SIEMENS

SENTRON

Miniature Circuit Breakers

Technology primer

Answers for infrastructure and cities.

Preface

Protection, switching, measuring or monitoring –
Siemens low-voltage circuit protection technology offers a wide range of devices for all areas of electric installations. They put you in control of all electric circuits - in industry, in non-residential buildings and in residential buildings.

Particular attention must be paid to the selection and installation of relevant protective devices - in this case: miniature circuit breakers (MCBs).

This primer was created to help you select the MCBs you need to create a perfectly adapted and protected electrical system.

In addition to general information on MCBs, it contains important notes on installation and implementation. You are therefore sure of always selecting the right device.

Your Team for
Low-Voltage Circuit Protection from Siemens

Contents

Product Overview

5SL Miniature Circuit Breaker
for Standard Applications in the Residential and Non-Residential Sector

For all applications up to 63 A
with tripping characteristics B, C, and D
with a 6/10 kA switching capacity
in accordance with IEC/EN 60898-1 (VDE 0641-11)

5SY Miniature Circuit Breaker
For Industrial Applications with Increased Short Circuit Vulnerability

For all applications up to 63 A with a switching capacity up to 15 kA (depending on model) in accordance with IEC/EN 60898-1 (VDE 0641-11) for universal current applications in accordance with IEC/EN 60898-2 (VDE 0641-12), and for applications up to 63 A with a switching capacity up to 25 kA in accordance with IEC/EN 60947-2 (VDE 0660-101)

5SP Miniature Circuit Breaker
For High-Voltage Applications

For applications between 80 and 125 A with a switching capacity of 10 kA in accordance with IEC/EN 60898-1 (VDE 0641 Part 11)

5SJ6...-.KS Miniature Circuit Breakers with Plug-In Terminal
Plug-In Terminal for Easy Installation

For wall socket and lighting power circuits in building installations up to 20 A with a switching capacity of 6 kA in accordance with IEC/EN 60898-1 (VDE 0641-11)

The manual plug-in terminal, into which conductors are inserted from the front, saves a great deal of installation time.

5SY6 0 Miniature Circuit Breaker 1+N in 1 MW
Low Space Requirements

For applications up to 40 A with tripping characteristics B, C, and a switching capacity up to 6 kA, where a switchable neutral conductor is required.

The MCB 1+N in versions N-left or N-right and compact design (width 1 MW = 18 mm) saves space on the distribution board.

5SJ4 ...-.HG.. Miniature Circuit Breaker in Accordance with UL 489 and IEC 60941-2
Certified for Global Use

MCB suitable for use as a branch circuit protector in accordance with UL 489 with characteristics B, C and D from 0.3 to 63 A, and suitable also for use as a circuit breaker in accordance with IEC/EN 60947-2 (VDE 0660-101)

5SP3 Main Miniature Circuit Breakers
The Perfect Solution for the Meter Panel or as Group Switch for Improved Selectivity

Voltage-independent, selective main miniature circuit breaker (MMCB) in accordance with DIN VDE 0641-21,
suitable for use in the pre-metering section or in system protection for improved selective device behavior with downstream MCBs.

1.0 Introduction

Miniature circuit breakers (MCBs) protect cables and lines against the effects of overload currents and short circuits. They provide reliable protection for buildings, systems, and in particular people.

Overview of core aspects for using MCBs from Siemens:

For system operations:

- Safe operability, particularly for non-professionals
- No maintenance
- High reliability
- High switching frequencies
- Single-pole or multi-pole (all-pole) protection and switching, incl. N-conductors
- Optional for selected types: Remote switching

In case of a fault:

- Automatic disconnection in case of overload or short circuit
- Safe disconnection independent of the handle position (trip-free)
- Safe (fast) current-limiting disconnection of short circuits, meaning:
  - Best selectivity and/or backup protection prerequisites
  - Greatest possible damage limitation (short circuit cannot develop its full power)

Economical and cost-effective – in terms of procurement and also during later operation:

- Low power loss
- Can be reactivated after overcurrent tripping
- Simple and cost-effective installation and integration:
  - Modular device design
  - Compact unit
  - Standardized DIN installation dimensions (modular installation device)
  - Easy integration with other protective devices
  - Fits any commercially available small distribution board
  - Optional integration with system components

For electric system planners:

- Simplified device and cable dimensioning in comparison with other LV protection equipment
- Planning reliability

2.0 Basics

2.1 Short Circuit Currents: Possible Consequences and Corrective Measures

Electric equipment, and specifically cables and conductors must – in accordance with the requirements outlined in international standards and installation requirements – be effectively protected against overload and short circuits by implementing relevant (protective) measures.
Preferably, such protection is achieved with the use of suitable switching/protective devices, which will automatically disconnect defective circuits or system sections from mains power in case of a fault.

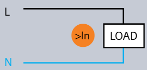
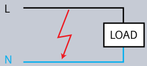
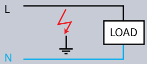
A key consideration here is the prevention or limitation of negative concomitant phenomena associated with electric overloads.

Another – in case of concurrent switching actions or the use of a defective consumer – is personal protection against electric shock during direct or indirect contact with live system components.

The service life of equipment may be durably compromised, or entire production facilities may shut down after a short circuit, where system faults of this type are not detected in time or deactivation occurs too late.

Short circuits in electric systems can occur suddenly, e.g. as the result of an operational fault during switching, an installation/commissioning fault or force majeure (e.g. lightning strike, earthquake, flooding, etc.). These short circuits conduct extremely high voltages, which are discharged explosively.
Where they occur, their destructive potential is enormous.

Far more frequent, but no less dangerous is the gradual build-up of cable overloads or short circuits, e.g. due to aging of the cable insulation, plug connections, or cable breaks.

Fault Incident		Protection acc. to IEC Standard	Protection acc. to UL-Standard
Serial		MCB	MCB
Parallel Phase – Neutral/ Phase – Phase		MCB AFDD	MCB AFCI
Parallel Phase-Protective Conductor		MCB RCD AFDD	MCB RCD AFCI

AFDD	Arc Fault Detection Device
MCB	Miniature Circuit Breaker
RCD	Residual Current Protective Device

AFCI	Combined MCB/AFDD
MCBI	Miniature Circuit Breaker
RCD	Residual Current Protective Device

These potential hazards exist frequently in the residential and non-residential sector, where periodic monitoring and testing of installed electrical systems and the devices used in the installation (e.g. household equipment) is not a requirement (e-check).

Here, MCBs fulfill the primary purpose of ensuring uninterrupted system monitoring and safety, specifically for installed cables and conductors.

MCBs contribute significantly to protecting people from the potential hazards of an electric shock while handling electrified system components or using electrical (household) equipment.

MCBs can perform this function particularly efficiently in combination with RCCBs or when used as RCBO combination devices or combined with an AFDD.

In addition, Siemens MCBs also fulfill the increased demands in industrial power supply systems, e.g. automotive or semi-conductor production facilities or data and computer centers.

In comparison with residential and non-residential applications, these demands are often significantly more extensive and complex in their network topology and subsequent system operations. In these cases the access points for power supply and switching operations are handled primarily by certified electricians.

Aside from the obvious safety functions, supply and system reliability are a top priority for these types of facilities. The objective is to prevent power outages and production downtime with device combinations selected specifically to complement each other in order to eliminate economic losses.

