



UNIVERSITAT  
POLITÈCNICA  
DE VALÈNCIA

# The Miniature Circuit Breaker (MCB)

|                       |  |
|-----------------------|--|
| <b>Surnames, name</b> | Antonino Daviu, Jose Alfonso (joanda@die.upv.es) |
| <b>Department</b>     | Departamento de Ingeniería Eléctrica             |
| <b>Centre</b>         | Universitat Politècnica de València              |



## 1 Summary

The aim of this paper is to present a basic introduction to the operation of the Miniature Circuit Breaker (MCB). This is a protection and switching element often used in electrical industrial installations. The paper intends to explain, in a very simple manner, the following aspects related to the MCB:

- Constituting elements and operation principles.
- Basic specifications.
- Characteristic curves.
- Types of MCB.
- Advantages/disadvantages.

This work is devoted to students or professionals that are involved in electrical installations design and, more specifically, in the basic switchgear used in those installations.

## 2 Introduction

A Miniature Circuit Breaker (MCB) is a small circuit breaker that is used for residential and industrial applications (tertiary sector) [1].

As every circuit breaker, it has both a *switching function* (it allows the connection/disconnection of the circuit where it is installed) but also a *protection function* (it must interrupt the circuit in the event of overcurrents (overloads and short-circuits) so that further damage in the installation is prevented). This second function is the most important.

Some basic features of the MCBs are the following [1]:

- Modular design.
- Simple use and maintenance.
- Standardized time-current curves.
- They have a fixed thermal and a fixed magnetic trip setting.
- Usually, they do not have secondary trip units (though some manufacturers enable their optional inclusion).

Specific information on MCB can be found in the norm UNE EN 60898.

## 3 Objectives

The following learning objectives are pursued in this paper:

- To understand the operation of the basic elements of a MCB.
- To be able to list and describe the basic terms defining a MCB and enabling its specification.
- To know the characteristic curves of a MCB.

- To be able to describe and compare the different types of MCB.
- To know the main advantages and drawbacks of the MCB.

## 4 Development

### 4.1 Basic components and operation principle

Figure 1 shows the basic components of a MCB from a specific manufacturer (ABB).

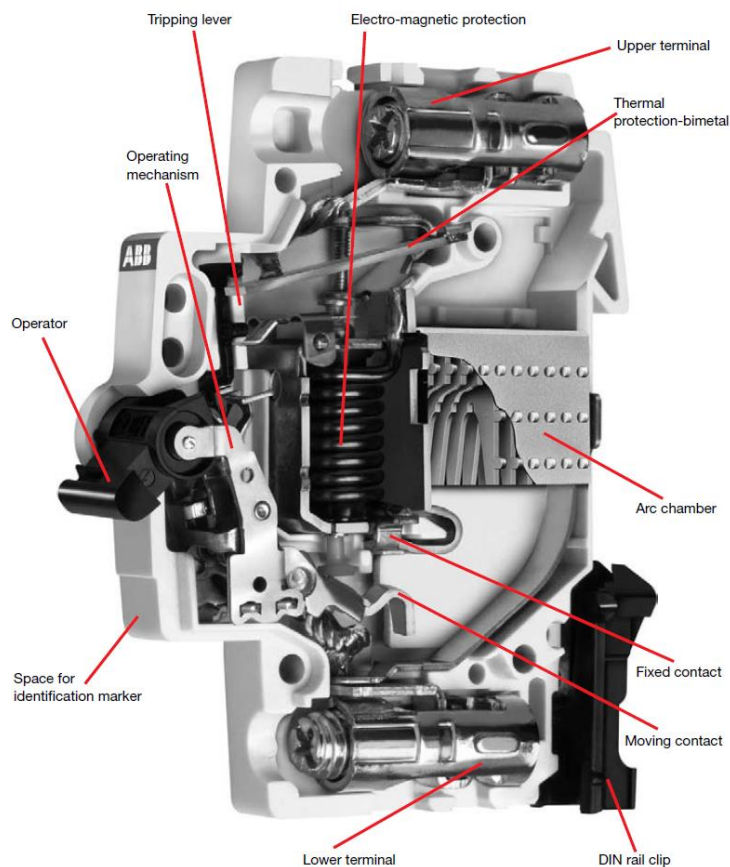


Figure 1. Basic components of a MCB (Source: [4])

