Due to possible developments of standards as well as of materials, the characteristics and dimensions specified in this document may only be considered binding after confirmation by ABB SACE.

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Protection and control devices

Electrical installation handbook
Volume 1
5th edition

Protection and control devices

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ABB SACE

Electrical installation handbook

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Introduction

Scope and objectives

The scope of this electrical installation handbook is to provide the designer and user of electrical plants with a quick reference, immediate-use working tool. This is not intended to be a theoretical document, nor a technical catalogue, but, in addition to the latter, aims to be of help in the correct definition of equipment, in numerous practical installation situations.

The dimensioning of an electrical plant requires knowledge of different factors relating to, for example, installation utilities, the electrical conductors and other components; this knowledge leads the design engineer to consult numerous documents and technical catalogues. This electrical installation handbook, however, aims to supply, in a single document, tables for the quick definition of the main parameters of the components of an electrical plant and for the selection of the protection devices for a wide range of installations. Some application examples are included to aid comprehension of the selection tables.

Electrical installation handbook users

The electrical installation handbook is a tool which is suitable for all those who are interested in electrical plants: useful for installers and maintenance technicians through brief yet important electrotechnical references, and for sales engineers through quick reference selection tables.

Validity of the electrical installation handbook

Some tables show approximate values due to the generalization of the selection process, for example those regarding the constructional characteristics of electrical machinery. In every case, where possible, correction factors are given for actual conditions which may differ from the assumed ones. The tables are always drawn up conservatively, in favour of safety; for more accurate calculations, the use of DOCWin software is recommended for the dimensioning of electrical installations.

1 Standards

1.1 General aspects

In each technical field, and in particular in the electrical sector, a condition sufficient (even if not necessary) for the realization of plants according to the **“status of the art”** and a requirement essential to properly meet the demands of customers and of the community, is the respect of all the relevant laws and technical standards.
Therefore, a precise knowledge of the standards is the fundamental premise for a correct approach to the problems of the electrical plants which shall be designed in order to guarantee that **“acceptable safety level”** which is never absolute.

Juridical Standards
These are all the standards from which derive rules of behavior for the juridical persons who are under the sovereignty of that State.

Technical Standards
These standards are the whole of the prescriptions on the basis of which machines, apparatus, materials and the installations should be designed, manufactured and tested so that efficiency and function safety are ensured.
The technical standards, published by national and international bodies, are circumstantially drawn up and can have legal force when this is attributed by a legislative measure.

Application fields

	Electrotechnics and Electronics	**Telecommunications**	**Mechanics, Ergonomics and Safety**
International Body	IEC	ITU	ISO
European Body	CENELEC	ETSI	CEN

This technical collection takes into consideration only the bodies dealing with electrical and electronic technologies.

IEC International Electrotechnical Commission

The *International Electrotechnical Commission* (IEC) was officially founded in 1906, with the aim of securing the international co-operation as regards standardization and certification in electrical and electronic technologies. This association is formed by the International Committees of over 40 countries all over the world.
The IEC publishes international standards, technical guides and reports which are the bases or, in any case, a reference of utmost importance for any national and European standardization activity.
IEC Standards are generally issued in two languages: English and French.
In 1991 the IEC has ratified co-operation agreements with CENELEC (European standardization body), for a common planning of new standardization activities and for parallel voting on standard drafts.

1 Standards

CENELEC European Committee for Electrotechnical Standardization

The *European Committee for Electrotechnical Standardization* (CENELEC) was set up in 1973. Presently it comprises 30 countries (Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Portugal, Poland, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom) and cooperates with 8 affiliates (Albania, Bosnia and Herzegovina, Tunisia, Croatia, Former Yugoslav Republic of Macedonia, Serbia and Montenegro, Turkey, Ukraine) which have first maintained the national documents side by side with the CENELEC ones and then replaced them with the Harmonized Documents (HD).
There is a difference between EN Standards and Harmonization Documents (HD): while the first ones have to be accepted at any level and without additions or modifications in the different countries, the second ones can be amended to meet particular national requirements.
EN Standards are generally issued in three languages: English, French and German.
From 1991 CENELEC cooperates with the IEC to accelerate the standards preparation process of International Standards.
CENELEC deals with specific subjects, for which standardization is urgently required.
When the study of a specific subject has already been started by the IEC, the European standardization body (CENELEC) can decide to accept or, whenever necessary, to amend the works already approved by the International standardization body.

EC DIRECTIVES FOR ELECTRICAL EQUIPMENT

Among its institutional roles, the European Community has the task of promulgating directives which must be adopted by the different member states and then transposed into national law.
Once adopted, these directives come into juridical force and become a reference for manufacturers, installers, and dealers who must fulfill the duties prescribed by law.
Directives are based on the following principles:
- harmonization is limited to essential requirements;
- only the products which comply with the essential requirements specified by the directives can be marketed and put into service;
- the harmonized standards, whose reference numbers are published in the Official Journal of the European Communities and which are transposed into the national standards, are considered in compliance with the essential requirements;
- the applicability of the harmonized standards or of other technical specifications is facultative and manufacturers are free to choose other technical solutions which ensure compliance with the essential requirements;
- a manufacturer can choose among the different conformity evaluation procedure provided by the applicable directive.

The scope of each directive is to make manufacturers take all the necessary steps and measures so that the product does not affect the safety and health of persons, animals and property.

1 Standards

"Low Voltage" Directive 2006/95/CE

The Low Voltage Directive refers to any electrical equipment designed for use at a rated voltage from 50 to 1000 V for alternating current and from 75 to 1500 V for direct current.
In particular, it is applicable to any apparatus used for production, conversion, transmission, distribution and use of electrical power, such as machines, transformers, devices, measuring instruments, protection devices and wiring materials.
The following categories are outside the scope of this Directive:
- electrical equipment for use in an explosive atmosphere;
- electrical equipment for radiology and medical purposes;
- electrical parts for goods and passenger lifts;
- electrical energy meters;
- plugs and socket outlets for domestic use;
- electric fence controllers;
- radio-electrical interference;
- specialized electrical equipment, for use on ships, aircraft or railways, which complies with the safety provisions drawn up by international bodies in which the Member States participate.

Directive EMC 89/336/EEC* ("Electromagnetic Compatibility")

The Directive on electromagnetic compatibility regards all the electrical and electronic apparatus as well as systems and installations containing electrical and/or electronic components. In particular, the apparatus covered by this Directive are divided into the following categories according to their characteristics:
- domestic radio and TV receivers;
- industrial manufacturing equipment;
- mobile radio equipment;
- mobile radio and commercial radio telephone equipment;
- medical and scientific apparatus;
- information technology equipment (ITE);
- domestic appliances and household electronic equipment;
- aeronautical and marine radio apparatus;
- educational electronic equipment;
- telecommunications networks and apparatus;
- radio and television broadcast transmitters;
- lights and fluorescent lamps.

The apparatus shall be so constructed that:
a) the electromagnetic disturbance it generates does not exceed a level allowing radio and telecommunications equipment and other apparatus to operate as intended;
b) the apparatus has an adequate level of intrinsic immunity to electromagnetic disturbance to enable it to operate as intended.

An apparatus is declared in conformity to the provisions at points a) and b) when the apparatus complies with the harmonized standards relevant to its product family or, in case there aren't any, with the general standards.

(*) The new Directive 2004/108/CE has become effective on 20th January, 2005. Anyway a period of transition (up to July 2009) is foreseen during which time the putting on the market or into service of apparatus and systems in accordance with the previous Directive 89/336/CE is still allowed.
The provisions of the new Directive can be applied starting from 20th July, 2007.

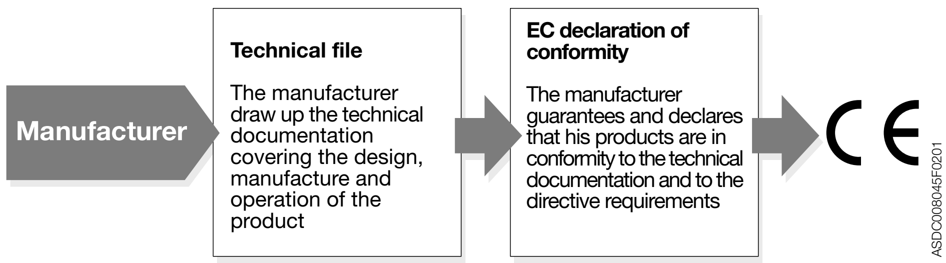
1 Standards

CE conformity marking

The CE conformity marking shall indicate conformity to all the obligations imposed on the manufacturer, as regards his products, by virtue of the European Community directives providing for the affixing of the CE marking.