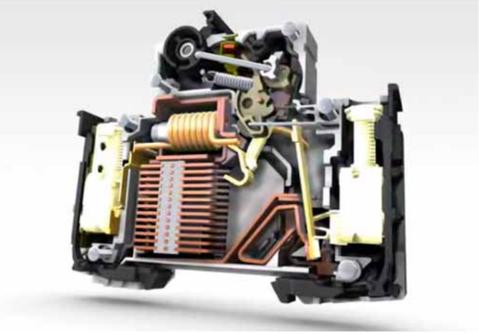
2.2 Structure and Basic Function of an MCB

MCBs are an electro-mechanical combination of an overload protection device and a short circuit protection device.

The overload protection consists of a thermal release (delayed tripping), and short circuit protection is ensured by a magnetic tripping device (instantaneous tripping).

Image 7: Structure of an MCB

The actuator (handle) is located at the top with the breaker mechanism.
The trigger coil for short circuit disconnection is located at the center, alongside the contact system. Below that, the extinguishing device extinguishes any arcing generated during a short circuit. The thermal bimetal (release) is located to the right, which trips in case of overcurrents.



The current path leads from the terminal via the triggering coil (magnetic trigger) to the contact system, and onwards via the thermal bimetal to the second terminal.

Manual triggering or a tripping due to overload or short circuit will open the switching contacts. Arcing generated by high currents will move across the guide plate and the core into the arcing chamber. Inside the chamber, the arcing separates into several individual smaller arcs, and a high arcing voltage is generated.

Once the arcing has been extinguished, the current flow is interrupted and the (faulty) circuit is disconnected. The entire process lasts only a few milliseconds.

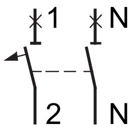
MCBs are also equipped with a so-called trip-free mechanism. The mechanism ensures that the switching contacts will be set to OFF when tripped (overload, short circuit, coupling location for system components) even if the handle is locked in ON position
(e.g. while sealed or during a switching operation).

MCBs allow the switching and protection of single-pole or multi-pole circuits or consumers.

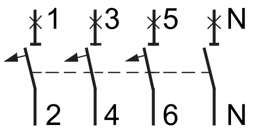
IEC/EN 60898-1 (VDE 0641-11) differentiates between 1, 1+N, 2, 3, 3+N, and 4-pole switching devices.

Siemens MCB versions with 1, 2, 3 or 4 poles are equipped with independent overcurrent and short circuit detectors on all poles.

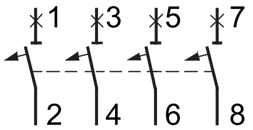
In the versions 1+N and 3+N, the neutral conductor is only switched
(no independent overcurrent or short circuit detector).



Switching symbol for version 1+N, neutral conductor will (also) be switched



Switching symbol for version 3+N, neutral conductor will (also) be switched

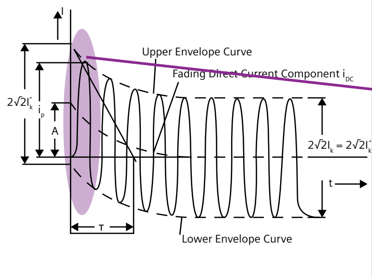


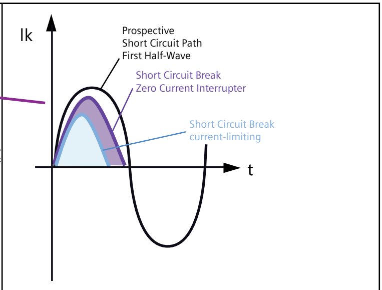
Switching symbol 4-pole version, independent overcurrent/short circuit detector on all poles

Individual poles are mechanically coupled to each other in multi-pole MCBs.
As the result, disconnection across all poles is ensured if an acute overload occurs in only one phase conductor, or if the tripping pulse is fed in via a connected system component.

The function and action of previous MCB generations was based on the so-called zero current interrupter. This is characterized by interruption of the current during the zero crossing of the first half-wave in a short circuit. The achievable switching capacity of these devices is limited by their size.

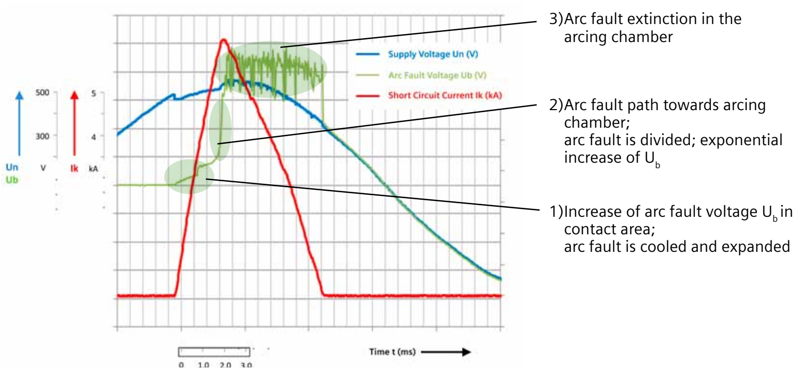
The function and action of modern MCB generations is based on the so-called current limiter. This is characterized by interruption of the current before the zero crossing of the first half-wave is reached in a short circuit, while the amplitude of the current peak value is limited. This energy limitation allows higher switching capacity values for the same sizes.





Visualization of prospective short circuit paths remote from generator terminals in accordance with IEC 60909 (DIN VDE 0102)	Visualization of short circuit path/ disconnection at first half wave

Oscillogram Visualization: Sample Path Current-limiting Short Circuit Disconnection by MCB



2.3 Tecéical Specifications – Selecting a Suitable MCB

From the technical specifications of an MCB it is possible to deduce which – if any – circuit breaker types are basically suitable for the planned protection and switching task.

1. Terminal Block (Cable/Busbar)
Depending on the MCB model, various types of cables/lines (single/multi-core, with/without core end sleeve) can be connected in combination with busbars.

2. MCB Type Label
Contains:

Manufacturer brand name	Siemens
MCB Order No.	5SL6116-7
Indication of tripping characteristic/rated current	C16
Usability in an electric supply network:	230/400 V AC

3. Quality Label Approval **VDE**

The product has been tested by an independent testing body and the quality label has been approved. (Additional assurance for the end user.)

4. Switching Capacity of the Device in Ampere/Energy Limitation Class

in accordance with IEC/EN 60898-1 (VDE 0641-11) 6000
3

The MCB shown has a switching capacity of Icn 6 kA, and satisfies the requirements of Energy Limitation Class 3.
In accordance with the Technical Connection Requirements (TAB) for German network operators, only MCBs with a rated switching capacity of min. 6 kA and energy limitation class 3 are permitted for use in residential constructions.

5. Handle for Manual Actuation of the MCB

With integrated switch position indicator (I-ON/0-OFF):

- red identification for switch position ON
- green identification for switch position OFF

The main contact position may deviate from the handle position.
Main contacts may e.g. be in OFF position, although the handle is in ON position (trip-free).
Some MCBs have an additional mechanical display for the actual position of the main contacts.

6. Switching Symbol

Identification for easy recognition of the correct terminal type.
Shown here MCB terminals in single-pole version
The N conductor terminal is identified with the symbol 'N'.

In multi-pole devices, a horizontal dashed line over the switching contact symbols identifies the mechanical coupling of the switching poles.

