Contents

1. Introduction

Unlike circuit-breakers conforming to *BS EN 60898* (sometimes referred to as 'miniature circuit-breakers' or 'MCBs'), moulded-case circuit-breakers (MCCBs) are not intended for household and similar installations, but for use, generally in larger installations, by electrically skilled or instructed persons.

MCCBs are widely used as protective and control devices for distribution circuits and, to some extent, final circuits. They are fitted in a variety of distribution gear types, including switchboards, distribution boards, and control panels, as well as individually in separate enclosures.

This topic gives general information about MCCBs as far as protection against indirect contact, protection against overcurrent, and isolation and switching are concerned. Information concerning the tripping characteristics of MCCBs will be found in Topic ***C81-23***.

The information in this topic relates to MCCBs conforming to *BS EN 60947-2, Low-voltage switchgear and controlgear: Circuit-breakers*, which was first issued in 1992. (Formerly, MCCBs were produced to *BS 4752: Part 2, Specification for switchgear and controlgear for voltages up to and including 1000 V a.c. and 1200 V d.c.*, now withdrawn.)

A typical MCCB conforming to *BS EN 60947-2* (shown without an enclosure)

Photograph courtesy of Terasaki Electric Co Ltd

2. General description

'Moulded-case' is one of two design classifications of circuit-breaker given in *BS EN 60947-2* (the other being 'open construction'). The definition of a moulded-case circuit-breaker (MCCB), as given in that standard, is:

> *'A circuit-breaker having a supporting housing of moulded insulating material forming an integral part of the circuit-breaker.'*

MCCBs are normally of the air-break type. They are produced for rated voltages of up to 1 000 V a.c. or 1 500 V d.c., in single-pole and multipole types, with frame sizes ranging between about 50 A and 2 500 A (see item 6 regarding frame size), and with rated ultimate short-circuit breaking capacities (see item 8) up to 50 kA or more at rated voltage.

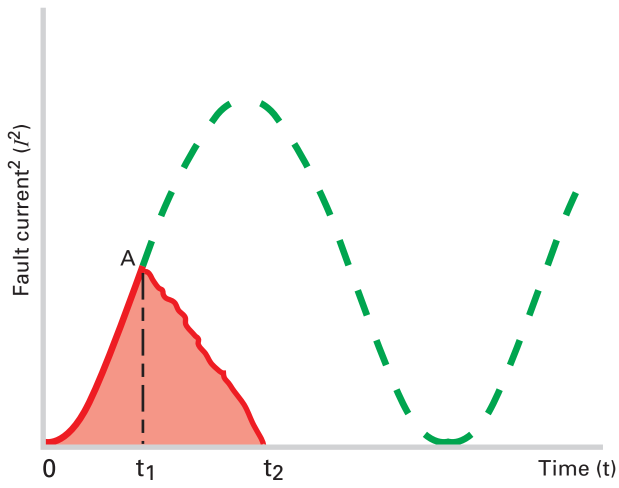
Opening and closing of an MCCB may be manually initiated only (i.e. a non-automatic MCCB). More commonly, however, one or more types of release are incorporated for opening (tripping) an MCCB under various circuit conditions, in addition to manually initiated opening (see item 10). A power closing mechanism is sometimes also provided, in addition to manually initiated closing (see item 11).

Facilities such as auxiliary contacts and residual current protection may be incorporated in an MCCB.

An MCCB may or may not be suitable for providing isolation (see item 13).

Many MCCBs have current limiting capabilities. 'Current limiting' occurs where a protective device, be it a circuit-breaker or a fuse, 'cuts off' or limits fault current, by clearing the fault in less than half a cycle (i.e. less than 10 ms at 50 Hz). The cutting off process limits not only the instantaneous value of current but also the so-called 'energy let-through' (or 'I^2t let-through') of the protective device. The general concept of energy let-through is illustrated in Fig 1, in which the dotted curve represents the waveform of the square of the prospective fault current, the fault having been initiated at time $t = 0$. At time t_1 the circuit-breaker contacts have opened to interrupt the circuit. At time t_2 the arc across the contacts, produced by the circuit interruption, has been extinguished. The total energy let-through (I^2t) is represented by the area 0At_2 (shown shaded).