When the CE marking is affixed on a product, it represents a declaration of the manufacturer or of his authorized representative that the product in question conforms to all the applicable provisions including the conformity assessment procedures. This prevents the Member States from limiting the marketing and putting into service of products bearing the CE marking, unless this measure is justified by the proved non-conformity of the product.

Flow diagram for the conformity assessment procedures established by the Directive 2006/95/CE on electrical equipment designed for use within particular voltage range:



Naval type approval

The environmental conditions which characterize the use of circuit breakers for on-board installations can be different from the service conditions in standard industrial environments; as a matter of fact, marine applications can require installation under particular conditions, such as:
- environments characterized by high temperature and humidity, including salt-mist atmosphere (damp-heat, salt-mist environment);
- on board environments (engine room) where the apparatus operate in the presence of vibrations characterized by considerable amplitude and duration.

In order to ensure the proper function in such environments, the shipping registers require that the apparatus has to be tested according to specific type approval tests, the most significant of which are vibration, dynamic inclination, humidity and dry-heat tests.

1 Standards

ABB SACE circuit-breakers (Tmax-Emax) are approved by the following shipping registers:

• **RINA**	Registro Italiano Navale	Italian shipping register
• **DNV**	Det Norske Veritas	Norwegian shipping register
• **BV**	Bureau Veritas	French shipping register
• **GL**	Germanischer Lloyd	German shipping register
• **LRs**	Lloyd's Register of Shipping	British shipping register
• **ABS**	American Bureau of Shipping	American shipping register

It is always advisable to ask ABB SACE as regards the typologies and the performances of the certified circuit-breakers or to consult the section certificates in the website **http://bol.it.abb.com**.

Marks of conformity to the relevant national and international Standards

The international and national marks of conformity are reported in the following table, for information only:

COUNTRY	Symbol	Mark designation	Applicability/Organization
EUROPE		–	Mark of compliance with the harmonized European standards listed in the ENEC Agreement.
AUSTRALIA		AS Mark	Electrical and non-electrical products. It guarantees compliance with SAA (Standard Association of Australia).
AUSTRALIA		S.A.A. Mark	Standards Association of Australia (S.A.A.). The Electricity Authority of New South Wales Sydney Australia
AUSTRIA		Austrian Test Mark	Installation equipment and materials

1 Standards

COUNTRY	Symbol	Mark designation	Applicability/Organization
AUSTRIA		ÖVE Identification Thread	Cables
BELGIUM	CEBEC	CEBEC Mark	Installation materials and electrical appliances
BELGIUM	CEBEC	CEBEC Mark	Conduits and ducts, conductors and flexible cords
BELGIUM	CEBEC	Certification of Conformity	Installation material and electrical appliances (in case there are no equivalent national standards or criteria)
CANADA		CSA Mark	Electrical and non-electrical products. This mark guarantees compliance with CSA (Canadian Standard Association)
CHINA		CCC Mark	This mark is required for a wide range of manufactured products before being exported to or sold in the Peoples Republic of China market.
Czech Republic		EZU' Mark	Electrotechnical Testing Institute
Slovakia Republic		EVPU' Mark	Electrotechnical Research and Design Institute

1 Standards

COUNTRY	Symbol	Mark designation	Applicability/Organization
CROATIA	KONČAR	KONKAR	Electrical Engineering Institute
DENMARK		DEMKO Approval Mark	Low voltage materials. This mark guarantees the compliance of the product with the requirements (safety) of the "Heavy Current Regulations"
FINLAND		Safety Mark of the Elektriska Inspektoratet	Low voltage material. This mark guarantees the compliance of the product with the requirements (safety) of the "Heavy Current Regulations"
FRANCE	CONTRÔLE NF LIMITÈ À LA SÈCURITÈ	ESC Mark	Household appliances
FRANCE		NF Mark	Conductors and cables – Conduits and ducting – Installation materials
FRANCE		NF Identification Thread	Cables
FRANCE		NF Mark	Portable motor-operated tools
FRANCE		NF Mark	Household appliances

1 Standards

COUNTRY	Symbol	Mark designation	Applicability/Organization
GERMANY		VDE Mark	For appliances and technical equipment, installation accessories such as plugs, sockets, fuses, wires and cables, as well as other components (capacitors, earthing systems, lamp holders and electronic devices)
GERMANY		VDE Identification Thread	Cables and cords
GERMANY		VDE Cable Mark	For cables, insulated cords, installation conduits and ducts
GERMANY		VDE-GS Mark for technical equipment	Safety mark for technical equipment to be affixed after the product has been tested and certified by the VDE Test Laboratory in Offenbach; the conformity mark is the mark VDE, which is granted both to be used alone as well as in combination with the mark GS
HUNGARY		MEEI	Hungarian Institute for Testing and Certification of Electrical Equipment
JAPAN	JIS GIAPPONE	JIS Mark	Mark which guarantees compliance with the relevant Japanese Industrial Standard(s).
IRELAND	IIRS IRLANDA	IIRS Mark	Electrical equipment
IRELAND	MARK OF CONFORMITY I.I.R.S.	IIRS Mark	Electrical equipment

1 Standards

COUNTRY	Symbol	Mark designation	Applicability/Organization
ITALY		IMQ Mark	Mark to be affixed on electrical material for non-skilled users; it certifies compliance with the European Standard(s).
NORWAY		Norwegian Approval Mark	Mandatory safety approval for low voltage material and equipment
NETHERLANDS	KEMA-KEUR	KEMA-KEUR	General for all equipment
POLAND		KWE	Electrical products
RUSSIA		Certification of Conformity	Electrical and non-electrical products. It guarantees compliance with national standard (Gosstandard of Russia)
SINGAPORE	APPROVED TO SINGAPORE STANDARD	SISIR	Electrical and non-electrical products
SLOVENIA	SIQ - Slovenia	SIQ	Slovenian Institute of Quality and Metrology
SPAIN	MARCA DE CONFORMIDAD A NORMAS UNE	AEE	Electrical products. The mark is under the control of the Asociación Electrotécnica Española (Spanish Electrotechnical Association)

1 Standards

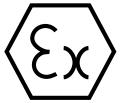
COUNTRY	Symbol	Mark designation	Applicability/Organization
SPAIN	AENOR Producto Certificado	AENOR	Asociación Española de Normalización y Certificación. (Spanish Standarization and Certification Association)
SWEDEN		SEMKO Mark	Mandatory safety approval for low voltage material and equipment.
SWITZERLAND	* PZ 1	Safety Mark	Swiss low voltage material subject to mandatory approval (safety).
SWITZERLAND	+ S + S + S	–	Cables subject to mandatory approval
SWITZERLAND		SEV Safety Mark	Low voltage material subject to mandatory approval
UNITED KINGDOM		ASTA Mark	Mark which guarantees compliance with the relevant "British Standards"
UNITED KINGDOM	BASEC	BASEC Mark	Mark which guarantees compliance with the "British Standards" for conductors, cables and ancillary products.
UNITED KINGDOM		BASEC Identification Thread	Cables

1.1 General aspects

1 Standards

COUNTRY	Symbol	Mark designation	Applicability/Organization
UNITED KINGDOM		BEAB Safety Mark	Compliance with the "British Standards" for household appliances
UNITED KINGDOM		BSI Safety Mark	Compliance with the "British Standards"
UNITED KINGDOM	APPROVED TO BRITISH STANDARD	BEAB Kitemark	Compliance with the relevant "British Standards" regarding safety and performances
U.S.A.	LISTED (Product Name) (Control Number)	UNDERWRITERS LABORATORIES Mark	Electrical and non-electrical products
U.S.A.	UL U.S.A.	UNDERWRITERS LABORATORIES Mark	Electrical and non-electrical products
U.S.A.	UL U.S.A.	UL Recognition	Electrical and non-electrical products
CEN		CEN Mark	Mark issued by the European Committee for Standardization (CEN): it guarantees compliance with the European Standards.
CENELEC	HAR	Mark	Cables

1 Standards

COUNTRY	Symbol	Mark designation	Applicability/Organization
CENELEC		Harmonization Mark	Certification mark providing assurance that the harmonized cable complies with the relevant harmonized CENELEC Standards – identification thread
EC		Ex EUROPEA Mark	Mark assuring the compliance with the relevant European Standards of the products to be used in environments with explosion hazards
CEEel		CEEel Mark	Mark which is applicable to some household appliances (shavers, electric clocks, etc).

EC - Declaration of Conformity

The EC Declaration of Conformity is the statement of the manufacturer, who declares under his own responsibility that all the equipment, procedures or services refer and comply with specific standards (directives) or other normative documents.