Switching symbols used in accordance with DIN/EN 60617-7

7. Coupling Location for System Components

The coupling location for additional system components on the MCB ensures indirect tripping of the MCB by forwarding the triggering command to the MCB contact system or by transmitting the tripping information to the system component(s).

8. Manual Slide Operation for Quick Fitting System

Easy manual actuation of the MCB for toolless removal from the standard mounting rail.

MCBs are generally type-tested and approved in accordance with IEC/EN 60898-1. Where the MCB is labeled for additional product standards (e.g. IEC/EN 60947-2), type testing in accordance with IEC/EN 60898-1 (VDE 0641-11) will include testing for the additional product standard.
The device labeling will offer relevant details.

Figure 11a: MCB labeling example, approved in accordance with IEC/EN 60898-1, additional labeling Icu in accordance with IEC/EN 60947-2

Possible areas of application:

a) Residential and non-residential, end user-friendly, max. switching capacity 10 kA

b) Industrial facilities, accessibility restricted to certified electricians, max. breaking capacity 20 kA

Figure 11b: MCB labeling example, approved in accordance with IEC/EN 60898-1

Possible areas of application:

a) Residential and non-residential, suitability for operation by ordinary persons, max. switching capacity 6 kA

b) Industrial facilities, accessibility/use restricted to certified electricians, max. breaking capacity 6 kA

Possible Decision-Making and Selection Criteria from the Viewpoint of the Customer Reflected in Associated Device Standards

Product Standard	Use Case/Area of Application
IEC/EN 60898-1 (VDE 0641-11)	Area of Application: Residential, non-residential and industrial taking into account that the protective switching devices are also operated by individuals without special technical knowledge in the power supply field. The standard refers to suitability for operation by ordinary persons.
IEC/EN 60898-2 (VDE 0641-12)	
IEC/EN 60947-2 (VDE 0660-101)	Area of Application: Industrial facilities with mostly higher requirements for the rated ultimate short circuit breaking capacity of the MCB. Access and operation by ordinary persons must be precluded (access only for electrotechnical personnel).
UL489	Area of Application: Protection of main circuits as a branch circuit protection device
UL 1077	Area of Application: Protection of control circuits as a supplementary protection device
DIN VDE 0641-21	Device standard for use as MMCB in Germany

MCBs must satisfy additional requirements for specific areas of application (e.g. railway, ship building) or for country-specific certifications (e.g. CCC label in China).

A current overview of valid certifications for MCBs can be found here:
www.siemens.com/lowvoltage/technical-support
or
www.siemens.de/lowvoltage/technical-support

Additional National MCB Requirements (Country-Specific Installation Conventions)

Additional country-specific requirements for the installation of MCBs may have to be taken into consideration in addition to international standards.

In Central and Northern Europe, for example, the infeed point is at the bottom of the unit, in Southern Europe it is preferred at the top.

In regions where MCBs with switching N conductors are a requirement, a specific position of the N conductor terminal (either on the left or right) may be mandatory.

There may also be regional specifications regarding the placement of device combinations within a distribution system or requirements for the characteristics of a supply line to an MCB (version with cable/conductor, busbar or wire strand).

Siemens MCBs can be universally implemented within the scope of applicable regulations, as all regional installation conventions are fulfilled.

2.4 MCB Characteristic Curves

Characteristic curves describe the operational and tripping behavior of MCBs in the event of an overload or short circuit. They represent an important element for the configuration and dimensioning of devices.

As part of assessing a device in terms of selectivity and backup protection, the probability of a short circuit (power) limitation during a short circuit disconnection can be deduced from the so-called cut-off characteristics.

The various characteristic curve types and their significance are described in detail in the following.

Application examples can be found in chapter 4.0 "Device Dimensioning".

2.4.1 I-t Tripping Characteristics

The expected tripping behavior, and in particular the expected break time of the desired MCB can be determined from its I-t tripping characteristic.

In line with the two existing tripping systems (overload release = bimetal, short circuit release = short circuit coil), the path of the I-t tripping characteristic consists of two characteristic curve sections:

- Overload section (thermal)
- Short circuit release section (magnetic)

The overload section of the curve describes the tripping behavior of the bimetal, while the short circuit release section of the characteristic curve describes the release behavior of the short circuit coil.

Depending on the equipment used and the operational behavior of the connected consumers, the short circuit release of the MCB must trip at various speeds to ensure safe and efficient short circuit protection.
These are called the tripping characteristics.

The following tripping characteristics for MCBs are standardized internationally in accordance with IEC/EN 60898-1 (VDE 0641-11):

- Tripping Characteristic B
- Tripping Characteristic C
- Tripping Characteristic D

Other, manufacturer-specific tripping characteristics may apply for specific use cases.

All MCBs approved in accordance with IEC/EN 60898-1 (VDE 0641-11) must satisfy specific prescribed test currents during device testing.

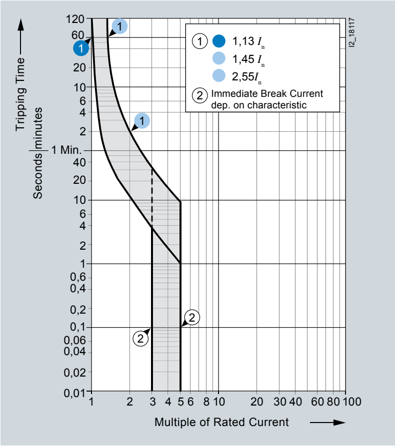


Figure 12: Schematic representation of a I-t- tripping characteristic incl. test currents based on the example of tripping characteristic B, reference calibration temperature +30 °C

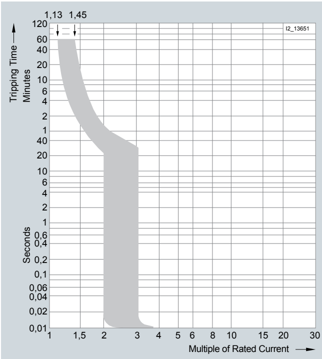
Standard requirements for test currents:

1.13 x In	defined non-tripping current I_{nt} specified limits for non-tripping times: t <= 1 h (for In <= 63 A) the MCB must not trip within these times	t <= 2 h (for In > 63 A)
1.45 x In	defined tripping current I_t specified limit for tripping times: t <= 1 h (for In <= 63 A) the MCB must trip within these times	t <= 2 h (for In > 63 A)
2.55 x In	defined tripping current I_t specified time frame for tripping: 1s < t < 60 s (for In <= 32 A) the MCB must trip within these times	1 s < t < 120 s (for In > 32 A)

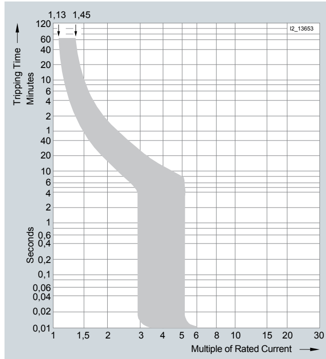
Standard ranges for immediate tripping in accordance with IEC/EN 60898-1, Table 2:

Tripping characteristic B	3-5 x In
Tripping characteristic C	5-10 x In
Tripping characteristic D	10-20 x In

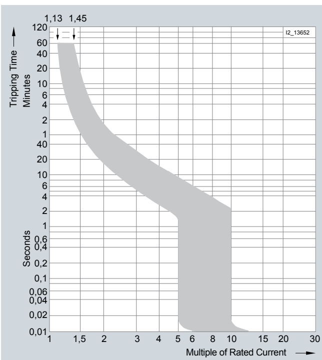
Overview of Tripping Characteristic Curves and Characteristics for Siemens MCBs



Tripping characteristic A
For semiconductor protection and protection of measuring circuits with transformers

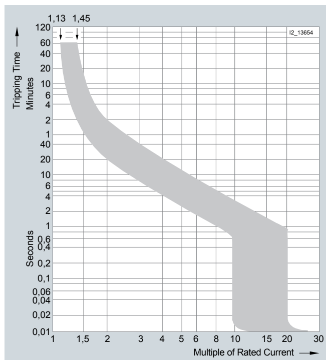


Tripping characteristic B
For universal use in socket outlet and lighting circuits



Tripping characteristic C

Ideally suitable for use in lamp and motor circuits with higher starting currents



Tripping characteristic D
For circuits with high pulse-generating equipment, e.g. transformers or solenoid valves

2.4.2 Cut-Off Characteristics

Cut-off characteristics can be used to verify compliance with design requirements in the course of device dimensioning.
Cut-off characteristics describe the behavior of the MCB during a short circuit, and they indicate current and power limitations.