Illustration of cut-off and energy let-through of a current-limiting overcurrent protective device



Area 0At_2 (shown shaded) represents energy let-through

Fig 1

3. Rated voltages

3.1 Rated operational voltage (U_e)

Circuit-breakers (including MCCBs) conforming to *BS EN 60947-2* may be manufactured in rated operational voltages of up to 1 000 V a.c. or 1 500 V d.c.

The rated operational voltage of an MCCB is given the symbol U_e. For a multipole device, U_e is stated as the voltage between phases; for a single-pole device it is the voltage across the pole (for example, in a single-phase and neutral circuit, the phase to neutral voltage).

3.2 Rated impulse withstand voltage (U_{imp})

The rated impulse withstand voltage (U_{imp}) of an MCCB is relevant to the requirements of Section 443 of *BS 7671* for protection against overvoltages of atmospheric origin (i.e. lightning) and due to switching.

U_{imp} is the peak value of an impulse voltage of prescribed form and polarity which the MCCB can withstand under specified test conditions without failure. The preferred values of U_{imp}, given in *BS EN 60947-2,* are given in the following table.

Preferred values of rated impulse withstand voltage (U_{imp}) kV (peak)
0.33 – 0.5 – 0.8 – 1.5 – 2.5 – 4.0 – 6.0 – 8.0 – 12

For protection of an MCCB according to Section 443 of *BS 7671* to be expected, its rated impulse withstand voltage (U_{imp}) must (as for any other item of equipment) be not less than that stated in Table 44A of *BS 7671*, for the impulse withstand category* of the equipment and the nominal voltage of the installation.

For example, for an MCCB in an installation having a nominal voltage (U_0) of 230 V, located in the main distribution board or further downstream, U_{imp} is required to be not less than 4 kV.

3.3 Rated control supply voltage

Where a control circuit of an MCCB (such as that of a closing device or a shunt release) is to have a rated supply voltage different from that of the main circuit, *BS EN 60947-2* recommends that the manufacturer chooses the value of rated control supply voltage from Table 5 (reproduced in this item). The specifier of an MCCB should select the required value of control circuit voltage from the range provided by the manufacturer.

* The impulse category of the equipment may be determined from Table 44B of *BS 7671*.

Table 5 of *BS EN 60947-2* – Preferred values of the rated control voltage, if different from that of the main circuit	
d.c V	**Single-phase a.c V**
24 – 48 – 110 – 125 – 220 – 250	24 – 48 – 110 – 127 – 220 – 230
NOTE – The manufacturer should be prepared to state the value or values of the current taken by the control circuits at the rated control supply voltage.	

4. Rated frequency

An MCCB may be assigned a number or a range of rated frequencies by its manufacturer or be rated for both a.c and d.c.

5. Rated current (I_n)

The rated current (I_n) of an MCCB is the current the device can carry without interruption for periods of more than eight hours† (weeks, months, even years) when at a reference ambient air temperature specified by the manufacturer and unenclosed‡ in free air.

Also, for an MCCB incorporating inverse time-delay (or 'thermal') overload releases (as most MCCBs do), I_n is normally the current setting of those releases (or the maximum current setting, where the releases are adjustable).

For a four-pole MCCB of rated current exceeding 63 A, the neutral pole is permitted by *BS EN 60947-2* either to have a reduced current rating of not less than half that of the other poles, subject to a minimum of 63 A, or to be fully rated. An MCCB with reduced neutral pole should not be selected unless the electrical installation designer is satisfied that the current rating of the pole is adequate for the requirements of the circuit, taking account of:

- inequality of phase loading,
- inequality of power factor in each phase, and
- harmonic currents in the neutral conductor.

Note – In some circumstances, overcurrent detection must be provided for the neutral conductor of a polyphase circuit (see Regulations 473-03-04 to 473-03-06 of *BS 7671*, with regard to harmonic currents, reduced neutral conductor cross-sectional area and IT systems).

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† The current an MCCB can carry for periods of **less** than eight hours may be higher than I_n. Information should be obtained from the manufacturer.

‡ For an **enclosed** MCCB, the current it can carry for long periods may be **lower** than I_n. Information should be obtained from the manufacturer.