The EC Declaration of Conformity should contain the following information:
- name and address of the manufacturer or by its European representative;
- description of the product;
- reference to the harmonized standards and directives involved;
- any reference to the technical specifications of conformity;
- the two last digits of the year of affixing of the CE marking;
- identification of the signer.

A copy of the EC Declaration of Conformity shall be kept by the manufacturer or by his representative together with the technical documentation.

1 Standards

1.2 IEC Standards for electrical installation

STANDARD	YEAR	TITLE
IEC 60027-1	1992	Letter symbols to be used in ectrical technology - Part 1: General
IEC 60034-1	2004	Rotating electrical machines - Part 1: Rating and performance
IEC 60617-DB-Snapshot	2007	Graphical symbols for diagrams
IEC 61082-1	2006	Preparation of documents used in electrotechnology - Part 1: Rules
IEC 60038	2002	IEC standard voltages
IEC 60664-1	2002	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests
IEC 60909-0	2001	Short-circuit currents in three-phase a.c. systems - Part 0: Calculation of currents
IEC 60865-1	1993	Short-circuit currents - Calculation of effects - Part 1: Definitions and calculation methods
IEC 60076-1	2000	Power transformers - Part 1: General
IEC 60076-2	1993	Power transformers - Part 2: Temperature rise
IEC 60076-3	2000	Power transformers - Part 3: Insulation levels, dielectric tests and external clearances in air
IEC 60076-5	2006	Power transformers - Part 5: Ability to withstand short circuit
IEC/TR 60616	1978	Terminal and tapping markings for power transformers
IEC 60076-11	2004	Power transformers - Part 11: Dry-type transformers
IEC 60445	2006	Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals and conductor terminations
IEC 60073	2002	Basic and safety principles for man-machine interface, marking and identification – Coding for indicators and actuators
IEC 60446	1999	Basic and safety principles for man-machine interface, marking and identification - Identification of conductors by colours or numerals
IEC 60447	2004	Basic and safety principles for man-machine interface, marking and identification - Actuating principles
IEC 60947-1	2004	Low-voltage switchgear and controlgear - Part 1: General rules
IEC 60947-2	2006	Low-voltage switchgear and controlgear - Part 2: Circuit-breakers

1 Standards

STANDARD	YEAR	TITLE
IEC 60947-3	2005	Low-voltage switchgear and controlgear - Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units
IEC 60947-4-1	2002	Low-voltage switchgear and controlgear - Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters
IEC 60947-4-2	2007	Low-voltage switchgear and controlgear - Part 4-2: Contactors and motor-starters – AC semiconductor motor controllers and starters
IEC 60947-4-3	2007	Low-voltage switchgear and controlgear - Part 4-3: Contactors and motor-starters – AC semiconductor controllers and contactors for non-motor loads
IEC 60947-5-1	2003	Low-voltage switchgear and controlgear - Part 5-1: Control circuit devices and switching elements - Electromechanical control circuit devices
IEC 60947-5-2	2004	Low-voltage switchgear and controlgear - Part 5-2: Control circuit devices and switching elements – Proximity switches
IEC 60947-5-3	2005	Low-voltage switchgear and controlgear - Part 5-3: Control circuit devices and switching elements – Requirements for proximity devices with defined behaviour under fault conditions
IEC 60947-5-4	2002	Low-voltage switchgear and controlgear - Part 5: Control circuit devices and switching elements – Section 4: Method of assessing the performance of low energy contacts. Special tests
IEC 60947-5-5	2005	Low-voltage switchgear and controlgear - Part 5-5: Control circuit devices and switching elements - Electrical emergency stop device with mechanical latching function
IEC 60947-5-6	1999	Low-voltage switchgear and controlgear - Part 5-6: Control circuit devices and switching elements – DC interface for proximity sensors and switching amplifiers (NAMUR)
IEC 60947-6-1	2005	Low-voltage switchgear and controlgear - Part 6-1: Multiple function equipment – Transfer switching equipment
IEC 60947-6-2	2002	Low-voltage switchgear and controlgear - Part 6-2: Multiple function equipment - Control and protective switching devices (or equipment) (CPS)
IEC 60947-7-1	2002	Low-voltage switchgear and controlgear - Part 7: Ancillary equipment - Section 1: Terminal blocks for copper conductors

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STANDARD	YEAR	TITLE
IEC 60947-7-2	2002	Low-voltage switchgear and controlgear - Part 7: Ancillary equipment - Section 2: Protective conductor terminal blocks for copper conductors
IEC 60439-1	2004	Low-voltage switchgear and controlgear assemblies - Part 1: Type-tested and partially type-tested assemblies
IEC 60439-2	2005	Low-voltage switchgear and controlgear assemblies - Part 2: Particular requirements for busbar trunking systems (busways)
IEC 60439-3	2001	Low-voltage switchgear and controlgear assemblies - Part 3: Particular requirements for low-voltage switchgear and controlgear assemblies intended to be installed in places where unskilled persons have access for their use - Distribution boards
IEC 60439-4	2004	Low-voltage switchgear and controlgear assemblies - Part 4: Particular requirements for assemblies for construction sites (ACS)
IEC 60439-5	2006	Low-voltage switchgear and controlgear assemblies - Part 5: Particular requirements for assemblies for power distribution in public networks
IEC 61095	2000	Electromechanical contactors for household and similar purposes
IEC/TR 60890	1987	A method of temperature-rise assessment by extrapolation for partially type-tested assemblies (PTTA) of low-voltage switchgear and controlgear
IEC/TR 61117	1992	A method for assessing the short-circuit withstand strength of partially type-tested assemblies (PTTA)
IEC 60092-303	1980	Electrical installations in ships. Part 303: Equipment - Transformers for power and lighting
IEC 60092-301	1980	Electrical installations in ships. Part 301: Equipment - Generators and motors
IEC 60092-101	2002	Electrical installations in ships - Part 101: Definitions and general requirements
IEC 60092-401	1980	Electrical installations in ships. Part 401: Installation and test of completed installation
IEC 60092-201	1994	Electrical installations in ships - Part 201: System design - General
IEC 60092-202	1994	Electrical installations in ships - Part 202: System design - Protection

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STANDARD	YEAR	TITLE
IEC 60092-302	1997	Electrical installations in ships - Part 302: Low-voltage switchgear and controlgear assemblies
IEC 60092-350	2001	Electrical installations in ships - Part 350: Shipboard power cables - General construction and test requirements
IEC 60092-352	2005	Electrical installations in ships - Part 352: Choice and installation of electrical cables
IEC 60364-5-52	2001	Electrical installations of buildings - Part 5-52: Selection and erection of electrical equipment – Wiring systems
IEC 60227		Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V
	1998	Part 1: General requirements
	2003	Part 2: Test methods
	1997	Part 3: Non-sheathed cables for fixed wiring
	1997	Part 4: Sheathed cables for fixed wiring
	2003	Part 5: Flexible cables (cords)
	2001	Part 6: Lift cables and cables for flexible connections
	2003	Part 7: Flexible cables screened and unscreened with two or more conductors
IEC 60228	2004	Conductors of insulated cables
IEC 60245		Rubber insulated cables - Rated voltages up to and including 450/750 V
	2003	Part 1: General requirements
	1998	Part 2: Test methods
	1994	Part 3: Heat resistant silicone insulated cables
	2004	Part 4: Cord and flexible cables
	1994	Part 5: Lift cables
	1994	Part 6: Arc welding electrode cables
	1994	Part 7: Heat resistant ethylene-vinyl acetate rubber insulated cables
	2004	Part 8: Cords for applications requiring high flexibility
IEC 60309-2	2005	Plugs, socket-outlets and couplers for industrial purposes - Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories
IEC 61008-1	2006	Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) - Part 1: General rules
IEC 61008-2-1	1990	Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCB's). Part 2-1: Applicability of the general rules to RCCB's functionally independent of line voltage

1.2 IEC standards for electrical installation

1 Standards

STANDARD	YEAR	TITLE
IEC 61008-2-2	1990	Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCB's). Part 2-2: Applicability of the general rules to RCCB's functionally dependent on line voltage
IEC 61009-1	2006	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) - Part 1: General rules
IEC 61009-2-1	1991	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBO's) Part 2-1: Applicability of the general rules to RCBO's functionally independent of line voltage
IEC 61009-2-2	1991	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBO's) - Part 2-2: Applicability of the general rules to RCBO's functionally dependent on line voltage
IEC 60670-1	2002	Boxes and enclosures for electrical accessories for household and similar fixed electrical installations - Part 1: General requirements
IEC 60669-2-1	2002	Switches for household and similar fixed electrical installations - Part 2-1: Particular requirements – Electronic switches
IEC 60669-2-2	2006	Switches for household and similar fixed electrical installations - Part 2: Particular requirements – Section 2: Remote-control switches (RCS)
IEC 60669-2-3	2006	Switches for household and similar fixed electrical installations - Part 2-3: Particular requirements – Time-delay switches (TDS)
IEC 60079-10	2002	Electrical apparatus for explosive gas atmospheres - Part 10: Classification of hazardous areas
IEC 60079-14	2002	Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines)
IEC 60079-17	2002	Electrical apparatus for explosive gas atmospheres - Part 17: Inspection and maintenance of electrical installations in hazardous areas (other than mines)
IEC 60269-1	2006	Low-voltage fuses - Part 1: General requirements
IEC 60269-2	2006	Low-voltage fuses. Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) examples of standardized system of fuses A to I

