Manual Motor Starter Series for Motor Circuit Protection

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1. Introduction

In recent years, there have been two big changes that effect low-voltage switching devices such as circuit breakers and magnetic starters, one is the globalization of standards and the other is the globalization of customers.

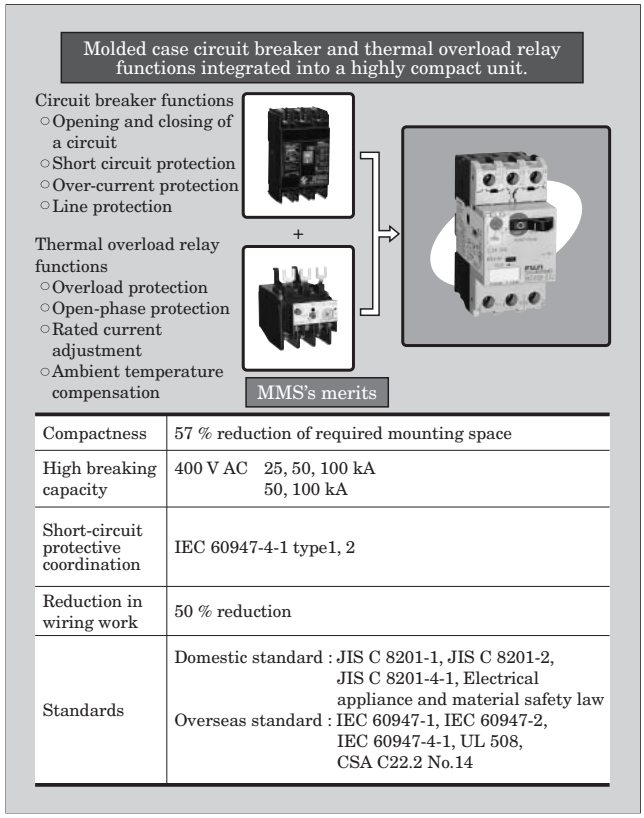
The former change involves the introduction of IEC standards for low-voltage switching devices into JIS standards. For example, IEC 60947-1 pertaining to general regulations for "low-voltage switchgears and control-gears", including regulations concerning the safety of electrical equipment and motor control panels to which industrial devices are applied, was standardized as JIS C 8201-1. Individual product standards such as IEC 60947-2 pertaining to circuit breakers or IEC 60947-4-1 pertaining to magnetic starters were also enacted as JIS C 8201-2 and 8201-4-1. Furthermore, IEC standards were also introduced into the technical standards for electrical equipment, and from these trends, we can say that the globalization of devices and electric equipment is advancing from the field of standards and regulations.

The latter change involves the globalization of customers and the unification of electrical equipment without differentiation between models for domestic and overseas use, leading to lower total cost. Low-voltage switching devices must be capable of being safely and economically installed in a panel in such a manner that reduces the wiring work and requires less mounting space within the panel.

To understand this situation, let us consider, for example, a motor protection circuit. Such circuits were formerly composed of three devices: a circuit breaker (MCCB) for short-circuit protection, a magnetic contactor (MC) for switching the circuit, and a thermal overload relay (TOR) for overload protection.

In this paper, we introduce the manual motor starter (hereafter, MMS) that compactly integrates the functions of a MCCB and TOR as shown in Fig. 1. This new product conforms to global specifications by satisfying IEC and UL standards, and has the potential to bring about great changes in the composition of devices for motor protection. An overview of the specifications, as well as the features and structure of the MMS are described below.

Fig.1 Features of MMS



Compactness	57 % reduction of required mounting space
High breaking capacity	400 V AC 25, 50, 100 kA 50, 100 kA
Short-circuit protective coordination	IEC 60947-4-1 type1, 2
Reduction in wiring work	50 % reduction
Standards	Domestic standard : JIS C 8201-1, JIS C 8201-2, JIS C 8201-4-1, Electrical appliance and material safety law Overseas standard : IEC 60947-1, IEC 60947-2, IEC 60947-4-1, UL 508, CSA C22.2 No.14

2. Aim and Features of MMS

2.1 Conformance with the globalization of motor protection circuits

The MMS is a motor circuit breaker applied to motor protection circuits. It is capable of switching the motor by manual operation according to IEC60947-4-1 as utilization category AC-3. Moreover, the MMS is equipped with functions such as overload and open-phase protection that differ significantly from the existing motor breaker. Furthermore, since the MMS has a high current-limiting ability to reduce the energy generated during a short-circuit interruption, its rated

ultimate short-circuit breaking capacity, Icu, is much higher than that of the conventional motor breaker or MCCB.