MCB (Ic) Cut-Off Characteristic

The value of the peak cut-off current Ic for a specified prospective short circuit current Ip can be read from the cut-off characteristic under define framework conditions.

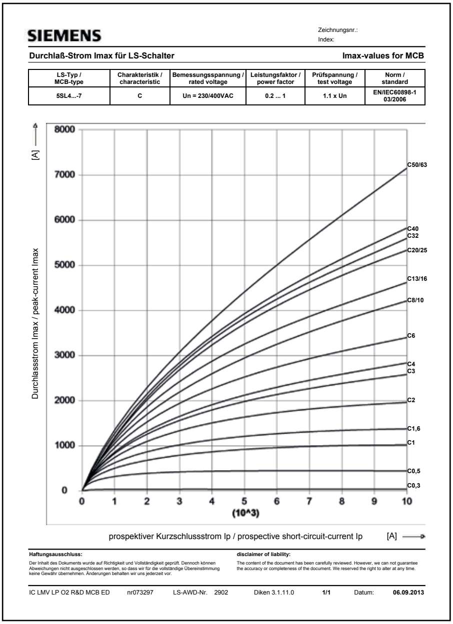


Figure 13: Cut-Off Characteristic Ic
Displayed as a family of characteristics
Valid for MCBs of series
5SL4, C characteristic

MCB (I^2t) Cut-Off Characteristic

The I^2t cut-off characteristic describes the cut-off integral (cut-off power) of the MCB up to the time of tripping during a given prospective short circuit current Ip.

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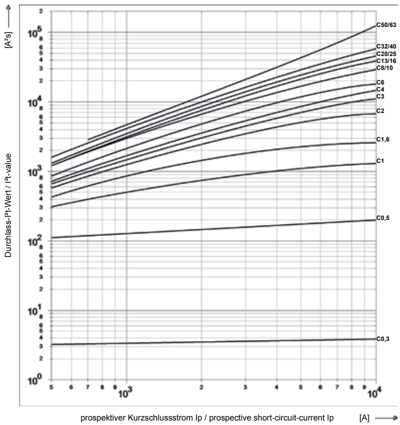
Zeichnungsnr.:
Index:

Durchlaß-I²t-Werte für LS-Schalter — **I²t-values for MCB**

LS-Typ / MCB-type	Charakteristik / characteristic	Bemessungsspannung / rated voltage	Leistungsfaktor / power factor	Prüfspannung / test voltage	Norm / standard
5SL4...-7	C	Un = 230/400VAC	0.2 ... 1	1.1 x Un	EN/IEC60898-1 03/2006



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disclaimer of liability:
The content of the document has been carefully reviewed. However, we can not guarantee the accuracy or completeness of the document. We reserved the right to alter at any time.

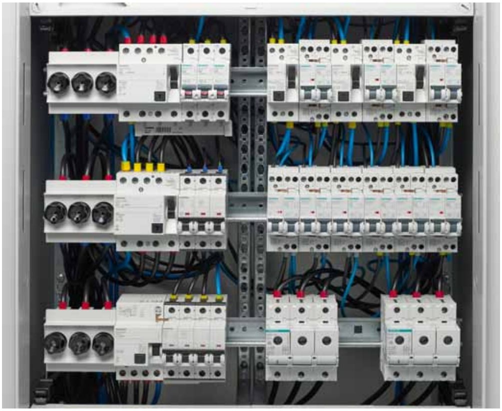
IC LMV LP O2 R&D MCB ED nr073297 LS-AWD-Nr. 2901 Diken 3.1.11.0 **1/1** Datum: **06.09.2013**

Figure 14: Cut-Off Characteristic I²t
Displayed as a family of characteristics
Valid for MCBs of series
5SL4, C characteristic

3.0 Areas of Application - MCB Use Options

Virtually no other switching protection device is as versatile as an MCB.
Here are some practical examples to demonstrate the point:

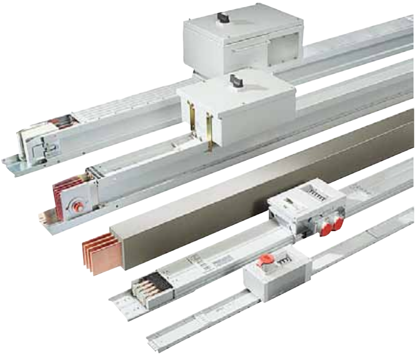
...for safeguarding branch circuits in a residential building with MCBs, RCBOs, and AFDDs for enhanced fire protection



...for safeguarding power circuits in story or floor distribution boards of a skyscraper or office complex

...for safeguarding control circuits in a MotorControlCenter (MCC)

... within a busbar outlet box of a production facility as an integrated system and personal safety device for outlet cables and consumers



...as protection for the charging cable within an eCar charging station

...as protection for auxiliary circuits of a wind farm

...as protection for PV system components

...as protection for electric circuits in the distributor box at a construction site

...equipped with a remotely controlled operating mechanism and an auxiliary switch as an integral part of the safety system in a central control center, or for building automation with knx eib components

...as protection for the control units in an automation system

3.1 Special Use Cases

3.1.1 UL Tecéology

UL standards are applied in North America, as well as in several other countries. This is of particular importance for European exporters of electric switchgear assemblies and equipment for machines, as their products will only be accepted if they meet the relevant UL standards.

UL 489-approved MCBs can be used as all-round solutions (branch protector in accordance with UL 508A) for protection tasks in distribution feeders, switchgear cubicles and control systems. They are also approved in particular for circuit protection in HVAC systems (heating, ventilation, air-conditioning). The special busbar system in accordance with UL 489 allows for quick and easy component installation.

Various protection tasks are thus covered for residential and non-residential construction use, as well as for industry use within the scope of 120/240 V, 240 V, and 480Y/277 V supply networks.
The tripping characteristics B, C, and D in accordance with IEC/EN 60898-1 (DIN VDE 0641-11) have been retained for the most part, and thermal tripping has been adapted to UL489/IEC 60947-2.

The terminals comply with „Field wiring“ class. That means that the devices can be installed not only in ex works distribution boards and control cabinets, but also on-site in a cutomer's system.

Single-, two- and three-phase busbars in three lengths with 6, 12 or 18 pins can be used as accessories for all device series. Infeed is via terminals, which are available in two versions: direct infeed at the busbar or on the MCB.