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STANDARD	YEAR	TITLE
IEC 60269-3	2006	Low-voltage fuses - Part 3-1: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications) - Sections I to IV: examples of standardized system of fuses A to F
IEC 60127-1/10		Miniature fuses -
	2006	Part 1: Definitions for miniature fuses and general requirements for miniature fuse-links
	2003	Part 2: Cartridge fuse-links
	1988	Part 3: Sub-miniature fuse-links
	2005	Part 4: Universal Modular Fuse-Links (UMF) Through-hole and surface mount types
	1988	Part 5: Guidelines for quality assessment of miniature fuse-links
	1994	Part 6: Fuse-holders for miniature cartridge fuse-links
	2001	Part 10: User guide for miniature fuses
EC 60364-1	2005	Low-voltage electrical installations Part 1: Fundamental principles, assessment of general characteristics, definitions
IEC 60364-4-41	2005	Low-voltage electrical installations Part 4-41: Protection for safety - Protection against electric shock
IEC 60364-4-42	2001	Electrical installations of buildings Part 4-42: Protection for safety - Protection against thermal effects
IEC 60364-4-43	2001	Electrical installations of buildings Part 4-43: Protection for safety - Protection against overcurrent
IEC 60364-4-44	2006	Electrical installations of buildings Part 4-44: Protection for safety - Protection against voltage disturbances and electromagnetic disturbances
IEC 60364-5-51	2005	Electrical installations of buildings Part 5-51: Selection and erection of electrical equipment Common rules
IEC 60364-5-52	2001	Electrical installations of buildings Part 5-52: Selection and erection of electrical equipment Wiring systems
IEC 60364-5-53	2002	Electrical installations of buildings Part 5-53: Selection and erection of electrical equipment Isolation, switching and control
IEC 60364-5-54	2002	Electrical installations of buildings Part 5-54: Selection and erection of electrical equipment Earthing arrangements, protective conductors and protective bonding conductors

1.2 IEC standards for electrical installation

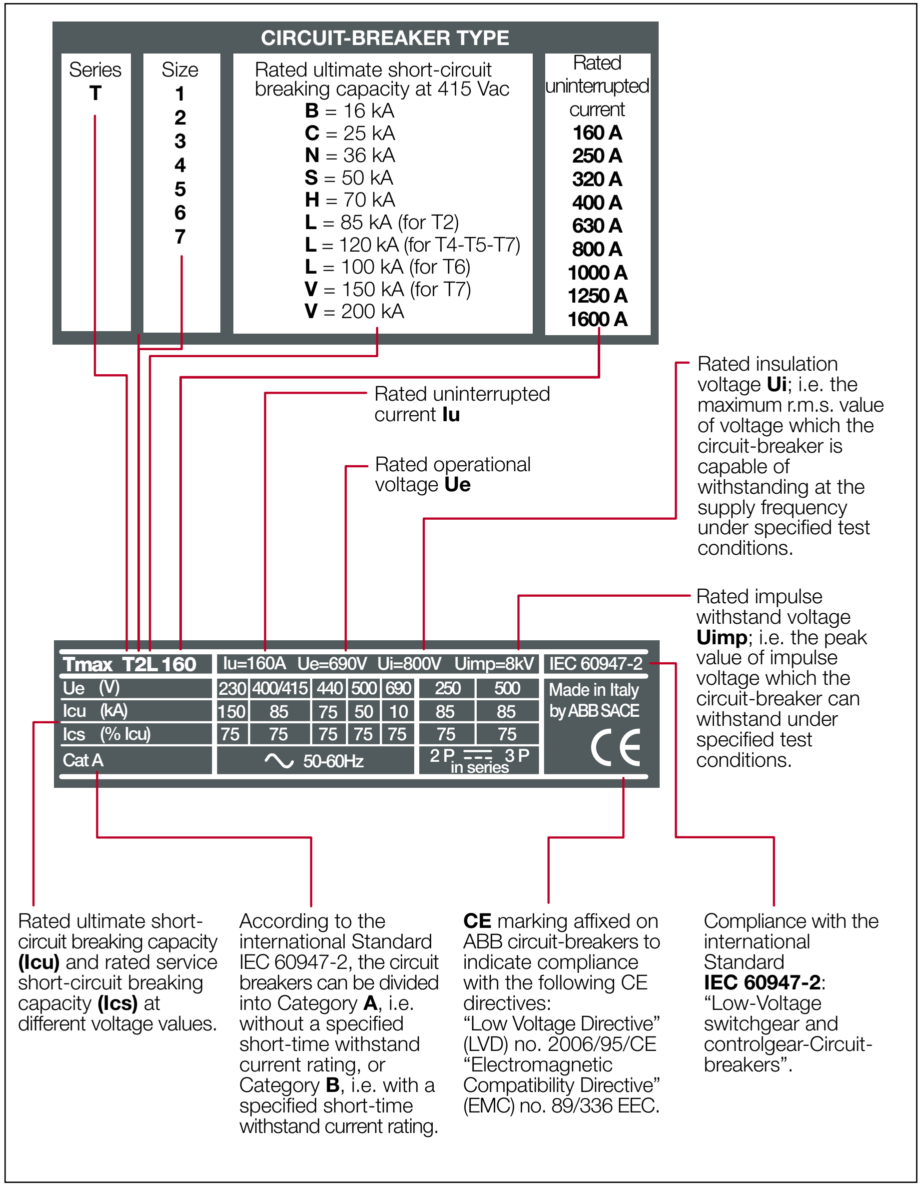
1 Standards

STANDARD	YEAR	TITLE
IEC 60364-5-55	2002	Electrical installations of buildings Part 5-55: Selection and erection of electrical equipment Other equipment
IEC 60364-6	2006	Electrical installations of buildings Part 6: Verification
IEC 60364-7	1984…2006	Electrical installations of buildings Part 7: Requirements for special installations or locations
IEC 60529	2001	Degrees of protection provided by enclosures (IP Code)
IEC 61032	1997	Protection of persons and equipment by enclosures - Probes for verification
IEC/TR 61000-1-1	1992	Electromagnetic compatibility (EMC) Part 1: General - Section 1: application and interpretation of fundamental definitions and terms
IEC/TR 61000-1-3	2002	Electromagnetic compatibility (EMC) Part 1-3: General - The effects of high-altitude EMP (HEMP) on civil equipment and systems