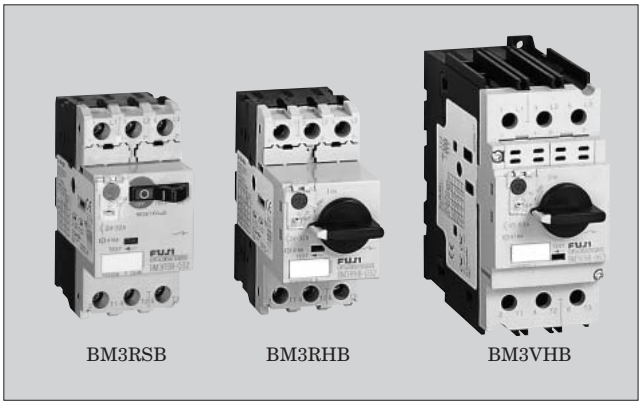
In cases where the MMS needs to perform high frequency and remote-controlled switching of the motor, it is used together with a MC. One of the most important characteristics when used with a MC concerns short-circuit accidents that arise on the load side of a MC. The extent to which damage on the MC can be reduced or prevented by the protector is a big factor in determining the capability of the short-circuit protector. The IEC standard has two classifications, "type 1" and "type 2", according to the degree of damage. "Type 2" is defined as a level where the MC can be re-used. Due to the high current limiting capability of Fuji Electric's MMS, it can satisfy "type 2" combinations with a MC up to high breaking capacities.

Another important feature of the MMS is the reduction in size. Since the MMS compactly integrates the functions of a MCCB and a TOR, the mounting space required within the panel is 57 % less than that of existing devices. Other advantages, such as the reduction of wiring work, and the unified width of the MMS and magnetic contactor (types SC-M and SC-E) all contribute to the rationalization of device composition within the control panel.

2.2 Abundant rating

The external appearance of the MMS is shown in Fig. 2. In order to enhance the visibility of operating means or markings such as rated current scales, the surface of the MMS cover is colored in a uniform bright hue. The ratings and specifications of the MMS are shown in Table 1. The BM3R type has a maximum rated current up to 32 A (rated insulation voltage 690 V) and has a line-up of 15 current ratings. The larger BM3V type has a maximum rated current up to 63 A (rated insulation voltage 1,000 V) and has a line-up of 9 current ratings. The MMS is applicable to a wide range of motor capacities, from 200 V/7.5 kW AC to 400 V/15 kW AC for the BM3R type, and from 200 V/15 kW AC to 400 V/30 kW AC for the BM3V type. These MMSs are available in two series, according to their breaking capacity, the standard series rated up to 415 V/25 kA AC, and the high breaking capacity series rated up to 415 V/50 kA AC.

Fig.2 Appearance of MMS



2.3 Internationalization of products

The MMS conforms to the new JIS standards (JIS C 8201-2 and 8201-4-1), IEC standards (IEC 60947-2, 60947-4-1), and is categorized under "Group installation" and "Suitable for motor disconnect" for manual motor controllers according to Part Ⅲ of UL508. Since the MMS can be used as a control panel device in major world regions such as Japan, Europe and North America, it is a global product that can greatly contribute to the standardization of components and enable customers to carry less stock. Moreover, the MMS is also an eco-friendly product that utilizes cadmium-free contacts and recyclable thermoplastic resin.

2.4 Safety considerations

In order to avoid electric accidents such as electric shock, the terminal structure provides IP20-degree of protection to secure the operator's safety when the power is on. This mechanism is a finger protection structure that prevents the finger of an operator or maintenance inspector from directly touching a charged terminal. Moreover, the MMS complies with the isolation requirements prescribed by the IEC standard for MCCBs. This means that a fail-safe structure prevents the handle from being locked in the "off" position or indicating "off" when the main contacts have been welded. These safety mechanisms enable the MMS to be utilized as a "supply disconnected device" according to the international standard for safety of machinery EN 60204-1.