Touch protection caps can be used to cover any unassigned pins.
Other system components are provided for use as additional accessories.

MCBs in accordance with UL 1077 offer supplementary protection in control circuits or for direct pick-off downstream of the branch circuit protective device in networks up to 480Y/277 V.
These must not be used as branch circuit protective devices.

3.1.2 Extreme Ambient Temperatures

Siemens MCBs are designed for use in temperatures between -25 and +55 °C.
Some special models can used in the temperature range between -40 °C and +70 °C.

Correction factors must be taken into consideration, as MCBs are not temperature-compensated.

For details on correction factors, see the MCB Configuration Manual at:

www.siemens.com/lowvoltage/technical-support

3.1.3 Railway Applications

Special MCBs can be used in fixed railway systems and in rolling material to protect system components from overcurrent and short circuit. These devices offer an application temperature range of -40 °C to +70 °C, and are suitable for networks up to 230/400 V AC or 220/440 V DC. They also satisfy the requirements for fire behavior in accordance with DIN EN 45545-2, and the increased requirements for vibration and impact behavior in accordance with IEC/EN 61373 (VDE 0115-106) in railway applications.

3.1.4 Ship Building

Installations on board a ship are also subject to increased requirements. Different voltages and frequencies behavior play an important role as do special requirements for vibration and impact. Select Siemens MCBs were tested and approved for this particular area of application.

3.1.5 Power Plants

Power plant operations can be disrupted by shock waves generated by earthquakes. This area of application is therefore particularly safety-relevant. Here too, a special product portfolio has been developed to satisfy the requirements in power plants.

3.1.6 Selective MMCBs

Selective main miniature circuit breakers (MMCBs) are used as safety switches in meter panels or as group switches for improved selectivity in residential, non-residential, and industry applications.

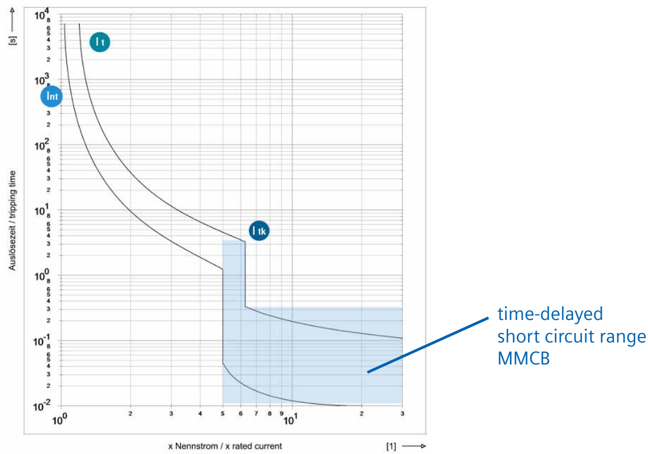
Standard:	DIN VDE 0641-21
Designation according to standard:	Main miniature circuit breaker
Subcategory:	MMCB (Main miniature circuit breaker without control circuit)
Rated nominal current I_n:	16 A to 100 A
Tripping characteristic:	E
Rated switching capacity I_{cn}:	25 kA
Rated voltage Un:	230/400 V, 50/60 Hz
Rated insulation voltage Ui:	690 V

The functionality and method of operation of the MMCB are adapted to the special implementation requirements of upstream cascade switching between LV HRC melting fuses and downstream MCBs.

In these special device combinations, the MMCB really proves its extraordinary capabilities:

- Higher current limitation (system protection)
- Full selectivity in comparison with MCBs up to Icn 6/10 kA
- At the same time: Backup protection for downstream MCBs
- Easy reactivation
- User-friendliness
- Isolating properties (enabling of the distribution board for maintenance tasks)

The tripping characteristic E of this device is visualized as follows:



Visualization of the I-t tripping characteristic 5SP3

Standard values for tripping characteristic E
in accordance with VDE 0641 Part 21

I_{nt} (specified non-tripping current)	1.05 x In
Limitations of the tripping/non-tripping time	t >= 2 h
I_t (specified tripping time)	1.2 x In
Limitations of the tripping/non-tripping time	t >= 2 h
I_{tv} (delayed tripping current)	5 x In
Limitations of the tripping/non-tripping time	0.05 s < t < 15 s
I_{tk} (short-term delayed tripping current)	6.25 x In
Limitations of the tripping/non-tripping time	0.01 s <= t <= 0.3 s

3.2 System Components

Depending on the MCB version, the following additional components can be retrofitted or combined with the MCB:

- Arc fault detection device (AFDD)
- RC unit
- Auxiliary current switch (AS)
- Fault signal contact (FC)
- Shunt trip (ST)
- Undervoltage release (UR)
- Remotely controlled mechanism (RC)
- Busbar system with pin terminals

MCBs are easily combined with other components from the modular system to form a compact unit.

3.2.1 Arc Fault Detection Device (AFDD)

5SM6 AFD units can be fitted to an MCB to detect arcing faults caused by insulation faults or loose contacts between live conductors or to a protective conductor.
The 5SM6 AFD unit (AFD = Arc Fault Detection) can be combined on-site by the user with an MCB or an RCBO, and offers effective protection against electric fires.

The technical primer “5SM6 AFD units” offers in-depth information on this new protective device

Two versions are available:

a) 5SM6011-1 AFD
designed for retrofitting to an 5SY60 MCB (1+N, modular width = 1)
with rated currents to max. 16 A.

Space-saving overall width of the device combination: 2 MW

5SM6011-1 AFD with and without retrofitted 5SY60 MCB

b) 5SM6021-1 AFD
designed for retrofitting to a series 5SY MCB (1+N, modular width = 1) or a series 5SU1 RCBO (1+N, modular width = 2), each with a rated current to max. 16 A.

Complete protection against overload/short circuit/electric shock (personal protection) and fire protection

5SM6021-1 AFD unit with and without a mounted 5SU1 RCBO

3.2.2 RCBO

RCBOs are a combination of an RCCB and an MCB in a compact, space-saving 2 MW design for overload/short circuit and personal protection (protection against electric shock).

The combination RCBO with MCB of type A, $I\Delta n$ 30 mA also satisfies the additional protection requirements in accordance with IEC 60364-4-41 and DIN VDE 0100-410.

RCBO Device Combination, 5SU1

The technical primer "Residual Current Protective Devices" offers in-depth information on RCBOs.

3.2.3 RC Unit

RC units are suitable for installation on MCBs in accordance with IEC/DIN EN 61009-1 (VDE 0664-20):2000-09, Appendix G. The customer can combine these RC units with a suitable MCB for the same functionality as ex-works RCBOs.

The technical primer "Residual Current Protective Devices" offers in-depth information on RCBOs.

3.2.4 Auxiliary Current Switch (AS)

The auxiliary current switch (AS) signals the contact position of the MCB regardless of whether it was tripped by hand or by a fault (overload/short circuit).
An additional version for the switching of small currents and voltages for e.g. programmable logic controllers (PLCs) is also available.

The version 'auxiliary switch with test button' allows testing of the control circuit without any need for switching the MCB.

MCB with AS shown on the right

3.2.5 Fault Signal Contact (FC)

An FC signals the automatic disconnection of the MCB in case of a fault (overload/short circuit/trip arm tripping).
If the FC is activated, the contact position will not change when the MCB is actuated manually. An FC with a TEST and RESET button allows testing of the control circuit without any need for tripping the MCB. The red RESET button integrated in the handle indicates in addition the automatic disconnection of the MCB.
The signal can be acknowledged manually using the RESET button.