2 Protection and control devices

2.1 Circuit-breaker nameplates

Moulded-case circuit-breaker: Tmax



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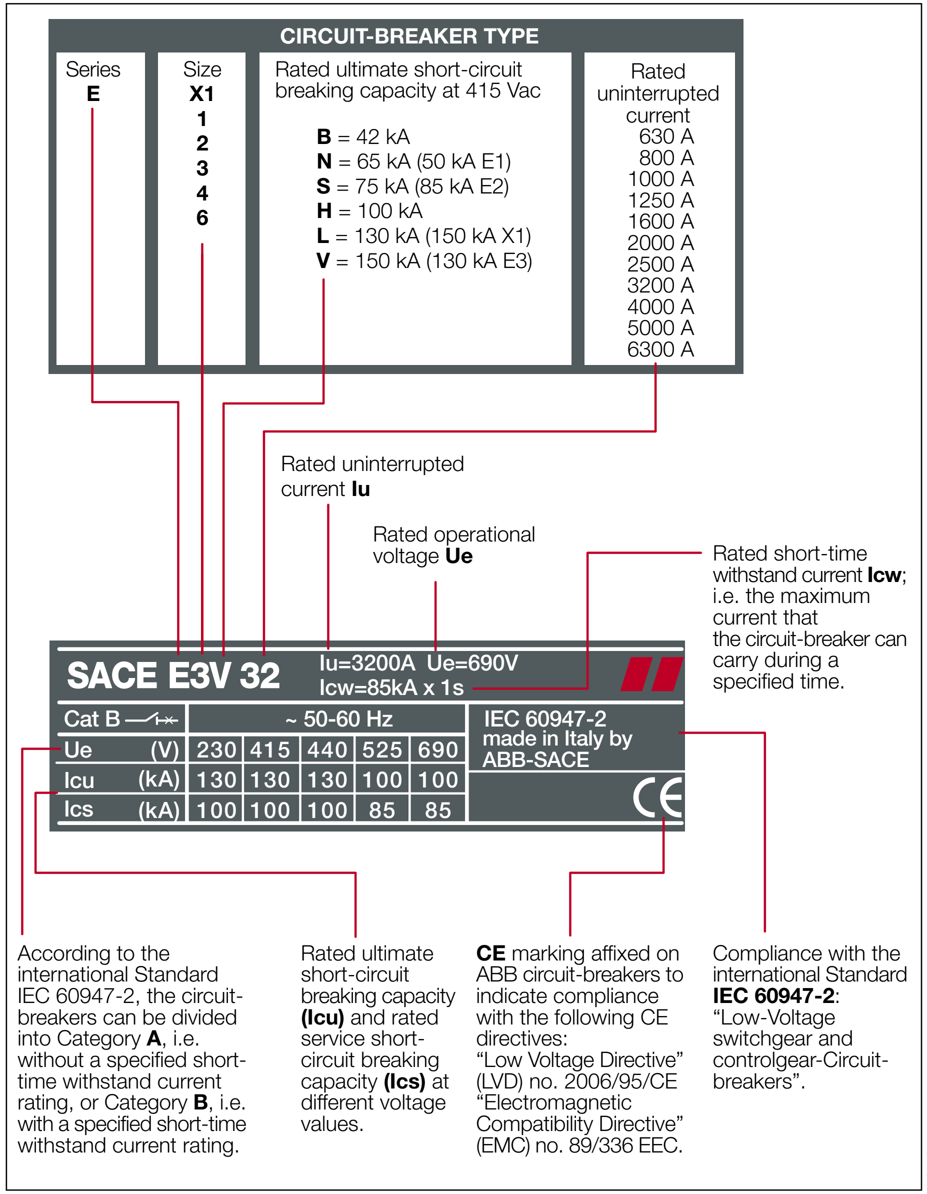
2 Protection and control devices

Air circuit-breaker: Emax



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2 Protection and control devices

2.2 Main definitions

The main definitions regarding LV switchgear and controlgear are included in the international Standards IEC 60947-1, IEC 60947-2 and IEC 60947-3.

Main characteristics

Circuit-breaker
A mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short-circuit.

Current-limiting circuit-breaker
A circuit-breaker with a break-time short enough to prevent the short-circuit current reaching its otherwise attainable peak value.

Plug-in circuit-breaker
A circuit-breaker which, in addition to its interrupting contacts, has a set of contacts which enable the circuit-breaker to be removed.

Withdrawable circuit-breaker
A circuit-breaker which, in addition to its interrupting contacts, has a set of isolating contacts which enable the circuit-breaker to be disconnected from the main circuit, in the withdrawn position, to achieve an isolating distance in accordance with specified requirements.

Moulded-case circuit-breaker
A circuit-breaker having a supporting housing of moulded insulating material forming an integral part of the circuit-breaker.

Disconnector
A mechanical switching device which, in the open position, complies with the requirements specified for the isolating function.

Release
A device, mechanically connected to a mechanical switching device, which releases the holding means and permits the opening or the closing of the switching device.

2 Protection and control devices

Fault types and currents

Overload
Operating conditions in an electrically undamaged circuit which cause an over-current.

Short-circuit
The accidental or intentional connection, by a relatively low resistance or impedance, of two or more points in a circuit which are normally at different voltages.

Residual current (I_{Δ})
It is the vectorial sum of the currents flowing in the main circuit of the circuit-breaker.

Rated performances

Voltages and frequencies

Rated operational voltage (U_e)
A rated operational voltage of an equipment is a value of voltage which, combined with a rated operational current, determines the application of the equipment and to which the relevant tests and the utilization categories are referred to.

Rated insulation voltage (U_i)
The rated insulation voltage of an equipment is the value of voltage to which dielectric tests voltage and creepage distances are referred. In no case the maximum value of the rated operational voltage shall exceed that of the rated insulation voltage.

Rated impulse withstand voltage (U_{imp})
The peak value of an impulse voltage of prescribed form and polarity which the equipment is capable of withstanding without failure under specified conditions of test and to which the values of the clearances are referred.

Rated frequency
The supply frequency for which an equipment is designed and to which the other characteristic values correspond.

Currents

Rated uninterrupted current (I_u)
The rated uninterrupted current of an equipment is a value of current, stated by the manufacturer, which the equipment can carry in uninterrupted duty.

Rated residual operating current ($I_{\Delta n}$)
It is the r.m.s. value of a sinusoidal residual operating current assigned to the CBR by the manufacturer, at which the CBR shall operate under specified conditions.

2 Protection and control devices

Performances under short-circuit conditions

Rated making capacity
The rated making capacity of an equipment is a value of current, stated by the manufacturer, which the equipment can satisfactorily make under specified making conditions.

Rated breaking capacity
The rated breaking of an equipment is a value of current, stated by the manufacturer, which the equipment can satisfactorily break, under specified breaking conditions.

Rated ultimate short-circuit breaking capacity (I_{cu})
The rated ultimate short-circuit breaking capacity of a circuit-breaker is the maximum short-circuit current value which the circuit-breaker can break twice (in accordance with the sequence O – t – CO), at the corresponding rated operational voltage. After the opening and closing sequence the circuit-breaker is not required to carry its rated current.

Rated service short-circuit breaking capacity (I_{cs})
The rated service short-circuit breaking capacity of a circuit-breaker is the maximum short-circuit current value which the circuit-breaker can break three times in accordance with a sequence of opening and closing operations (O - t - CO - t – CO) at a defined rated operational voltage (U_e) and at a defined power factor. After this sequence the circuit-breaker is required to carry its rated current.

Rated short-time withstand current (I_{cw})
The rated short-time withstand current is the current that the circuit-breaker in the closed position can carry during a specified short time under prescribed conditions of use and behaviour; the circuit-breaker shall be able to carry this current during the associated short-time delay in order to ensure discrimination between the circuit-breakers in series.

Rated short-circuit making capacity (I_{cm})
The rated short-circuit making capacity of an equipment is the value of short-circuit making capacity assigned to that equipment by the manufacturer for the rated operational voltage, at rated frequency, and at a specified power-factor for ac.

2.2 Main definitions

2 Protection and control devices

Utilization categories

The utilization category of a circuit-breaker shall be stated with reference to whether or not it is specifically intended for selectivity by means of an intentional time delay with respect to other circuit-breakers in series on the load side, under short-circuit conditions (Table 4 IEC 60947-2).

Category A - Circuit-breakers not specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. without a short-time withstand current rating.

Category B - Circuit-breakers specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. with and intentional short-time delay provided for selectivity under short-circuit conditions. Such circuit-breakers have a short-time withstand current rating.
A circuit-breaker is classified in category B if its I_{cw} is higher than (Table 3 IEC 60947-2):

12·In or 5 kA, whichever is the greater	for In ≤ 2500A
30 kA	for In > 2500A

Electrical and mechanical durability

Mechanical durability
The mechanical durability of an apparatus is expressed by the number of no-load operating cycles (each operating cycle consists of one closing and opening operation) which can be effected before it becomes necessary to service or replace any of its mechanical parts (however, normal maintenance may be permitted).

Electrical durability
The electrical durability of an apparatus is expressed by the number of on-load operating cycles and gives the contact resistance to electrical wear under the service conditions stated in the relevant product Standard.

2 Protection and control devices

2.3 Types of releases

A circuit-breaker must control and protect, in case of faults or malfunctioning, the connected elements of a plant. In order to perform this function, after detection of an anomalous condition, the release intervenes in a definite time by opening the interrupting part.
The protection releases fitted with ABB SACE moulded-case and air circuit-breakers can control and protect any plant, from the simplest ones to those with particular requirements, thanks to their wide setting possibilities of both thresholds and tripping times.
Among the devices sensitive to overcurrents, the following can be considered:

- thermomagnetic releases and magnetic only releases;
- microprocessor-based releases;
- residual current devices.

The choice and adjusting of protection releases are based both on the requirements of the part of plant to be protected, as well as on the coordination with other devices; in general, discriminating factors for the selection are the required threshold, time and curve characteristic.

2.3.1 THERMOMAGNETIC RELEASES AND MAGNETIC ONLY RELEASES

The thermomagnetic releases use a bimetal and an electromagnet to detect overloads and short-circuits; they are suitable to protect both alternating and direct current networks.

The following table shows the types of thermo-magnetic and magnetic only trip units available for Tmax circuit-breakers.