2.5 Operability

MMS has two types of handle structures, a rocker-type and a rotary-type. The rocker-type has different indications for on, off and trip conditions and displays a red color symbol in the off position to convey the meaning of "stop" in accordance with IEC standards. This helps to easily identify the off operation during an emergency stop situation. The rotary-type has a structure that stops the rotary handle in the trip state at an angle midway between the on and off positions. Furthermore, the MMS is equipped with a test trip function similar to the trip button of a circuit breaker, to check the function sequence and contact signal of the MMS and its accessories.

2.6 Accessories

Internal and external accessories are standardized for usage with all MMS models. The accessories have a structure that enables "one-touch" attachment by the customer. Since accessories can easily be installed from the outside without having to remove a screw or

Table 1 MMS specifications

<table>
<tr><td colspan="2">Item \ Frame (A)</td><td colspan="5">32</td><td colspan="5">63</td></tr>
<tr><td colspan="2">Type</td><td colspan="3">BM3RSB</td><td colspan="2">BM3RHB</td><td colspan="5">BM3VHB</td></tr>
<tr><td colspan="2">Number of poles</td><td colspan="3">3</td><td colspan="2">3</td><td colspan="5">3</td></tr>
<tr><td colspan="2">Handle type</td><td colspan="3">Rocker</td><td colspan="2">Rotary</td><td colspan="5">Rotary</td></tr>
<tr><td colspan="2">Rated current (A)</td><td colspan="3">0.16 to 32</td><td colspan="2">0.16 to 32</td><td colspan="5">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="3">AC690/6</td><td colspan="2">AC690/6</td><td colspan="5">AC1,000/8</td></tr>
<tr><td rowspan="2">Utilization category</td><td>IEC60947-2, JIS C 8201-2</td><td colspan="3">Category A</td><td colspan="2">Category A</td><td colspan="5">Category A</td></tr>
<tr><td>IEC60947-4-1, JIS C 8201-4-1</td><td colspan="3">AC-3</td><td colspan="2">AC-3</td><td colspan="5">AC-3</td></tr>
<tr><td colspan="2">Overload protection, Open-phase protection</td><td colspan="3">Provided</td><td colspan="2">Provided</td><td colspan="5">Provided</td></tr>
<tr><td colspan="2">Instantaneous tripping characteristic</td><td colspan="3">13 × I_e max.</td><td colspan="2">13 × I_e max.</td><td colspan="5">13 × I_e max.</td></tr>
<tr><td rowspan="2">Durability</td><td>Mechanical durability</td><td colspan="3">100,000 : I_n = 0.16 to 25 A
70,000 : I_n = 32 A</td><td colspan="2">100,000 : I_n = 0.16 to 25 A
70,000 : I_n = 32 A</td><td colspan="5">50,000</td></tr>
<tr><td>Electrical durability</td><td colspan="3">100,000 : I_n = 0.16 to 25 A
70,000 : I_n = 32 A</td><td colspan="2">100,000 : I_n = 0.16 to 25 A
70,000 : I_n = 32 A</td><td colspan="5">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>1.6 or less</td><td rowspan="5">100</td><td rowspan="5">100</td><td rowspan="3">100</td><td>100</td><td rowspan="8">100</td><td rowspan="8">100</td><td rowspan="4">100</td><td>100</td><td colspan="4" rowspan="3">—</td></tr>
<tr><td>1.6 to 2.5</td><td rowspan="7">3</td><td>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="4">6</td></tr>
<tr><td>6.3 to 10</td><td>15</td><td rowspan="3">100</td><td rowspan="3">50</td><td rowspan="3">100</td><td rowspan="3">50</td><td rowspan="3">6</td></tr>
<tr><td>9 to 13</td><td>50</td><td rowspan="3">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="4">50</td></tr>
<tr><td>14 to 20</td><td rowspan="3">50</td></tr>
<tr><td>19 to 25</td><td rowspan="3">35</td></tr>
<tr><td>24 to 32</td><td rowspan="3">5</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 colspan="2">Dimensions W × H × D (mm)</td><td colspan="4">45 × 90 × 68</td><td colspan="4">45 × 90 × 79</td><td colspan="4">55 × 110 × 96</td></tr>
</table>

cover, the MMS can be quickly reconfigured within the control panel to conform to various specification changes. Moreover, a wide variety of wiring components are provided to reduce the amount of wiring and to reduce the occupied floor space for the customer.

