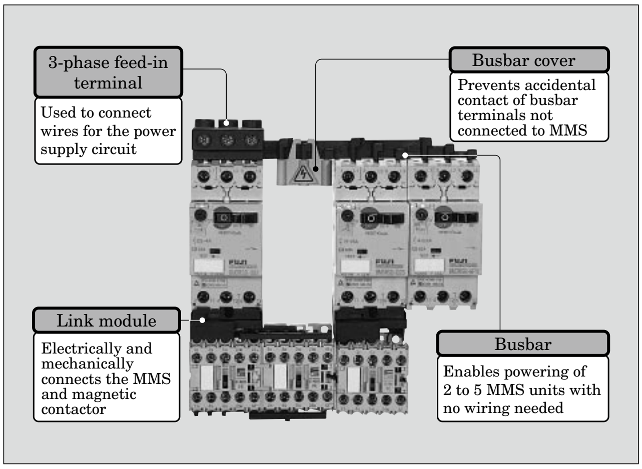
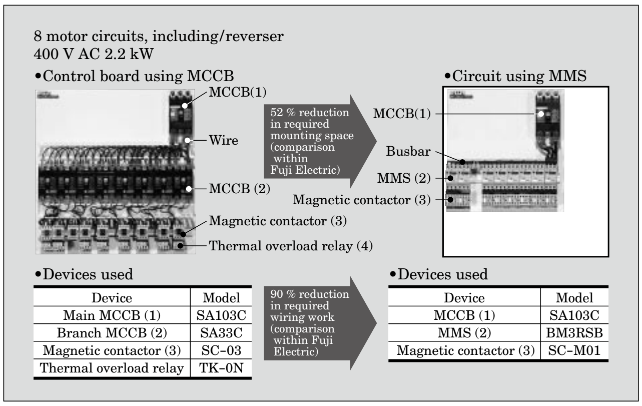


Fig.10 Comparison between MMS and MCCB



6. Greater Efficiency Using a Combination Starter

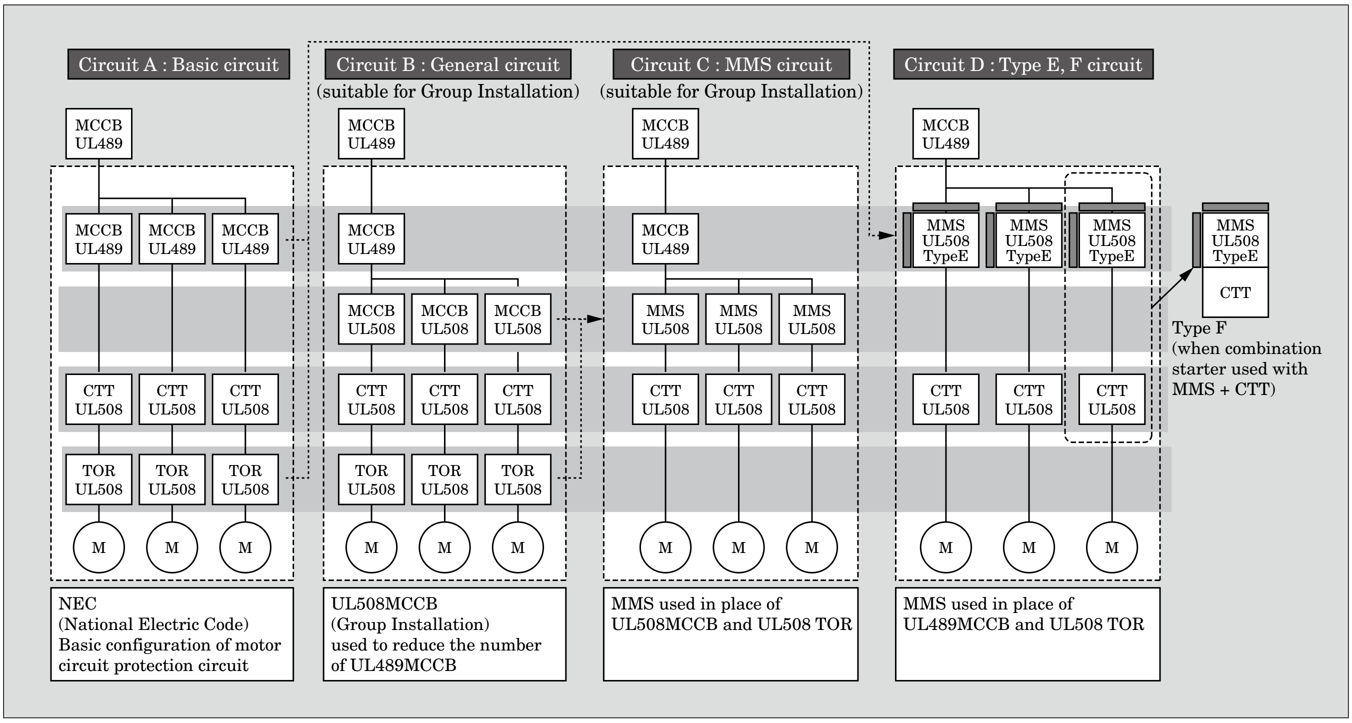
Figure 9 shows an example of a combination starter system. The system is constructed by wiring such parts as 3-phase feed-in terminals, busbars, and link modules, and is used to reduce the wiring work necessary when constructing the system. A specific comparison is made in Fig. 10. The circuit consists of eight 400 V AC 2.2 kW motors, one of which being reversible. Use of the combination starter instead of the conventional style enables a space savings of 52 % in the installation area and a 90 % reduction in wiring work. From this, we can see that the combination starter system is very effective for increasing the efficiency of motor circuits.