CBs	thermomagnetic releases					
	MF	MA	TMF	TMD	TMA	TMG
T1	-	-	■	■	-	-
T2	■	■	-	■	-	■
T3	-	■	-	■	-	■
T4	-	■	-	■	■	-
T5	-	-	-	-	■	■
T6	-	-	-	-	■	-

Legenda
MF Fixed magnetic only releases
MA Adjustable magnetic only releases
TMG Thermomagnetic release for generator protection
TMF Thermomagnetic release with thermal and fixed magnetic threshold
TMD Thermomagnetic release with adjustable thermal and fixed magnetic threshold
TMA Thermomagnetic release with adjustable thermal and magnetic threshold

2 Protection and control devices

Power distribution

<table>
<tr><th>MCCBs</th><th>T1</th><th>T2</th><th>T3</th><th>T4</th><th colspan="2">T5</th><th colspan="2">T6</th></tr>
<tr><th>In \ Iu</th><th>160</th><th>160</th><th>250</th><th>250</th><th>400</th><th>630</th><th>630</th><th>800</th></tr>
<tr><td>1,6</td><td rowspan="10"></td><td rowspan="10">TMD</td><td rowspan="14"></td><td rowspan="11"></td><td rowspan="23"></td><td rowspan="23"></td><td rowspan="26"></td><td rowspan="27"></td></tr>
<tr><td>2</td></tr>
<tr><td>2,5</td></tr>
<tr><td>3,2</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td></tr>
<tr><td>6,3</td></tr>
<tr><td>8</td></tr>
<tr><td>10</td></tr>
<tr><td>12.5</td></tr>
<tr><td>16</td><td rowspan="11">TMF
TMD</td><td>TMD
TMG</td></tr>
<tr><td>20</td><td>TMD</td><td>TMD</td></tr>
<tr><td>25</td><td>TMD
TMG</td><td></td></tr>
<tr><td>32</td><td>TMD</td><td>TMD</td></tr>
<tr><td>40</td><td>TMD
TMG</td><td>TMG</td><td></td></tr>
<tr><td>50</td><td>TMD</td><td></td><td>TMD</td></tr>
<tr><td>63</td><td rowspan="5">TMD
TMG</td><td rowspan="7">TMD
TMG</td><td></td></tr>
<tr><td>80</td><td rowspan="6">TMA</td></tr>
<tr><td>100</td></tr>
<tr><td>125</td></tr>
<tr><td>160</td></tr>
<tr><td>200</td><td rowspan="7"></td><td rowspan="7"></td></tr>
<tr><td>250</td></tr>
<tr><td>320</td><td rowspan="5"></td><td rowspan="5"></td><td rowspan="2">TMA
TMG</td><td rowspan="3">TMA
TMG</td></tr>
<tr><td>400</td></tr>
<tr><td>500</td><td rowspan="3"></td></tr>
<tr><td>630</td><td rowspan="2"></td><td>TMA</td></tr>
<tr><td>800</td><td></td><td>TMA</td></tr>
</table>

Motor protection

<table>
<tr><th>MCCBs</th><th>T2</th><th>T3</th><th>T4</th></tr>
<tr><th>In \ Iu</th><th>160</th><th>250</th><th>250</th></tr>
<tr><td>1</td><td rowspan="12">MF</td><td rowspan="17"></td><td rowspan="9"></td></tr>
<tr><td>1,6</td></tr>
<tr><td>2</td></tr>
<tr><td>2,5</td></tr>
<tr><td>3,2</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td></tr>
<tr><td>6,5</td></tr>
<tr><td>8,5</td></tr>
<tr><td>10</td><td>MA</td></tr>
<tr><td>11</td><td rowspan="3"></td></tr>
<tr><td>12,5</td></tr>
<tr><td>20</td><td>MA</td></tr>
<tr><td>25</td><td></td><td>MA</td></tr>
<tr><td>32</td><td rowspan="4">MA</td><td></td></tr>
<tr><td>52</td><td rowspan="6">MA</td></tr>
<tr><td>80</td></tr>
<tr><td>100</td><td rowspan="4">MA</td></tr>
<tr><td>125</td><td rowspan="3"></td></tr>
<tr><td>160</td></tr>
<tr><td>200</td></tr>
</table>

Legenda
MF Fixed magnetic only releases
MA Adjustable magnetic only releases
TMG Thermomagnetic release for generator protection
TMF Thermomagnetic release with thermal and fixed magnetic threshold
TMD Thermomagnetic release with adjustable thermal and fixed magnetic threshold
TMA Thermomagnetic release with adjustable thermal and magnetic threshold

2 Protection and control devices

2.3.2 ELECTRONIC RELEASES

These releases are connected with current transformers (three or four according to the number of conductors to be protected), which are positioned inside the circuit-breaker and have the double functions of supplying the power necessary to the proper functioning of the release (self-supply) and of detecting the value of the current flowing inside the live conductors; therefore they are compatible with alternating current networks only.
The signal coming from the transformers and from the Rogowsky coils is processed by the electronic component (microprocessor) which compares it with the set thresholds. When the signal exceeds the thresholds, the trip of the circuit-breaker is operated through an opening solenoid which directly acts on the circuit-breaker operating mechanism.
In case of auxiliary power supply in addition to self-supply from the current transformers, the voltage shall be 24 Vdc ± 20%.

Besides the standard protection functions, releases provide:

- measurements of currents (PR222, PR232, PR331, PR121);
- measurement of currents,voltage,frequency,power,energy,power factor (PR223,PR332,PR122) and moreover for PR333 and PR123, the measurement of harmonic distortions is available;
- serial comunication with remote control for a complete management of the plant (PR222, PR223, PR232, PR331, PR332, PR333, PR121, PR122, PR123).

The following table shows the types of electronic trip units available for Tmax and Emax circuit-breakers.

CBs	electronic releases with ABB circuit breakers										
	PR221	PR222	PR223	PR231	PR232	PR331	PR332	PR333	PR121	PR122	PR123
T2	■	-	-	-	-	-	-	-	-	-	-
T4	■	■	■	-	-	-	-	-	-	-	-
T5	■	■	■	-	-	-	-	-	-	-	-
T6	■	■	■	-	-	-	-	-	-	-	-
T7	-	-	-	■	■	■	■	-	-	-	-
X1	-	-	-	-	-	■	■	■	-	-	-
E1	-	-	-	-	-	-	-	-	■	■	■
E2	-	-	-	-	-	-	-	-	■	■	■
E3	-	-	-	-	-	-	-	-	■	■	■
E4	-	-	-	-	-	-	-	-	■	■	■
E5	-	-	-	-	-	-	-	-	■	■	■
E6	-	-	-	-	-	-	-	-	■	■	■

2 Protection and control devices

The following table shows the available rated currents with the Tmax and Emax circuit- breakers.

MCCBs	T2	T4		T5		T6			T7			
In \ Iu	160	250	320	400	630	630	800	1000	800	1000	1250	1600
10	■	-	-	-	-	-	-	-	-	-	-	-
25	■	-	-	-	-	-	-	-	-	-	-	-
63	■	-	-	-	-	-	-	-	-	-	-	-
100	■	■	■	-	-	-	-	-	-	-	-	-
160	■	■	■	-	-	-	-	-	-	-	-	-
250	-	■	■	-	-	-	-	-	-	-	-	-
320	-	-	■	■	■	-	-	-	-	-	-	-
400	-	-	-	■	■	-	-	-	■	■	■	■
630	-	-	-	-	■	■	-	-	■	■	■	■
800	-	-	-	-	-	-	■	-	■	■	■	■
1000	-	-	-	-	-	-	-	■	-	■	■	■
1250	-	-	-	-	-	-	-	-	-	-	■	■
1600	-	-	-	-	-	-	-	-	-	-	-	■

ACBs		E3H-V	E3 N-S-H-V		E3 S-H-V-L		E3 N-S-H-V	E4S-H-V		E6V	E6H-V		
		E2S	E2N-S-L	E2B-N-S-L	E2B-N-S								
		E1B-N											
	X1B-N-L			X1B-N									
In \ Iu	630	800	1250*	1600	2000	2500	3200		4000	3200	4000	5000	6300
400	■	■	■	■	■	■	■	-	-	-	-	-	-
630	■	■	■	■	■	■	■	-	-	-	-	-	-
800	-	■	■	■	■	■	■	-	-	-	-	-	-
1000	-	-	■	■	■	■	■	-	-	-	-	-	-
1250	-	-	■	■	■	■	■	■	■	-	-	-	-
1600	-	-	-	■	■	■	■	■	■	-	-	-	-
2000	-	-	-	-	■	■	■	■	■	-	-	-	-
2500	-	-	-	-	-	■	■	■	■	-	-	-	-
3200	-	-	-	-	-	-	■	■	■	■	■	■	■
4000	-	-	-	-	-	-	-	-	■	-	■	■	■
5000	-	-	-	-	-	-	-	-	-	-	-	■	■
6300	-	-	-	-	-	-	-	-	-	-	-	-	■

* Also for Iu = 1000 A (not available for E3V and E2L).