6. Frame size

Every MCCB has a frame size. This designates the device as one of a group of MCCBs whose external physical dimensions are common to a range of current ratings. The frame size is expressed in amperes corresponding to the highest current rating of the group. Within a frame size, the width may vary according to the number of poles.

7. Utilization categories A and B

The utilization category (A or B) of an MCCB relates to discrimination (otherwise known as selectivity) under short-circuit conditions. Discrimination is explained in item 14 of this topic.

7.1 Utilization category A

An MCCB of utilization category A **is not** specifically intended to provide discrimination under short-circuit or earth fault conditions with respect to other fault current protective devices in series on the load side. It does not incorporate an intentional short time delay for that purpose.

7.2 Utilization category B

An MCCB of utilization category B **is** specifically intended to provide discrimination under short-circuit or earth fault conditions with respect to other fault current protective devices in series on the load side. The device incorporates an intentional short time delay for that purpose, which may be adjustable. The delay time is at least 0.05 s, and the preferred values given in *BS EN 60947-2* are 0.05 s, 0.1 s, 0.25 s, 0.5 s and 1 s.

Discrimination will not necessarily be ensured up to the rated ultimate short-circuit breaking capacity (I_{cu}) of the MCCB. For example, this may be the case where an instantaneous release operates the device, such as may result from high fault current. However, discrimination should be assured at least up to the rated short time withstand current (I_{cw}) of the MCCB, assigned by the manufacturer. (I_{cw} is the current that the MCCB in the closed position can carry during a specified short time under prescribed conditions of use or behaviour.)

8. Rated short-circuit breaking capacity

The rated ultimate short-circuit breaking capacity (I_{cu}) of an MCCB is assigned by the manufacturer under specified conditions, and is expressed in kA (rms value for the a.c. component in the case of a.c.).

An MCCB also has a corresponding rated service short-circuit breaking capacity (I_{cs}), expressed in kA. This is either less than or equal to I_{cu}, as explained later in this item.

The distinction between the two rated short-circuit breaking capacities principally relates to the condition of an MCCB after it has been short-circuit type-tested, as follows:

- After type-testing at the rated service short-circuit breaking capacity (I_{cs}), the MCCB is required to be fully serviceable and the operating characteristics must remain unchanged.
- After type-testing at the rated ultimate short-circuit breaking capacity (I_{cu}), the operating characteristics of the MCCB may have changed.

Thus, where an MCCB has cleared a short-circuit fault or earth fault at a prospective fault current in excess of its I_{cs} value, the device may be unfit for continued service. The MCCB or certain of its components should therefore be replaced, as recommended by the manufacturer.

With certain exceptions, I_{cs} is equal to 25%, 50%, 75% or 100% of I_{cu}, as given in Table 1 of *BS EN 60947-2*, which is reproduced as follows for ease of reference.

Table 1 of *BS EN 60947-2* – Standard ratios between I_{cs} and I_{cu}

Utilization category A % of I_{cu}	Utilization category B % of I_{cu}
25	
50	50
75	75
100	100

Note: Where I_{cu} exceeds 200 kA for utilization category A, or 100 kA for utilization category B, the manufacturer may declare a value of I_{cs} of 50 kA.

To avoid the possibility of the operating characteristics of an MCCB being changed in the event of a fault (necessitating replacement of the MCCB or some of its components), the MCCB should be selected such that its I_{cs} value is not less than the prospective short-circuit current or prospective earth fault current (whichever is the larger) at its point of installation.

In any event, as required by Regulation 434-03-01 of *BS 7671*, either condition (i) or conditions (ii) as follows needs to be met:

(i) The rated ultimate short-circuit breaking capacity (I_{cu}) of an MCCB must be not less than the prospective fault current (short-circuit or earth fault) at the point where the device is installed.

(ii) Alternatively, back-up protection (i.e. a current-limiting circuit-breaker or HBC fuses) having the necessary breaking capacity rating must be provided on the supply side of the MCCB. The back-up protection must be so selected that, in the event of the fault current exceeding the I_{cu} value of the MCCB, the back-up protection will interrupt the supply before the energy let-through exceeds that which can be withstood without damage by the MCCB.