FC with TEST and RESET button

Three states of the MCB can be displayed directly or remotely with an AS/FC device combination:

- ON
- OFF
- OFF, tripped

3.2.6 Shunt Trip (ST)

STs are used for the remote tripping of MCBs. This may be a useful feature where the system is not directly accessible. The (re)activation of the MCB is effected directly on the unit or via a remotely controlled operating mechanism.

5ST3 Shunt Trip

3.2.7 Undervoltage Release (UR)

URs are used for tripping the MCB and with it the relevant circuit when a preset voltage is undercut.
Furthermore, certain URs can be integrated in EMERGENCY STOP loops to guarantee tripping of the MCB in case of emergency.

5ST3 Undervoltage Release

3.2.8 Remote-Controlled Operating Mechanism (RC)

Ideal use cases for remote-controlled operating mechanisms are large or sporadically manned work areas, such as water-treatment plants or radio stations, as well as automated systems for energy and operational management. The use of a remote-controlled operating mechanism allows the user direct and immediate access to the system even in remote or hard-to-access locations. Fast reconnection to the power supply following a fault saves considerable time and costs.

The remote-controlled operating mechanism has a mechanical function selector switch. In the “OFF” position, the remote-controlled mechanism is disabled and can be locked. “RC OFF” prevents remote switching and allows only manual actuation of the RCCB. As the result, unauthorized remote switching during servicing jobs can be prevented. In the "RC ON" position, “Remote ON” and “Remote OFF” switching as well as local operation are available. If a fault trip occurs, the connected handles on the RCCB and the remote-controlled operating mechanism are set to the "OFF" position. The circuit breaker is not allowed to be reactivated until all hazards have been eliminated.

Remote Operation for Switchgear and Control Systems

- **Reactivation after tripping with remote reset option**
- **Manual on-site actuation**
- **can be combined with MCB and additional components**

3.2.9 Busbar System with Pin Terminals

There are basically two different systems for connecting MCBs to each other and to other components.

The 5ST3 7 system can be configured to any length and matched perfectly to any given device combination. Altenatively there is the highly variable 5ST3 6.. system. Both systems are characterized by fixed-length prefabricated busbar sections that can be overlapped for any combination. Time consuming additional tasks such as like cutting, cross-cutting, deburring and cleaning of cut surfaces, plus the mounting of end caps are no longer required. Any unassigned pins on the busbars are covered for touch protection.

UL-approved busbars for the use of MCBs in accordance with UL 1077 or UL 489 are available for system implementations in North America in compliance with UL 508A.

5ST3 Busbar

4.0 Dimensioning – Selection and Testing of the MCB for Applicable Electro-Tecéical Requirements at the Installation Location

Dimensioning is the task of configuring all the equipment and components which are to be used within the electric network. They include e.g. MCBs and associated power lines (cable connections or busbar terminals).

The dimensioning process begins as soon as the planning and concept phases for the electric supply system are complete.

The aim of dimensioning is to create a technically viable combination of switching/protective devices for each individual circuit.

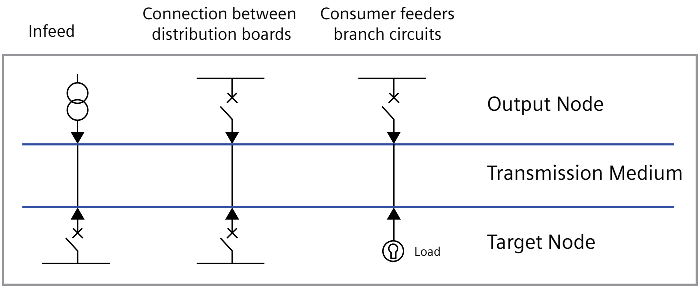


Figure 15: Visualization of Various Types of Circuits Within an Electric Network

Circuit dimensioning is based on the following basic principles and associated standards for the applicable protection objective:

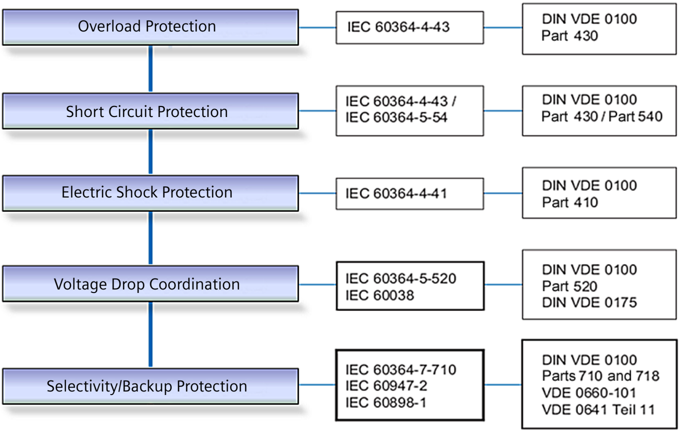


Figure 16: Overview of Basic Rules for Circuit Dimensioning

The dimensioning process within an electric network can have any degree of complexity, as the adjustment of one component often affects the dimensioning result of other network components in other circuits.

In order to safely control possible cross-circuit effects of dimensioning and to maintain an overall overview, electric planners usually utilize a professional network calculation/engineering tool, like

SIMARIS design:	Network and short circuit current calculation
SIMARIS curves:	Visualization of device characteristics (I-t, Ic, I^2t)
SIMARIS project:	Planning of low-voltage switchgear and electric distribution boards

For more information on SIMARIS planning tools available from Siemens please see
http://www.siemens.com/simaris
and
http://www.siemens.com/tip

The implementation of these Siemens software tools significantly reduces the workload of planners, engineering offices and installers while offering more reliability for network calculations and component design. Costs for testing are reduced considerably, while the danger of incorrect planning is greatly reduced.

Tools like these contribute significantly to the successful completion of required tasks – while the responsibility for the correctness and usability of the end result as required by the customer remains squarely in the hands of the experts.

It therefore makes sense to understand and be able to reproduce the principles of the (automated) dimensioning process used by the tools. Any project planning issues can then be remedied faster and with a specific focus, or they can be manipulated manually as needed.

Alternatively, the expected dimensioning of individual components can also be determined as estimates without any tools.

4.1 Dimensioning Process

Once the network planning stage is complete, the network structure and consumer information can be extrapolated for energy balancing.

Energy balancing allows the determination of max. load currents Ibmax for the associated transmission medium (cable/conductor or busbar system) for each circuit.

As a rule:

Ibmax = ∑ installed load rating * derating factor

Ibmax is compared with the max. permissible current load capacity Iz of the transmission medium.

Expected short circuit conditions (min/max) for the envisaged installation locations of the switching/protective devices (MCBs) can be calculated using the technical data provided for the selected transmission media (conductor cross-section, layout and number of systems, etc.) in accordance with IEC 60909-0/DIN EN 0102-0 (VDE 0102).

Multiple network calculation variations may be required where alternative supply paths or infeed options exist.

Once the short circuit conditions are known for all installation locations, the necessary switching/protective devices can then be selected within the scope of circuit dimensioning and can be tested for technical reliability in combination with the selected transmission media (see also Figure 16).