7. Applications in North America

MMS is UL-listed as a "manual motor controller," conforming to the UL508 standard for Industrial Control Equipment, which is the same standard for MCs, TORs, and push button switches.

According to the basic regulations of NFPA70, a fuse or a UL489-listed circuit breaker must be used for individual short-circuit protection of each branch

Fig.11 North American motor circuit example



circuit. There are some exceptions to this rule, one of them is when the conductor length and size satisfy the required values, and at the same time, the UL508 component is listed as "suitable for group installation."

Figure 11 is an example, showing several branch circuits taped from a UL489 circuit breaker when the abovementioned conditions are satisfied. Circuit A is an example of the most basic rule, which is to apply one UL489 circuit breaker to each motor load. Circuits B and C are more efficient circuits, composed from "suitable for group installation" components. C is an example using MMS, and because it has an overload protection function and is "suitable for group installation," the TORs in circuit B can be omitted. This saves cost and space on the control panel as mentioned in section 6.

There are two categories of "group installation." One is the ordinary "suitable for group installation" and the other is "suitable for tap conductor protection in group installation." The difference between the two is that the branch circuit conductor cross section can be 1/10th (when the length is shorter than 3 m) of the main circuit, compared to the ordinary group installation component that has a conductor size limit of 1/3rd of the main circuit (when the length is shorter than 7.6 m). This means that for a line-side UL489 circuit breaker of the same rating, a component that is "suitable for tap conductor protection in group installation" enables more loads to be connected, which makes the circuit more efficient. To obtain certification of this tap conductor protection, the component has to pass a very demanding short-circuit breaking test. But thanks to its high current limiting performance, the MMS has achieved this "suitable for tap conductor protection in group installation".

In North America, there are special conditions that allow use of the MMS instead of a UL489 circuit breaker for branch circuit protection of a motor circuit. This is when the component has been UL-certified as UL508 "type E" or "type F." Circuit D shows an example of a circuit constructed by using "type E" and "type F" components. When a MMS that is listed as "type E" is used, the component will be eligible to be used as a branch circuit short-circuit protective device, which means that the UL489 can be omitted to make the circuit more efficient. Figure 12 shows the external appearance of a UL508 "type E" MMS. In order to comply with the required insulation distances and indication of the cause of tripping, a terminal cover and a short-circuit alarm contact block are applied to the standard MMS. The advantages of "type E" are (1) the number of components for protection can be minimized, and (2) the components can be selected easily (because you can select the component based on the horsepower rating of the motor, instead of a complicated calculation of wire length, size, and short-circuit co-ordination required for group installation applications).

As can be seen, the use of MMS as components "suitable for group installation" and as "type E," means that the customer does not have to select different components according to whichever standard is used, IEC or UL. This means that the MMS and combination starter are totally global products that can contribute to the global unification of control panels.

Fig.12 Appearance of UL508 type E

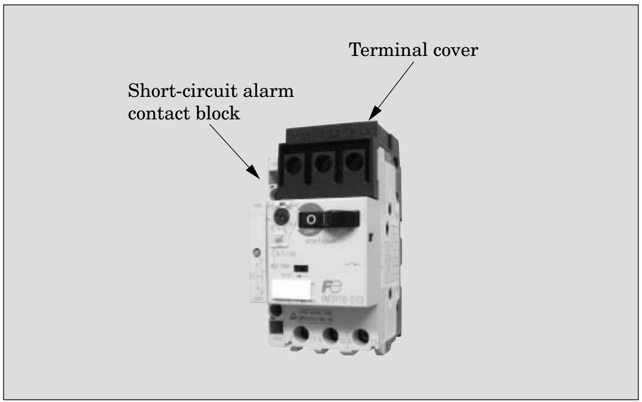
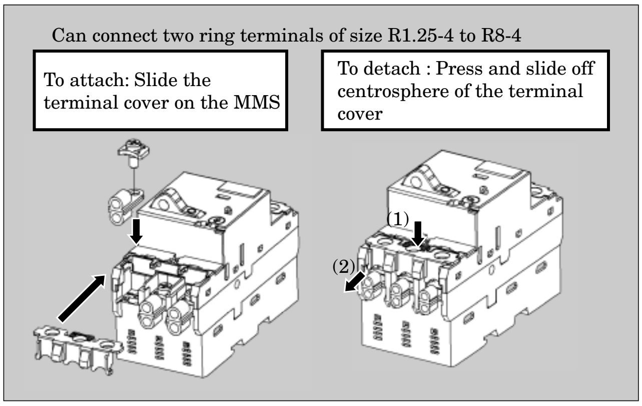


Fig.13 Ring terminal connecting-type MMS



8. Offers to Local Needs

As presented in section 7, the MMS and combination starter are truly global products conforming to worldwide standards. However, even a global product must meet the needs of local customers. The ring terminal connecting-type MMS and combination starter series are provided as special products for the Japanese wiring market.

This series (BM3R□R) is applicable up to 400 V 15 kW, and one of its main features is that the terminal cover is designed to slide off for easy wiring (Fig. 13). As with this series, Fuji Electric intends to continue to support local needs.

9. Conclusion

In this article, we have presented an overview of the changes in motor control caused by the globalization of electrical equipment and such components as the MMS and combination starter that adequately support these changes. Fuji Electric intends to continue to leverage its diverse experience and accumulated technology to offer products that match customers' values.