A basic description of the different components is provided next [4]:

- **Thermal/magnetic trip units:** typically, MCBs use an electromechanical (Thermal /Magnetic) trip unit to open the breaker contacts during an overcurrent event (Figure 2). The thermal trip unit is temperature sensitive and the magnetic trip unit is current sensitive. Both units act independently and mechanically with the breaker's trip mechanism to open the breaker's contacts.



- *Thermal trip unit:* The thermal trip unit protects against overload currents. The thermal unit is based on a bimetal element located behind the circuit breaker trip bar and is part of the breaker's current carrying path. When there is an overload, the increased current flow heats the bimetal causing it to bend. As the bimetal bends it pulls the trip bar which opens the breaker's contacts. The time required for the bimetal to bend and trip the breaker varies inversely with the current. Because of this, the tripping time becomes quicker as current increases in magnitude. Overload protection is applicable to any installation, conductor, or component which can be subjected to low-magnitude but long-time over-currents. Low-magnitude, long-time over-currents can be dangerous because they reduce the life of the electrical installation, conductor, and components and if left unchecked could result in fire.
- *Magnetic trip unit:* The Magnetic trip unit protects against a short circuit. The magnetic trip unit is comprised of an electromagnet and an armature. When there is a short circuit, a high magnitude of current passes through the coils creating a magnetic field that attracts the movable armature towards the fixed armature. The hammer trip is pushed against the movable contact and the contacts are opened.

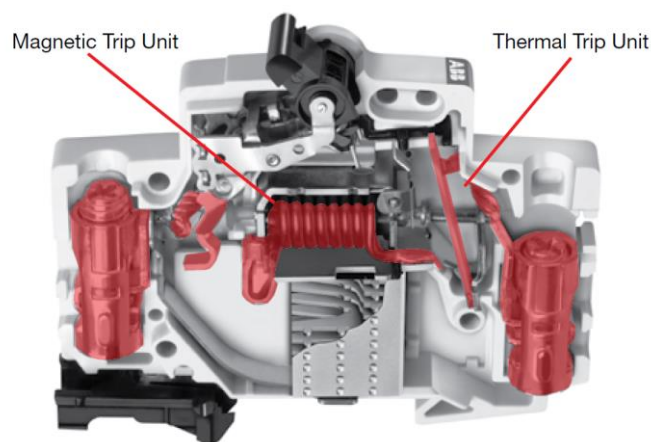


Figure 2. Trip units in a MCB (Source: [4])

- **Arc chamber:** the arc chamber, by the action of the arc runners and arc chute, limits and dissipate the arc energy during the interruption of an overload or short circuit event.
- **Operating mechanism:** it is the set of springs, levers and other internal elements that enable the opening of the contacts as well as to perform their independent closing [1]. It is a "trip-free" mechanism. This means that the tripping action works independently of the handle position for safety purposes.



## 4.2 Basic specifications

Some basic characteristics defining a MCB are explained next:

- **Ampere Rating or Rated Current ( $I_n$ ):** maximum uninterrupted current withstand at a given ambient temperature without abnormal temperature rise. Typical values of  $I_n$  for MCB are from 6 A to 125 A.
- **Conventional non-tripping current ( $I_{nt}=1,13 I_n$ ):** a specified value of current which the device can carry for a specified time (conventional time) without operating.
- **Conventional tripping current ( $I_t=1,45 I_n$ ):** a specified value of current which causes the device to operate within a specified time (conventional time).
- **Conventional time ( $t_c$ ):** it is equal to 1 hour if  $I_n \leq 63A$  and 2 hours if  $I_n > 63A$ .
- **Coordination:** The use of overcurrent protective devices that will isolate only that portion of an electrical system that has been overloaded or faulted.
- **Number of poles:** number of phases that it can interrupt at the same time.
- **Rated operating voltage ( $U_n$ ):** is the maximum voltage under which the supplier guarantees the normal operation of the device under continuous duty. Typically, MCB can be used up to 400 V in AC and they can also be used in D.C.
- **Rated frequency ( $f$ ):** is the supply frequency under which the supplier guarantees the normal operation of the device under continuous duty. Typical values: 50, 60 Hz.
- **Rated Breaking capacity or Rated Interrupting capacity ( $I_c$ ):** The maximum level of fault current that the MCB has been tested to safely interrupt under certain operating conditions specified by the regulation. Typical values of  $I_c$  for MCB are between 1,5 kA and 25 kA.
  - **Rated ultimate short-circuit breaking capacity ( $I_{cu}$ ):**  $I_{cu}$  (kA rms) is the maximum short-circuit current value that the MCB can break. It is verified according to a sequence of standardized tests. After this sequence, the MCB must not be dangerous. This characteristic is defined for a specific voltage rating [5].
  - **Rated service breaking capacity ( $I_{cs}$ ):**  $I_{cs}$  (kA rms) is given by the manufacturer and is expressed as a % of  $I_{cu}$ . This performance is very important as it gives the ability of a circuit-breaker to provide totally normal operation once it has broken this short-circuit current three times. The higher  $I_{cs}$ , the more effective the circuit-breaker [5].
- **Rated short-circuit making capacity ( $I_{cm}$ ):**  $I_{cm}$  (peak kA) is the maximum value of the asymmetrical short-circuit current that the circuit-breaker can make and break. For a circuit-breaker, the stress to be managed is greatest on closing on a short-circuit.

## 4.3 Characteristic curves

### 4.3.1 Time-current characteristic curves

Figure 3 shows the typical time-current curves for different families of MCB.

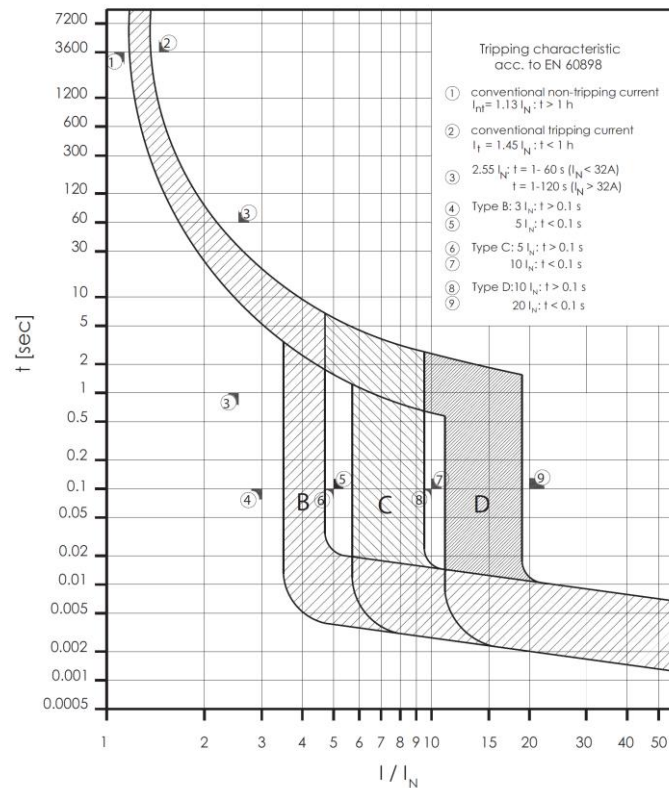


Figure 3. Time-current characteristic curves of MCB (source: [6])

The time-current curves have two main parts:

- 1) **Thermal Trip Unit (region one):** The first sloping region of the breaker curve is a graphical representation of the tripping characteristics of the thermal trip unit. This portion of the curve is sloped due to the nature of the thermal trip unit. The trip unit bends to trip the breaker's trip bar in conjunction with a rise in amperage (temperature) over time. As the current on the circuit increases, the temperature rises, the faster the thermal element will trip.
- 2) **Magnetic Trip Unit (region two):** It is the response time of the magnetic trip which differentiates each characteristic and for which an identifying letter is assigned. The IEC 898 standard only specifically covers the B, C and D characteristics. The rest can vary from brand to brand, but essentially follow a uniform convention:
  - **B curve magnetic trip point:** 3 to 5 times the rated current, typically used for computers and electronic equipment with very low inrush loads (PLC wiring) [6].
  - **C curve magnetic trip point:** 5 to 10 times the rated current. C-curve devices are suitable for applications where medium levels of inrush current are expected. Applications include small transformers, lighting, pilot devices, control circuits and coils. C-curve devices provide a medium magnetic trip point [6].



- **D curve magnetic trip point:** 10 to 20 times the rated current. D-curve devices are suitable for applications where high levels of inrush current are expected. The high magnetic trip point prevents nuisance tripping in high inductive applications such as motors, transformers and power supplies [6].

### 4.3.2. Thermal stress limitation curves

These curves provide the limited thermal stress (in  $A^2s$ ) as a function of the rms value of the assumed short-circuit current (see Figure 4).