Selection of back-up protection devices should be made in consultation with the manufacturer of the MCCB.

9. Rated short-circuit making capacity

The rated short-circuit making capacity (I_{cm}) of an MCCB is assigned by the manufacturer under specified conditions, and is expressed as a peak value of current.

Every MCCB must be selected such that its I_{cm} value is adequate for the maximum peak prospective fault current (short-circuit or earth fault) corresponding to a fault at the load terminals of the MCCB, and having due regard to the power factor of the circuit up to the point of the fault. More detailed information on this is given in item 9.1.

In terms of short-circuit making capacity, the most onerous circuit position for an MCCB or other fault current protective device to be installed is in close proximity to a low impedance inductive source of supply, such as a distribution transformer or alternator. For a fault occurring at the load terminals of the MCCB, the circuit resistance up to the point of fault is negligible compared with the inductive reactance. The resulting prospective fault current waveform can consequently have a decaying d.c component which makes it asymmetrical for the first few cycles after the instant of fault, as shown in Fig 2.

The maximum value of the d.c. component is for a short-circuit or earth fault occurring at the instant when the voltage waveform is at a zero, as illustrated in Fig 2. The maximum peak prospective fault current is then approximately 2.5 times the rms value of the symmetrical prospective fault current.

By comparison, for a fault current in which asymmetry is negligible (e.g. when a fault occurs remote from a transformer), the maximum peak current is equal to $\sqrt{2}$ (1.41) times the rms value of current.

Current and voltage waveforms for a short-circuit or earth fault occurring close to a low impedance inductive source of supply, such as a distribution transformer or alternator (at instant of voltage zero)

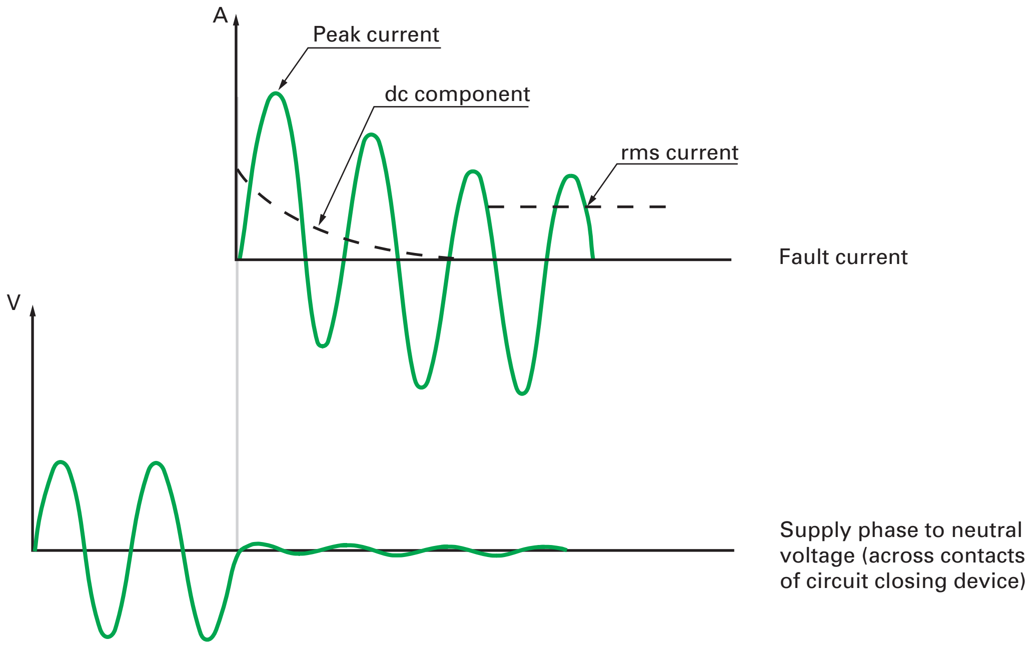

Fig 2

For MCCBs for use in a.c circuits, the I_{cm} value is required by *BS EN 60947-2* to be not less than the I_{cu} value multiplied by a factor n. The factor is given in the right-hand column of Table 2 of *BS EN 60947-2* (reproduced as follows), according to the I_{cu} value (given in the left-hand column of the table).