Example of reading from the table

The circuit-breaker type E3L is available with Iu=2000A and Iu=2500A, but it is not available with Iu=3200A.

2.3.2.1 PROTECTION FUNCTIONS OF ELECTRONIC RELEASES

The protection functions available for the electronic releases are:

L - Overload protection with inverse long time delay
Function of protection against overloads with inverse long time delay and constant specific let-through energy; it cannot be excluded.

L - Overload protection in compliance with Std. IEC 60255-3
Function of protection against overloads with inverse long time delay and trip curves complying with IEC 60255-3; applicable in the coordination with fuses and with medium voltage protections.

S - Short-circuit protection with adjustable delay
Function of protection against short-circuit currents with adjustable delay; thanks to the adjustable delay, this protection is particularly useful when it is necessary to obtain selective coordination between different devices.

2 Protection and control devices

S_2- Double S
This function allows two thresholds of protection function S to be set independently and activated simultaneously, selectivity can also be achieved under highly critical conditions.

D - Directional short-circuit protection with adjustable delay
The directional protection, which is similar to function S, can intervene in a different way according to the direction of the short-circuit current; particularly suitable in meshed networks or with multiple supply lines in parallel.

I - Short-circuit protection with instantaneous trip
Function for the instantaneous protection against short-circuit.

EFDP - Early Fault Detection and Prevention
Thanks to this function, the release is able to isolate a fault in shorter times than the zone selectivities currently available on the market.

Rc - Residual current protection
This function is particularly suitable where low-sensitivity residual current protection is required and for high-sensitivity applications to protect people against indirect contact.

G - Earth fault protection with adjustable delay
Function protecting the plant against earth faults.

U - Phase unbalance protection
Protection function which intervenes when an excessive unbalance between the currents of the single phases protected by the circuit-breaker is detected.

OT - Self-protection against overtemperature
Protection function controlling the opening of the circuit-breaker when the temperature inside the release can jeopardize its functioning.

UV - Undervoltage protection
Protection function which intervenes when the phase voltage drops below the preset threshold.

OV - Overvoltage protection
Protection function which intervenes when the phase voltage exceeds the preset threshold.

RV - Residual voltage protection
Protection which identifies anomalous voltages on the neutral conductor.

RP - Reverse power protection
Protection which intervenes when the direction of the active power is opposite to normal operation.

UF - Under frequency protection
This frequency protection detects the reduction of network frequency above the adjustable threshold, generating an alarm or opening the circuit.

OF - Overfrequency protection
This frequency protection detects the increase of network frequency above the adjustable threshold, generating an alarm or opening the circuit.

M - Thermal memory
Thanks to this function, it is possible to take into account the heating of a component so that the tripping is the quicker the less time has elapsed since the last one.

R - Protection against rotor blockage
Function intervening as soon as conditions are detected, which could lead to the block of the rotor of the protected motor during operation.

2 Protection and control devices

Iinst - Very fast instantaneous protection against short-circuit
This particular protection function has the aim of maintaining the integrity of the circuit-breaker and of the plant in case of high currents requiring delays lower than those guaranteed by the protection against instantaneous short-circuit. This protection must be set exclusively by ABB SACE and cannot be excluded.

Dual setting
With this function it is possible to program two different sets of parameters (LSIG) and, through an external command, to switch from one set to the other.

K - Load control
Thanks to this function, it is possible to engage/disengage individual loads on the load side before the overload protection L trips.

The following table summarizes the types of electronic release and the functions they implement:

PR221	PR222	PR223	PR231	PR232	PR331	PR332	PR333	PR121	PR122	PR123	Protection functions	Releases
■	■	■	■	■	■	■	■	■	■	■	**L** (t=k/I²)	Protection against overload
						■	■		■	■	**L**	Standard trip curve according to IEC 60255-3
	■	■		■	■	■	■	■	■	■	**S1** (t=k)	Protection against short-circuit with time delay
■	■	■	■	■	■	■	■	■	■	■	**S1** (t=k/I²)	Protection against short-circuit with time delay
							■			■	**S2** (t=k)	Protection against short-circuit with time delay
							■			■	**D** (t=k)	Protection against directional short-circuit
■	■	■	■	■	■	■	■	■	■	■	**I** (t=k)	Protection against instantaneous short-circuit
	■	■			■	■	■	■	■	■	**G** (t=k)	Protection against earth fault with adjustable delay
	■	■			■	■	■	■	■	■	**G** (t=k/I²)	Protection against earth fault with adjustable delay
						■	■		■	■	**Gext** (t=k)	Protection against earth fault with adjustable delay
						■	■		■	■	**Gext** (t=k/I²)	Protection against earth fault with adjustable delay
						■	■		■	■	**Gext** (Idn)	Protection against earth fault with adjustable delay
						○	■		○	■	**Rc** (t=k)	Residual current protection
						■	■		■	■	**U** (t=k)	Protection against phase unbalance
						■	■		■	■	**OT**	Protection against temperature out of range
						○	■		○	■	**UV** (t=k)	Protection against undervoltage
						○	■		○	■	**OV** (t=k)	Protection against overvoltage
						○	■		○	■	**RV** (t=k)	Protection against residual voltage
						○	■		○	■	**RP** (t=k)	Protection against reverse active power
						○	■		○	■	**UF**	Protection against underfrequency
						○	■		○	■	**OF**	Protection against overfrequency
						■	■	■	■	■	**Iinst**	Instantantaneous self-protection
		■									**EF**	Early Fault Detection and Prevention

○ Only with PR120/V for Emax and PR330/V for X1

2 Protection and control devices

2.3.3 RESIDUAL CURRENT DEVICES

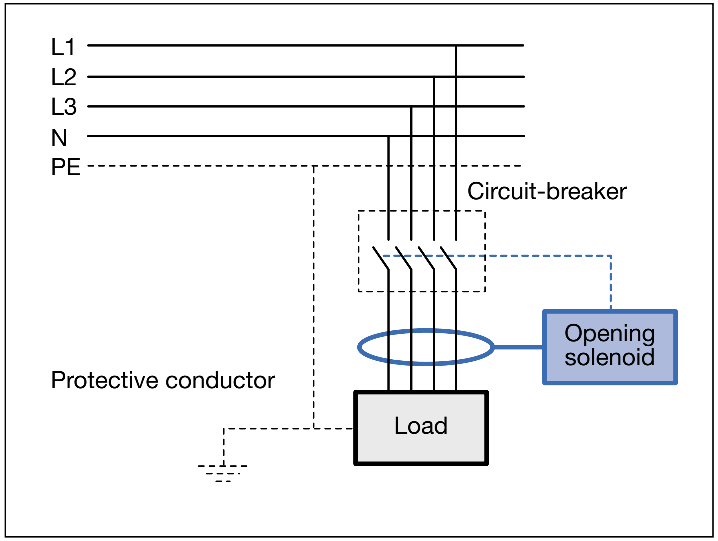
The residual current releases are associated with the circuit-breaker in order to obtain two main functions in a single device:
- protection against overloads and short-circuits;
- protection against indirect contacts (presence of voltage on exposed conductive parts due to loss of insulation).

Besides, they can guarantee an additional protection against the risk of fire deriving from the evolution of small fault or leakage currents which are not detected by the standard protections against overload.
Residual current devices having a rated residual current not exceeding 30 mA are also used as a means for additional protection against direct contact in case of failure of the relevant protective means.
Their logic is based on the detection of the vectorial sum of the line currents through an internal or external toroid.
This sum is zero under service conditions or equal to the earth fault current (I_Δ) in case of earth fault.

When the release detects a residual current different from zero, it opens the circuit-breaker through an opening solenoid.

As we can see in the picture the protection conductor or the equipotential conductor have to be installed outside the eventual external toroid.

Generic distribution system (IT, TT, TN)



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The operating principle of the residual current release makes it suitable for the distribution systems TT, IT (even if paying particular attention to the latter) and TN-S, but not in the systems TN-C. In fact, in these systems, the neutral is used also as protective conductor and therefore the detection of the residual current would not be possible if the neutral passes through the toroid, since the vectorial sum of the currents would always be equal to zero.