3. Structure and Performance

3.1 Composition

The main functional parts have single-unit structures, and are comprised in the most optimal arrangement. The operating mechanism, which utilizes the same basic parts even for different frames, has been arranged in the center of the main body. Other parts such as the line-side terminal and internal accessory insertion slots are provided on the line side, while the over-current release (OCR) unit and load side terminal are provided on the load side. The arc extinguishing chamber, which contains a moving conductor and arc extinguisher is located under the insulated wall and opposite the operating mechanism. All these units are inserted into the middle case of the MMS, and to miniaturize the 32 A frame, the design features efficient assembly structures having screw-less and snap-fit assembly systems that are applied to the three main parts, the cover, middle case, and case.

3.2 Operating mechanism

Figure 3 shows the internal structure and the combinations for different frames of the operating mechanism. The main parts are miniaturized to unify the mechanism for the 32 A frame (width 45 mm) and 63 A frame (width 55 mm). Furthermore, the linkage mechanisms are all common for each series, which raises the productivity. Consequently, the operating mechanism can easily be produced in the production line by changing the operating handle part to either the rocker or rotary handle type. Moreover, in order to correspond to the different phase pitches for each frame, an operating lever system is utilized to transfer the force of the operating mechanism to the moving conductor. Furthermore, in order to provide a common