Table 2 of *BS EN 60947-2* – Ratio n between short-circuit making capacity and short-circuit breaking capacity and related power factor[a] (for a.c. circuit-breakers)		
Short-circuit breaking capacity (I_{cu}) kA rms	**Power factor[a]**	**Minimum value for n (n = short-circuit making capacity (I_{cm}) ÷ short-circuit breaking capacity (I_{cu}))**
$4.5 \le I \le 6$	0.7	1.5
$6 < I \le 10$	0.5	1.7
$10 < I \le 20$	0.3	2.0
$20 < I \le 50$	0.25	2.1
$50 < I$	0.2	2.2

a. The power factor referred to is that of the circuit up to the point of fault, **not** the load power factor.

For example, according to Table 2, for an MCCB having an I_{cu} value of 10 kA (that is, 6 kA < I ≤ 10 kA), the minimum value of n is 1.7. Therefore the MCCB has to be manufactured to have a rated short-circuit making capacity (I_{cm}) of not less than 17 kA (given by 10 kA multiplied by 1.7). This assumes that the circuit power factor to the point of fault is not less than 0.5.

For MCCBs for use in d.c circuits, *BS EN 60947-2* requires the I_{cm} value to be not less than the I_{cu} value.

9.1 Ensuring that the rated short-circuit making capacity (I_{cm}) is adequate

As already stated, every MCCB must be selected such that its rated short-circuit making capacity (I_{cm}) is adequate for the maximum peak prospective fault current (short-circuit or earth fault) corresponding to a fault at the load terminals of the MCCB, having due regard to power factor.

Fortunately, the above requirement is normally met automatically (although still has to be considered) where the rated ultimate short-circuit breaking capacity (I_{cu}) of the MCCB is not less than the prospective short-circuit current or prospective earth fault current at the point where the device is installed. This is because, as explained in item 9, the I_{cm} value of an MCCB is related to its I_{cu} value, as given in Table 2 of *BS EN 60947-2*.

The situation is different, however, where the I_{cu} value of an MCCB is **less** than the prospective short-circuit current or prospective earth fault current at the point where the device is installed (such that suitable back-up protection has to be provided on the supply side of the MCCB – see item 8). In such circumstances, it **cannot** be assumed that the I_{cm} value of the MCCB will be adequate. Nevertheless, the requirement remains that the MCCB must be selected such that its I_{cm} value is adequate.

10. Means of opening

The majority of MCCBs can be opened automatically (tripped) by one or more types of release in addition to being manually openable. The most common types of release are as follows:

- **Overcurrent release**. This term includes overload releases (such as the thermal type) and short-circuit releases (such as the magnetic type), both of which are included in most MCCBs. The characteristics of MCCB overcurrent releases are covered in Topic ***C81-23***. The characteristics must be selected and, where applicable, set to meet the requirements of *BS 7671*, including those for protection against indirect contact where such protection is provided by the overcurrent release.
- **Shunt release**. This is a release energized by a source of voltage which may be independent of the voltage of the main circuit. A shunt release may be used to trip the MCCB in response to, for example, the operation of an emergency push button or a separate current monitoring device. A shunt release for opening is required to cause

tripping when the supply voltage of the shunt release measured during the tripping operation remains between 70 % and 110 % of the rated control supply voltage and, if a.c., at the rated frequency.

- **Undervoltage release**. This is required to operate to open the MCCB, with or without time delay, when the voltage falls to between 70 % and 35 % of the rated voltage of the release. The release prevents closing of the MCCB when the voltage is below 35 % of the rated value, and will permit closing when the voltage is equal to or above 85 % of the rated value.
- **No-voltage release**. This is a special form of undervoltage release in which the operating voltage is between 35 % and 10 % of the rated supply voltage.

Residual current protection may also be incorporated in an MCCB to cause automatic opening. The characteristics of such protection must be selected and, where applicable, set to suit the requirements of *BS 7671* for protection against electric shock and/or risk of fire, as applicable (see Topic ***R101-29*** for further information).

MCCBs which can be opened automatically are trip-free and generally have their energy for the tripping operation stored prior to the completion of the closing operation. 'Trip-free' means that, if the tripping operation is initiated during the closing operation, the moving contacts return to and remain in the open position, even if the closing command is maintained.