4.1.1 Overload Protection

Dimensioning Rule

a) for non-adjustable protective devices

Ib <= In <= Iz

The rated current of the selected switching/protective device must be within the range between the calculated max. load current Ib and the max. permissible load current Iz of the selected transmission medium (cable/conductor or busbar system).

b) adjustable protective devices

Ib <= Ir <= Iz

The set value of the overload release Ir for the selected switching/protective device must be within the range between the calculated max. load current Ib and the max. permissible load current Iz of the selected transmission medium (cable/conductor or busbar system).

As MCBs are non-adjustable, only case a) applies.

To ensure overload protection, compliance with standardized test currents for the relevant device is required.

Release Rule

$$I_2 <= 1.45 * Iz$$

For MCBs, test value I2 applies for ambient temperature 30 °C
in accordance with IEC/EN 60898-1/-2 (VDE 0641-11/-12) = 1.45 x In
In accordance with IEC/EN 60947-2 (VDE 0660-101) < 1.45 x In.

The release rule therefore does not pose any additional requirements for MCBs in terms of compliance with overload protection.

MCBs can be simply tested for the relationship **In <= Iz** to ensure compliance with the protection objective.

4.1.2 Short Circuit Protection

The energy released from the start of the short circuit to the time of circuit shut-down must at any time be smaller than the max. load capacity of the transmission medium to avoid irreparable damage.

It is therefore not sufficient to merely test for the calculated max. short circuit current.

Short Circuit Protection Objective 1

For break times $0.1 \leq t \leq 5$ s the following applies:

$$K^2S^2 >= Ik^2t$$

For break times $t < 0.1$ s the following applies:

$$K^2S^2 >= I^2t_{\text{cut-off}}$$

k:	Material coefficient of the transmission medium (115 As/mm^2 PVC-insul. Cu conductor, 76 As/mm2 PVC-insul. Al conductor)
S:	Conductor diameter of the transmission medium [mm^2]
Ik:	rms value of the short circuit flowing through this connection path [A]
t:	actual release time of the switching/protective device at Ik [sec]
I^2t cut-off:	cut-off energy as stated by the manufacturer of the switching/protective device as a function of Ik [A^2s]

Compliance with this basic rule must be ensured across the entire path of the I-t characteristic curve.

For short circuit release times under 100 msec, the cut-off power must be determined from data provided by the manufacturer or from the cut-off characteristic curves of the switching/ protective device and must then be compared with the k^2S^2 of the transmission medium.

Short Circuit Protection Objective 2

$$t\ a\ (Ikmin) <= 5\ s$$

The resulting break time tA of the selected protective device must be able to disconnect the smallest calculated short circuit current Ikmin at the installation location automatically within 5 seconds at the latest.

4.1.3 Electric Shock Protection

In addition to overload and short circuit protection, a further test for electric shock protection is required (aka indirect contact protection).

This protection objective should preferably be achieved with a timely automatic disconnection of the associated switching/protective device.

The following applies:

t a (Ik1min) <= ta_zul

In the event of a single-pole fault against ground (with current flow Ik1min), the resulting break time tA of the selected protective device must be smaller than the max. permissible break time ta_zul as per standard requirement.

Defined break times for branch circuits <= 32 A

Network system by ground connection type	50 V < U0 <= 120 V		120 V < U0 <= 230 V		230 V < U0 <= 400 V		U0 > 400 V	
	AC	DC	AC	DC	AC	DC	AC	DC
TN	0.8 s	kA	0.4 s	5 s	0.2 s	0.4 s	0.1 s	0.1 s
TT	0.3 s		0.2 s	0.4 s	0.07 s	0.2 s	0.04 s	0.1 s

IEC60364-4-41, DIN VDE 0100 Part 410, Tab 4-41
U_0 is equal to the conductor-ground voltage of the network

For all other circuits and branch circuits > 32 A a max. permissible break time applies:
in the TN system <= 5 s
in the TT system <= 1 s

A standardization and history of the I-t tripping characteristic curves of MCBs with their specific tripping characteristics allow simplification for the purpose of testing the protection objective and therefore simplification of the device selection.

Where Ik1min is > I5 (immediate break current in accordance with the tripping characteristic), the break times required as standard for the MCB in typical 230/400 V networks for residential and non-residential or industrial systems are indirectly complied with and will not require separate testing.

Electric Shock Protection - Additional Protection

Within the scope of personal safety in AC systems, additional protection by way of RCDs with $I_{\Delta N} \leq 30$ mA must be implemented for particular circuit types or areas of application.

This applies to:

- Wall socket circuits <= 20 A for use by ordinary persons and for general use

and

- Branch circuits for portable equipment used outdoors <= 32 A.

In order to comply with these protection requirements, MCBs must be combined with appropriate RCCBs or RC units, or RCBOs with $I_{\Delta N} = 30$ mA must be implemented.

For additional information on RCCBs and their use, please read the technical primer for residual current protective devices.

4.1.4 Voltage Drop Coordination

There are various recommendations for compliance with a max. permissible voltage drop (DIN 18015-1 and DIN VDE 0100-520), but no binding requirements or specifications.

It is therefore recommended that the voltage drop between the building inlet point and consumer should not exceed 4% of the rated network voltage.

Furthermore, equipment-specific or customer requirements for compliance with a voltage drop may apply and will have to be included in the scope of testing for consumer dimensioning.

In accordance with IEC 60038/DIN VDE 0175, the overall voltage drop between the infeed point and the consumer should not fall below the tolerance of +/-10 % for network standard voltages <= 1 kV.

4.1.5 Selectivity, Backup Protection

The selective interactive behavior of all switching/protective devices in the electric network must be analyzed and aligned, just as these devices were specified in accordance with the dimensioning rules 1 - 4.

The process is known as network protection coordination.

Definition of Selectivity

Selectivity means that only the protective device closest to the fault will trip in the event of a fault. The power flow to other parallel circuits remains intact (= supply security).

Full selectivity in this context refers to the ability to guarantee selective behavior for serially switched protective devices up to the calculated max. short circuit current Ikmax at the installation location.

Partial selectivity means that the selective device behavior is guaranteed only up to a specific max. current value.

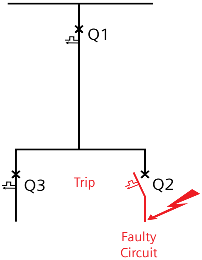


Figure 17 - Visualization of Selective Device Behavior

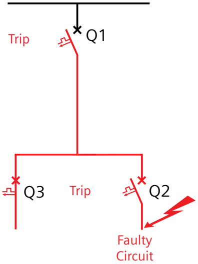
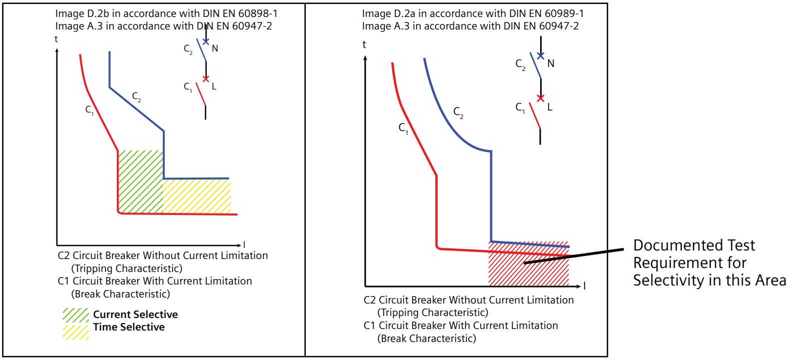


Figure 18 - Visualization of Non-Selective Device Behavior

The assessment of the selective device behavior in the time-delay overcurrent tripping range uses the I-t tripping characteristics of the implemented switching/protective devices including their tolerance ranges.