Fig.3 Composition of operating mechanism

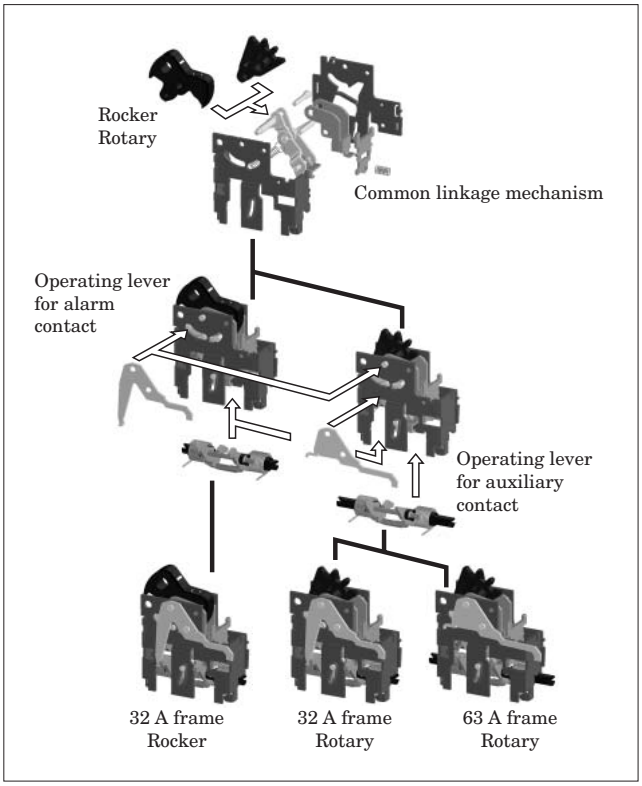


Fig.4 Internal structure of MMS, and motion of breaking arc

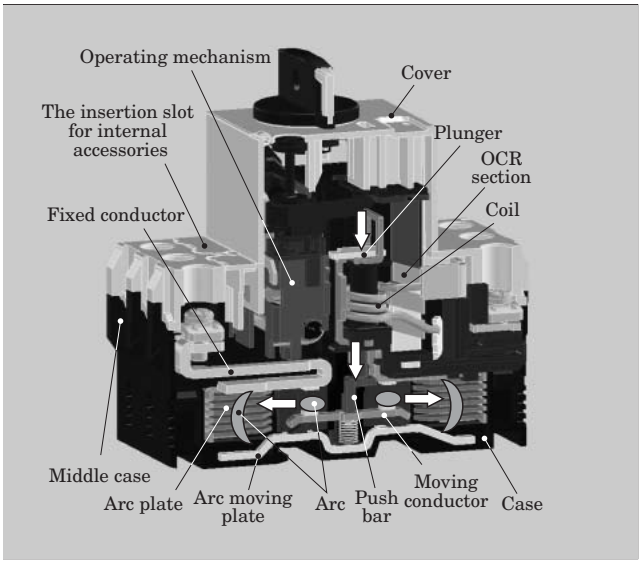
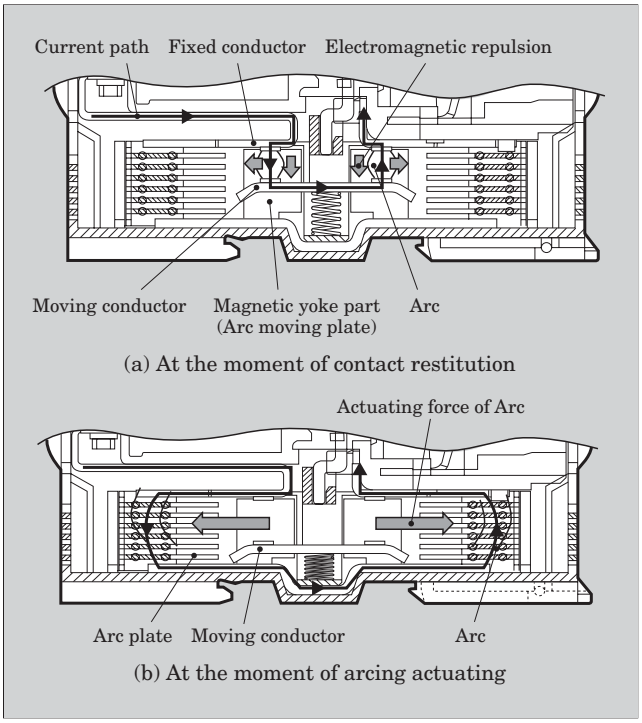


Fig.5 Short circuit breaking principle



method of accessory attachment for the entire MMS series, the accessory output transfer parts have been separated from the common linkage mechanism. The connecting functions mentioned above such as the operating lever and the alarm contact block are also specifically shown in Fig. 3.

3.3 Short-circuit interrupting

The main feature of the short-circuit interrupting part is the 2-point contact opening structure (for each phase), as shown in Fig. 4, to reduce the amount of let-through energy during the breaking of a short-circuit current. When a short-circuit occurs, the contacts will open an instant before the operating mechanism has functioned. This is because the moving conductor will receive a repulsion force from the electromagnetic force generated between the parallel parts of the fixed conductor and will be further accelerated by the magnetic yoke of the arc moving plate. Moreover, directly above the moving conductor, there is a push bar that is pushed by the plunger of the instantaneous tripping coil, to forcibly open the contacts during instantaneous tripping currents and to prevent the contacts from closing during the short-circuit current. Furthermore, as shown in Fig. 5, the arc moving plate will increase the electromagnetic force to drive the arc from the contacts to the arc plate and will extend the arc so that it can be extinguished immediately.

Figures 6 and 7 show a continuous photograph of the arc and an oscillograph of the voltage and current during the breaking of the arc. From Fig. 7, you can see that it only takes 2.5 ms for the 400 V/50 kA arc to be extinguished. The arcing voltage (V_p) is higher than the supply voltage of 600 V and the short-circuit current is limited to only 12 kA. The overall breaking time is only 1/4 of that of an ordinary MCCB (normally 10 ms), which leads to a very low short-circuit let-through I^2t of 1/5 (Fig. 8) that of our conventional MCCB.

IEC60947-4-1 “type 2” is a classification that defines the short-circuit protective co-ordination between MCCB and MC. The regulation stipulates that the combination must remain usable without requiring replacement or sustaining damages except slight weld-