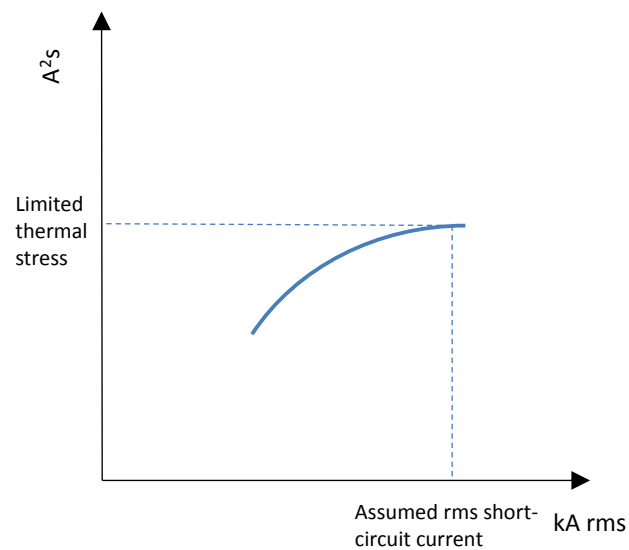


Figure 4. Thermal stress limitation curve



### C curve m.c.b.

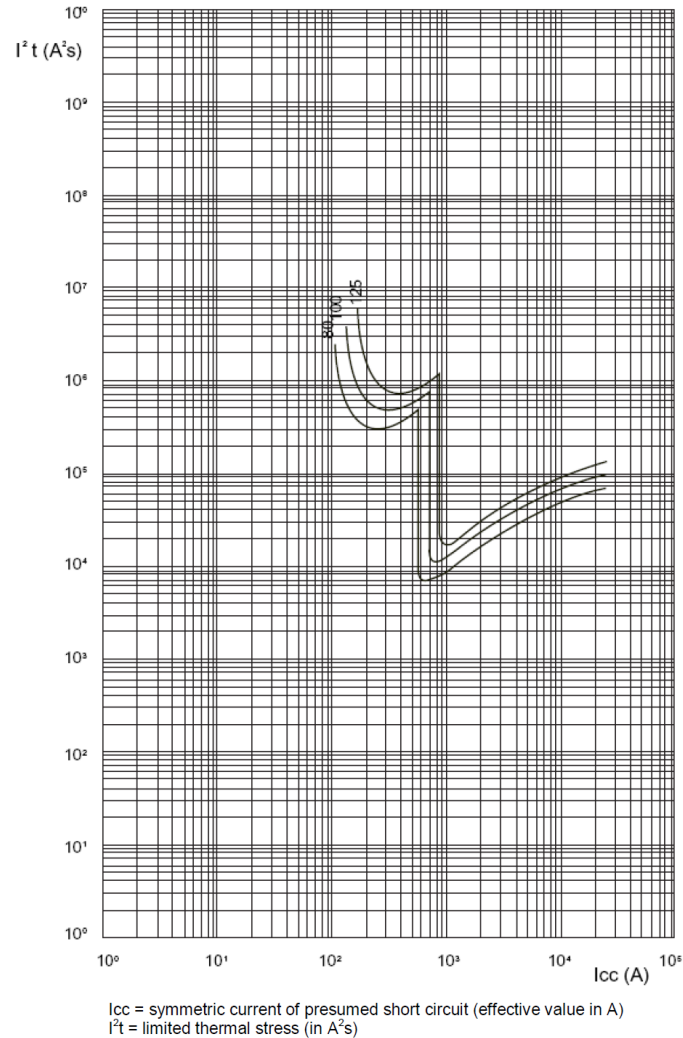


Figure 5. Thermal stress limitation curves. Type C MCBs from 80A to 125 A, (double pole, 230 V/50 Hz) (Source: [7])

### 4.3.3. Current limiting curves

When a short-circuit condition occurs, the “ideal” current limiting circuit breaker opens before the current waveform can reach its full potential magnitude which occurs at  $\frac{1}{4}$  cycle (5 ms for a grid frequency of 50 Hz). Current limiting breakers can typically interrupt a fault in about  $\frac{1}{2}$  cycle and limit the amount of current that can reach a circuit. Limiting the available current on the circuit provides additional protection against network, breaker, or bus damage and prevents the tripping of upstream breakers (selective coordination).