11. Means of closing

A power closing mechanism, including intermediate control relays where necessary, is sometimes provided for an MCCB, so that it can be closed from a remote position or by means of a control system. This is in addition to provision for manually initiated closing.

Closing mechanisms, whether manual or powered, are normally of the independent type. In such mechanisms, stored energy is released to close the MCCB in one continuous operation, such that the speed and force of the operation are independent of the action of the operator.

12. I^2t (Joule integral, or 'energy let-through')

Information on the I^2t of an MCCB is given in Topic ***C81-23***. The I^2t of an MCCB may be used in connection with the adiabatic equation of Regulations 434-03-03 and 543-01-03 of *BS 7671* for the protection against thermal effects of live conductors and protective conductors, respectively, of a circuit supplied through the MCCB. The I^2t may also be used to determine whether discrimination exists between the MCCB and a fuse on its supply side (item 14 gives further information).

13. Suitability for isolation

Most, but not all, MCCBs conforming *BS EN 60947-2* are suitable as devices for isolation. Those which are suitable for isolation are marked with the symbol shown in Fig 3.

Symbol denoting that distance between the contacts (when open) is sufficient for a device for isolation

Fig 3

The symbol in Fig 3 denotes that the following three requirements are met:

(i) The isolating distance specified in *BS EN 60947-2* is obtained between the contacts when in the 'open' position (Regulation 537-02-02 of *BS 7671* refers). Note: This distance is not necessarily obtained in the 'tripped' position.

(ii) A reliable means of indication of the position of the main contacts is provided (Regulation 537-02-04 of *BS 7671* refers), such as the position of the actuator or a separate mechanical indicator.

(iii) When means are provided by the manufacturer to lock the MCCB in the 'open' position, locking in that position is possible only when the main contacts are in the open position.

14. Discrimination

Discrimination (otherwise known as selectivity) is the co-ordination of fault current protective devices such that a fault occurring in an installation is cleared only by the first protective device upstream of the fault.

As discussed in item 7, MCCBs of utilization category B have an intentional time delay to allow them to discriminate under short-circuit conditions with respect to another short-circuit protective device in series on the load side.

Also, as mentioned in item 12, the I^2t of an MCCB may be used to determine whether discrimination exists between the MCCB and a fuse on its supply side. In order for an MCCB to discriminate with a fuse on its supply side, the I^2t let-through of the MCCB under both short-circuit and earth fault conditions has to be less than the pre-arcing I^2t of the fuse.

15. Back-up protection

Back-up protection is the provision of a current-limiting protective device to permit the use, on its load side, of a protective device whose rated ultimate short-circuit breaking capacity is lower than the prospective fault current at the point at which it is installed.

Back-up protection will be required for an MCCB if the rated ultimate short-circuit breaking capacity (I_{cu}) of the MCCB is less than the prospective short-circuit current or prospective earth fault current at the point at which it is installed (item 8 refers).

An MCCB having current-limiting capabilities may also be used to provide back-up protection for a downstream protective device, providing the characteristics of the two devices are appropriately co-ordinated (Regulation 434-03-01 of *BS 7671* refers). As already stated in item 2, many MCCBs conforming to *BS EN 60947-2* have current limiting capabilities.

Topics referred to in this text:

C81-5 CIRCUIT-BREAKERS: Ambient temperature and grouping, implications of
C81-23 CIRCUIT-BREAKERS: Moulded-case (MCCB), tripping characteristics
R101-29 RESIDUAL CURRENT DEVICES (RCD): Regulatory requirements

Topics not referred to in this text, which are related and may be of interest:

C81-13 CIRCUIT-BREAKERS: For household and similar installations (*BS EN 60898*)
C81-19 CIRCUIT-BREAKERS: Miniature, conforming to *BS 3871*
C81-25 CIRCUIT-BREAKERS: Selection, to suit load characteristics
I17-5 INDIRECT CONTACT, PROTECTION AGAINST: Earth fault loop impedance, maximum values of

***BS 7671* (Requirements for electrical installations)**

Some of the most important requirements are found in:

Switchgear (For protection, isolation and switching) Chapter 53