Fig.6 Continuous photograph of Arc

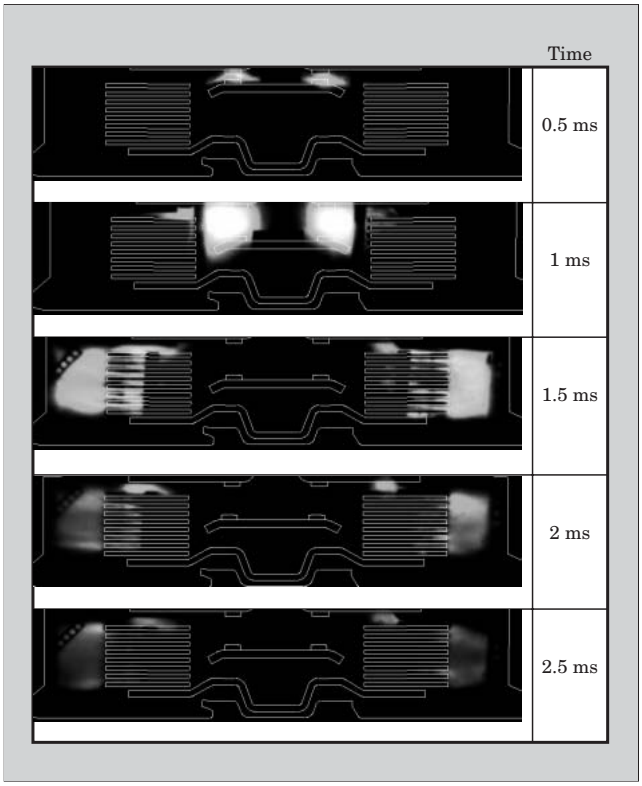
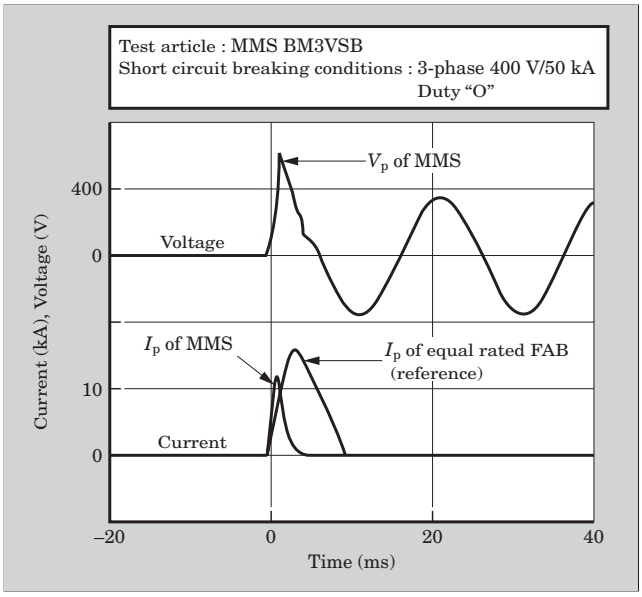


Fig.7 Short circuit breaking oscillogram



ing of the contacts of the MC. In order to prevent the contacts from welding, it is important to reduce the short-circuit let-through I^2t value. For example, in Fig. 9 the contacts of the SC-E series MC will weld when the I^2t value exceeds 90 kA^{2}s. If we look at the MMS, the I^2t of MMS:32 A at 400 V/50 kA is about 80 kA^{2}s, and is less than the value at which the MC contacts will weld. Accordingly, the MMS is a short-circuit protective device that conforms to "type 2" regulations. For details please refer to another article

Fig.8 Short circuit let-through I^2t (Comparison with breaker)

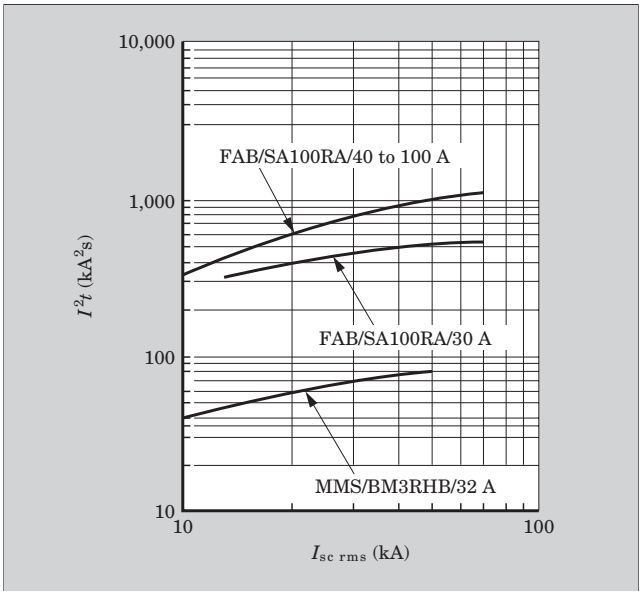
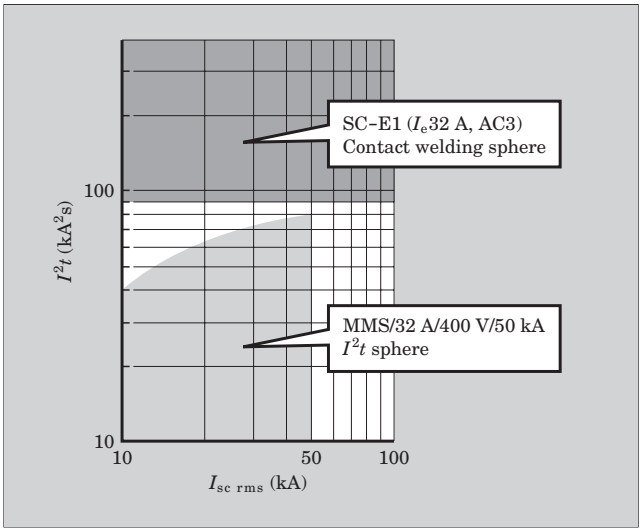