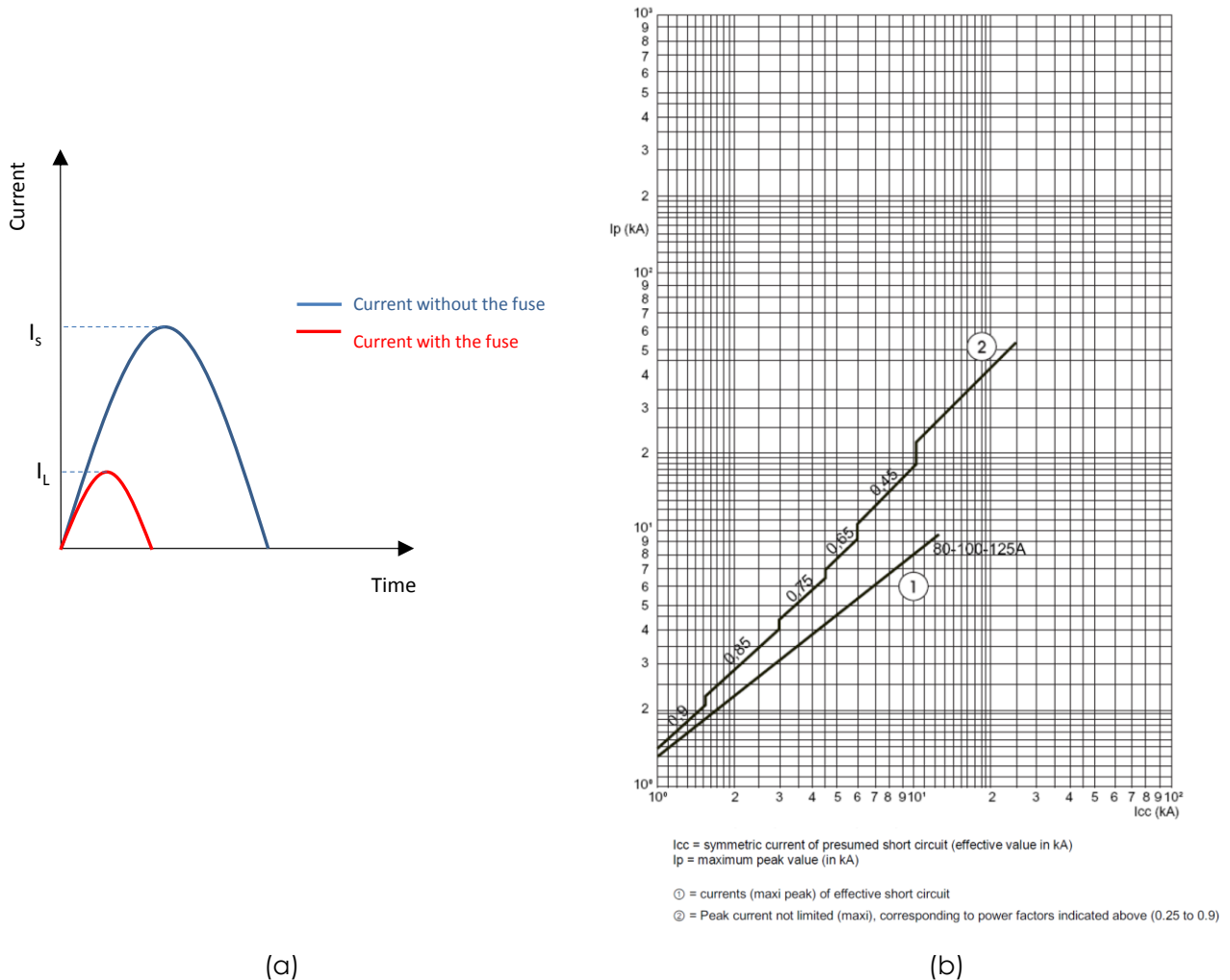


Figure 6. (a) Short-circuit current waveforms with and without limiting MCB, (b) Current-limitation for type B and C MCBs from 80' A to 125 A (Source: [7])

## 4.4 Advantages/Drawbacks

### Advantages:

- Simple maintenance.
- Modular constitution.
- Easy to be used by non-expert people.

### Drawbacks:

- Limited features (in comparison with normal Circuit Breakers).



## 5 Conclusions

This work constitutes a brief introduction to one of the most common elements in Low Voltage electric switchgear: the Miniature Circuit Breaker (MCB). The work explains the basic elements of a MCB and its operation principles. Moreover, the basic quantities used for the specification of a MCB are enumerated. The work describes the main characteristic curves of a MCB, namely, the time-current characteristic, thermal stress limitation curves and the current-limiting curves (for MCB operating under this principle). The MCB typology is also analyzed in the paper. Finally, the main advantages and drawbacks of a MCB are synthesized.

## 6 References

### 6.1 Textbooks:

- [1] Roger, J.; Riera, M.; Roldán, C.: "Tecnología Eléctrica", Ed. Síntesis, 2010, Cap. 8.
- [2] Roger, J.; Riera, M.; Roldán, C.; Antonino, J.A.: "Exercises and questions". Editorial UPV. 2010.
- [3] Reglamento Electrotécnico de B.T. (R.B.T.2002) (MIE-BT).

### 6.2 Technical catalogs:

- [4] ABB, Application guide - Miniature circuit breakers  
[http://www05.abb.com/global/scot/scot209.nsf/veritydisplay/8a6611845c5254a685257584006c57ae/\\$file/1sxu400130c0201.pdf](http://www05.abb.com/global/scot/scot209.nsf/veritydisplay/8a6611845c5254a685257584006c57ae/$file/1sxu400130c0201.pdf)
- [5] MERLIN GERIN, Circuit breaker application guide.
- [6] Automationdirect technical catalog, Circuit protection,  
<http://www.automationdirect.com/static/catalog/31-circuit-breaker-fuse-disconnect-motor-control-disconnect.pdf>
- [7] LEGRAND. Technical sheet F00133EN/02. France.  
<http://nederland.ecataleg.be/FT/F00133EN-02.pdf>