In the so-called dynamic short circuit quick tripping range (time range < 100 ms), the exact current-time behavior of a switching/protective device can be determined using relevant lab tests or device tests.



A fully selective device behavior is prerequisite for specific system types and must be documented by the testing body (TÜV, DEKRA etc.) for system approval.

This rule applies specifically for backup power supply systems

- for hospitals in accordance with IEC 60364-7-710 and DIN VDE 0100-710 (Nov. 2002) (formerly DIN VDE 0107)
- for communal facilities in accordance with IEC 60364-7-718 and DIN VDE 0100-718 (March 2004) (formerly DIN VDE 0108)

For other power supply systems, full selectivity incl. documentation may be an additional customer requirement, which is to be fulfilled within the scope of device dimensioning.

Backup Protection

In all cases, where a protective device (Q1) trips in addition to a downstream protective device (Q2), Q1 may represent a viable backup protection for Q2 if the short circuit current at the installation location surpasses the switching capacity of Q2 (see image 18)

Whether or not effective backup protection is provided depends on the current and power limitations, as well as on the actual break behavior of the two protective devices (Q1 and Q2).

As with selectivity, backup protection can only be guaranteed if the device manufacturer verifies the values for a specific device combination in documented lab tests or field tests (e.g. backup protection table).

The use of innovative switch technology will allow a targeted combination of selectivity and backup protection for specific devices (example: specific device combinations with MMCBs, Chapter 3.1.6).

5.0 Rules and Regulations

A collection of relevant standards and regulations in connection with the use of MCBs. Additional system-specific standards and regulations may apply, which are not explicitly mentioned within the scope of this primer.

5.1 Tecéical Connection Requirements (TAB)

In the Technical Connection Requirements TAB 2007 for the connection of low-voltage networks, the German Association of Network Operators (VDN) in the German Electricity Association (VDEW) provides important requirements for the connection, commissioning and operation of electric systems.

These Technical Connection Requirements are based on the Low Voltage Connection Ordinance (NAV) dated November 1, 2006. The regulations apply for the operation of systems connected or to be connected to the low-voltage network of the network operator in accordance with Article 1, Sect. 1 of the Ordinance.

The Technical Connection Requirements apply for systems that are to be initially connected to the distribution network or for customer systems undergoing an expansion or modification. There is no alignment requirement for the existing part of the customer system, provided that a safe and fault-free power supply can be guaranteed.

TAB defines the action requirements of the network operator, the installer, planner, connectee and connection user of customer systems in the sense of Article 13 NAV (electric system).

These action requirements apply in conjunction with Article 19 EnWG “Technical Regulations” and therefore form part of network connection contracts and network usage relationships in accordance with NAV.

5.2 Installation Regulations

Title	IEC	EN	DIN VDE
Low-Voltage Installations	60364-1...6		0100 – 100...710
Short Circuit Currents in Three-Phase Networks – Current Calculation	60909	60909	0102
Short Circuit Currents – Effect Calculation Terminology & Calculation Methods	60865	60865	0103
Low-Voltage Installations Part 4-43: Protective Measures – Overcurrent Protection	60364-43		0100-430
Low-Voltage Installations Part 4-41: Protective Measures – Electric Shock Protection	60364-41		0100-410
Low-Voltage Installations Part 530: Selection and Installation of Electrical Equipment – Switchgear & Controlgear	60364-5-53		0100-530
Low-Voltage Installations Part 5-54: Selection and Installation of Electrical Equipment – Grounding Systems & Ground Conductor	60364-54		0100-540
Low-Voltage Installations Part 5-52: Selection and Installation of Electrical Equipment – Cable & Wiring Systems	60364-52		0100-520
Standard Voltages for Electric Networks	60038	60038	VDE 0175-1
Low-Voltage Installations Part 7-710: Requirements for Non-Residential Establishments, Specialist Spaces and Facilities – Areas for Medical Use	60364-7-710		0100-710
Low-Voltage Installations - Requirements for Non-Residential Establishments, Specialist Spaces and Facilities Part 718: Communal Structures	60364-7-718		0100-718

5.3 Device Standards for MCBs

Title	IEC	EN	DIN VDE	UL
Electric Installation Material – MCBs for Building Installations and Similar Purposes Part 1: MCBs for AC Systems	60898-1	60898-1	0641 – 11	
Electric Installation Material – MCBs for Building Installations and Similar Purposes Part 2: MCBs for AC and DC Systems	60898-2	60898-2	0641 – 12	
Electric Installation Material – MCBs for Building Installations and Similar Purposes Part 21: Selective MMCBs			0641-21	
Low-Voltage Switchgear – Circuit Breakers	60947-2	60947-2	0660 – 101	
MCCBs, Molded Case Switches and Enclosures				UL489
Supplementary Protective Devices for Use in Electric Equipment				UL 1077

6.0 Glossary

Universal current
Short for AC/DC applications.

Back-up protection
Interaction of two coordinated, serially switched overcurrent protective devices at points where a device (e.g. MCB) will not be able to switch the expected short-circuit current without a backup in the event of a fault. The upstream overcurrent protective device will relieve the next downstream device should a high short circuit current occur, thus preventing overload. Both protective devices must have sufficient switching capacity.

E-Check
Professional term for periodic maintenance and repair work carried out on an electric network and/or electric equipment by a professional service provider.

E-Car
Term from the area of electromobility (vehicles with electric motor).

Short circuit
Connection with negligible small impedance between two live conductors. The current will be a multiple of the operational current, which may cause a thermal (rated short-time current) or mechanical (peak withstand current) overload of the electrical equipment and system components.

Prospective short-circuit current
The prospective short-circuit current is the theoretically applied max. short circuit current (effective value) that would be applied if there were no protective devices in the circuit.

Circuit (electric)
A circuit is created by interconnected electric equipment in a system, which are all protected by the same overcurrent protective devices.

Control circuit
Part of an auxiliary circuit, comprising all components of a circuit that do not belong to the main circuit. Control circuits are circuits for:

- Signal generation and signal input
- Signal processing, including conversion, storage, locking and amplification
- Signal output and the control of actuators and signal transmitters

Modular width (MW)
The width of modular installation devices is defined as n ( ) mm, whereby n = 0.5; 1.0; 1.5; 2.0; 2.5... etc. One modular width (MW) is 18 mm (17.5 + 0.5 mm) plus the mounting depth n*18mm for modular installation devices in e.g. distribution boards.

Overload
Operating conditions that create an overcurrent in an uninterrupted and fault-free electric circuit. Unchecked, sustained overloads may result in material damage.

Overcurrent
Generic term for all types of unwanted circuit overloads.
Overcurrent may result in an overload or a short circuit.

Overcurrent protective device
Equipment (e.g. circuit breaker, fuse, MCB) which triggers when predefined current values are surpassed and which protects the circuit by breaking the current.

Consumer/Consumption
Devices or installations which convert electrical energy into a different, non-electronic form of energy. AC technology differentiates three consumer categories:

- Ohmic consumers causing no phase displacement between current and voltage, e.g. heaters, light bulbs.
- Inductive consumers causing the current to lag behind the voltage, e.g. motors, coils, solenoids.
- Capacitive consumers causing the current to lead the voltage, e.g. capacitors.

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