Fig.9 Contact welding sphere for a contactor



"Development of Compact Combination Starter Series" in this journal.

3.4 Screw-less molded case

As prescribed in clause 3.1, the 32A frame is a screw-less assembly. In order to achieve this construction without affecting performance and assembly, stress analyses have been performed for the snap fit parts under the gas pressure exerted during the breaking of a short-circuit and for the parts assembly as shown in Fig. 10. The most optimal conditions, such as material type, thickness and form, were verified to achieve this compact and high current breaking MMS.

3.5 Over-current release (OCR)

The overload and open-phase protection of the MMS conforms to IEC60947-4-1. Table 2 shows the required value for each standard concerning overload

Fig.10 Stress analysis of the snap-fit during short-circuit breaking impact

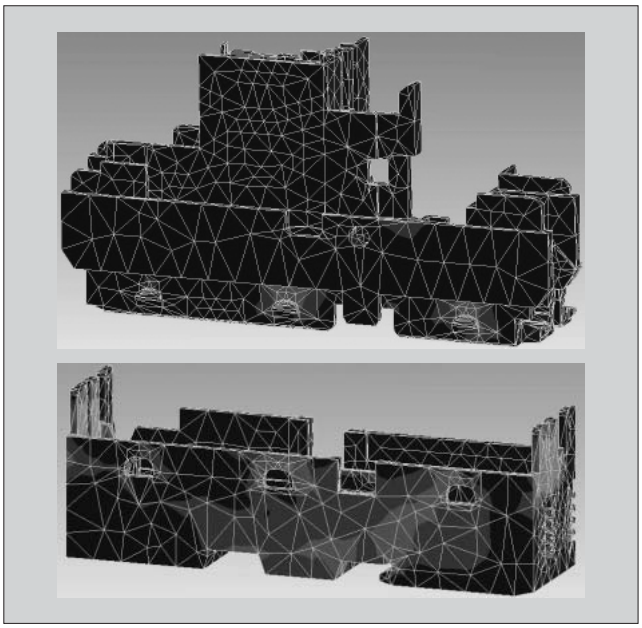


Fig.11 Composition of accessories

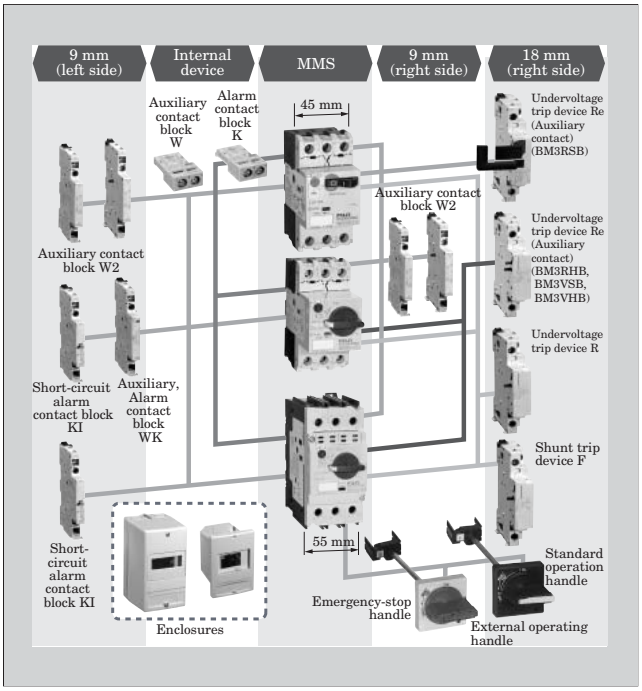


Table 2 Tripping regulations of standards

Classification / Item	Molded case circuit breaker		Thermal overload relay
	JIS C 8370	IEC60947-2	IEC60947-4-1
Overload tripping characteristic	100 % non-trip	105 % non-trip	105 % non-trip
	125 % trip	130 % trip	120 % trip
Open-phase characteristic	Non-required	Non-required	Required

protection. IEC60947-4-1 prescribes the operating current of the OCR to be 120 % of the rated current, in consideration of co-ordination with an MCCB. Furthermore, the regulation requires the normal 3-phase 3-elemental open-phase protection that is common in the European market. By adopting the "differential lever mechanism" of our TOR, the required performance including the open-phase protection of IEC has been attained.

4. Structures and Features of Accessories

4.1 Internal and external accessories

The variety of accessories is shown in Fig. 11. All accessories (internal and external) are easily attachable with "one-touch" and are common to all models. Since internal accessories can be attached inside the MMS, they may be installed even after completion of the internal wiring of the control panel. External accessories, can be mounted on the left or the right sides, or piled up on one side. A maximum of 6 contacts may be mounted, enabling a flexible response to compositional changes in the control panel. The external alarm contact blocks are equipped with a mechanical display that indicates the trip state. These indicating means are colored to enhance the visibility of the status of the MMS.

In addition to the contact blocks mentioned above, we have prepared plastic enclosures for the rocker-type MMS. These enclosures are available in two types of protection grades, IP 41 and IP55, and are utilized according to the environment at the installation site.

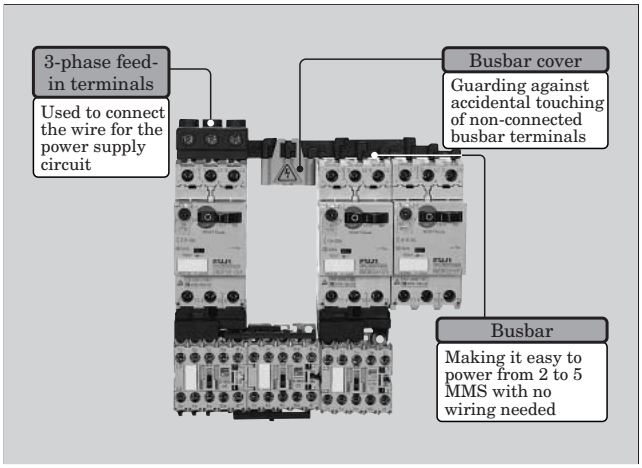
For the rotary type MMS, we have prepared an operation handle, similar to the V-type of Fuji Electric's MCCB, to enable switching of the MMS from the outside door of the control panel.

Based on the above, we can say that the MMS has an abundant array of accessories for both the interior and exterior, which meet various demands of the control panel.

4.2 The busbar system

The busbar system, as shown in Fig. 12, is a convenient wiring method for constructing branch circuits. The system consists of 3-phase feed-in terminal used to connect the power supply wire, a busbar to connect the line side of the MMS to make the circuit parallel and to simplify wiring work, and a busbar cover to prevent contact with charged parts when a portion of the busbar is not connected to the MMS. All these accessories also have a structure that prevents contact to charged terminal parts. Accordingly, the busbar system is a safe and simple way for complicated wiring work in the control panel. Use of the busbar will result in a reduction of the amount of wire used and will simplify the work involved in the installation of the control panel.

Fig.12 Busbar system



5. Conclusion

As has been described, Fuji Electric's MMS is a completely new product for motor control and protection. This new product conforms to Japanese demands for the globalization of control panels, and customer-driven demands for international specifications for control and protective devices. MMSs will bring about an enormous change in the component apparatuses of the conventional electric motor circuit. Because the aim was not only the pursuit of high product performance, but also to provide an abundant variety of accessories to reduce wiring, the MMS is sure to satisfy our customers' demands. Fuji Electric will continue to develop and supply high performance, low-cost and efficient products to provide convenience to our customers.