2 Protection and control devices

One of the main characteristics of a residual current release is its minimum rated residual current $I_{\Delta n}$. This represents the sensitivity of the release.
According to their sensitivity to the fault current, the residual current circuit-breakers are classified as:
- type AC: a residual current device for which tripping is ensured in case of residual sinusoidal alternating current, in the absence of a dc component whether suddenly applied or slowly rising;
- type A: a residual current device for which tripping is ensured for residual sinusoidal alternating currents in the presence of specified residual pulsating direct currents, whether suddenly applied or slowly rising.
- type B residual current device for which tripping is ensured for residual sinusoidal alternating currents in presence of specified residual pulsanting direct currents whether suddenly applied or slowy rising, for residual directs may result from rectifying circuits.

	Form of residual current	Correct functioning of residual current devices Type		
		AC	A	B
Sinusoidal ac	suddenly applied slowly rising	+	+	+
Pulsating dc	suddenly applied with or without 0,006A slowly rising		+	+
Smooth dc				+

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In presence of electrical apparatuses with electronic components (computers, photocopiers, fax etc.) the earth fault current might assume a non sinusoidal shape but a type of a pulsating unidirectional dc shape. In these cases it is necessary to use a residual current release classified as type A.
In presence of rectifying circuits (i.e. single phase connection with capacitive load causing smooth direct current, three pulse star connection or six pulse bridge connection, two pulse connection line-to-line) the earth fault current might assume a unidirectional dc shape. In this case it is necessary to use a residual current release classified as type B.

2 Protection and control devices

In order to fulfill the requirements for an adequate protection against earth faults ABB SACE has designed the following product categories:

-moulded case circuit breakers:

- RC221 residual current releases to be coupled with circuit-brakers Tmax T1, T2, T3 with rated current from 16 A to 250A;
- RC222 residual current releases to be coupled with circuit-breakers Tmax T1,T2,T3,T4,T5 with rated currents from 16A to 500A;
- RC223 residual current releases to coupled with circuit-breaker Tmax T4 with rated currents up to 250A;
- electronic releases PR222DS/P, PR223 DS/P LSIG for circuit breakers T4, T5, T6 with rated current from 100A to 1000A;
- electronic releases PR331, PR332 LSIG for the circuit breaker Tmax T7 with rated currents from 800A to 1600A;
- electronic release R332 with residual current integrated protection for the circuit-breaker type Tmax T7 with rated uninterrupted current from 800A to 1600A.

		RC221	RC222		RC223
Circuit-breaker size		T1-T2-T3	T1-T2-T3	T4 and T5 4p	T4 4p
Type		"L" shaped		placed below	
Technology		microprocessor-based			
Action		With trip coil			
Primary service voltage (1)	[V]	85…500	85…500	85…500	110…500
Operating frequence	[Hz]	45…66	45…66	45…66	0-400-700-1000
Self-supply		■	■	■	■
Test operation range (1)		85…500	85…500	85…500	110…500
Rated service current	[A]	up to 250 A	up to 250 A	up to 500 A	up to 250 A
Rated residual current trip	[A]	0.03-0.1-0.3 0.5-1-3	0.03-0.05-0.1-0.3 0.5-1-3-5-10	0.03-0.05-0.1 0.3-0.5-1-3-5-10	0.03-0.05-0.1 0.3-0.5-1
Time limit for non-trip	[s]	Istantaneous	Istantaneous - 0.1 -0.2-0.3-0.5-1-2-3	Istantaneous - 0.1 -0.2-0.3-0.5-1-2-3	Istantaneous -0- 0.1 -0.2-0.3-0.5-1-2-3
Tolerance over trip times			±20%	±20%	±20%

(1) Operation up to 50 V phase-neutral (55 V for RC223).

-air circuit breaker:

- PR331, PR332, PR333 LSIG electronic releases for the circuit breaker Emax X1 with rated uninterrupted currents from 630A to 1600A;
- Air circuit breaker equipped with electronic releases type PR121, PR122, PR123 LSIG for the circuit breaker Emax E1 to E6 with rated uninterrupted currents from 400A to 6300A.
- PR332, PR333 electronic releases with residual current integrated protection for circuit-breaker Emax X1 with rated uninterrupted currents from 630A to 1600A;
- PR122 and PR123 electronic releases with residual current integrated protection for circuit-breakers Emax E1 to E6 with rated uninterrupted currents from 400A to 6300A

2 Protection and control devices

The following table resume the range of ABB SACE circuit breakers for the protection against residual current and earth fault.

		In	RC221	RC222	RC223	PR222 LSIG	PR223 LSIG	PR331 PR332 PR333(2) LSIG	PR332 PR333(2) LSIRc	PR121 PR122 PR123 LSIG	PR122 LSIRc
		type	A-AC	A-AC	B	-	-	-	A-AC	-	A-AC
MCCb	T1	16÷160	■	■	-	-	-	-	-	-	-
	T2	10÷160	■	■	-	-	-	-	-	-	-
	T3	63÷250	■	■	-	-	-	-	-	-	-
	T4	100÷320	-	■	(1)■	■	■	-	-	-	-
	T5	320÷630	-	■	-	■	■	-	-	-	-
	T6	630÷1000	-	-	-	■	■	-	-	-	-
	T7	800÷1600	-	-	-	-	-	■	■	-	-
ACB	X1	400÷1600	-	-	-	-	-	■	■	-	-
	E1	400÷1600	-	-	-	-	-	-	-	■	■
	E2	400÷2000	-	-	-	-	-	-	-	■	■
	E3	400÷3200	-	-	-	-	-	-	-	■	■
	E4	1250÷4000	-	-	-	-	-	-	-	■	-
	E6	3200÷6300	-	-	-	-	-	-	-	■	-

(1) Only for T4 250.
(2) Only for X1.

Residual current relay with external transformer

ABB SACE circuit breaker can be combined also with the residual current relays RCQ with separate toroid in order to fulfill the requirements when the installation conditions are particulary restrictive, such as with circuit breakers already installed, limited space in the circuit breaker compartment etc.
Thanks to the settings characteristics of the residual current and of the trip times, the residual current relays with external transformer can be easily installed also in the final stages of the plant; in particolar, by selecting the rated residual current IΔn=0.03A with instantaneous tripping, the circuit-breaker guarantees protection against indirect contact and represents an additional measure against direct contact also in the presence of particulary high earth resistance values.
Such residual current relays are of the type with indirect action: the opening command given by the relay must cause the tripping of the circuit-breaker through a shunt opening release (to be provided by the user).

Residual current relays			SACE RCQ
Power supply voltage		AC [V]	80…500
		DC [V]	48…125
Operating frequency		[Hz]	45÷66
TripThreshold adjustement IΔn	1st range of settings'	[A]	0.03-0.05-0.1-0.3-0.5
	2nd range of settings'	[A]	1-3-5-10-30
Trip time adjustement		[s]	0-0.1-0.2-0.3-0.5-0.7-1-2-3-5

3 General characteristics

3.1 Electrical characteristics of circuit-breakers

Tmax moulded-case circuit-breakers

		Tmax T1 1P	Tmax T1			Tmax T2			
Rated uninterrupted current, **Iu**	[A]	160	160			160			
Poles	[Nr]	1	3/4			3/4			
Rated service current, **Ue** (AC) 50-60 Hz	[V]	240	690			690			
(DC)	[V]	125	500			500			
Rated impulse withstand voltage, **Uimp**	[kV]	8	8			8			
Rated insulation voltage, **Ui**	[V]	500	800			800			
Test voltage at industrial frequency for 1 min.	[V]	3000	3000			3000			
Rated ultimate short-circuit breaking capacity, **Icu**		**B**	**B**	**C**	**N**	**N**	**S**	**H**	**L**
(AC) 50-60 Hz 220/230 V	[kA]	25*	25	40	50	65	85	100	120
(AC) 50-60 Hz 380/415 V	[kA]	–	16	25	36	36	50	70	85
(AC) 50-60 Hz 440 V	[kA]	–	10	15	22	30	45	55	75
(AC) 50-60 Hz 500 V	[kA]	–	8	10	15	25	30	36	50
(AC) 50-60 Hz 690 V	[kA]	–	3	4	6	6	7	8	10
(DC) 250 V - 2 poles in series	[kA]	25 (at 125 V)	16	25	36	36	50	70	85
(DC) 250 V - 3 poles in series	[kA]	–	20	30	40	40	55	85	100
(DC) 500 V - 2 poles in series	[kA]	–	–	–	–	–	–	–	–
(DC) 500 V - 3 poles in series	[kA]	–	16	25	36	36	50	70	85
(DC) 750 V - 3 poles in series	[kA]	–	–	–	–	–	–	–	–
Rated service short-circuit breaking capacity, **Ics**									
(AC) 50-60 Hz 220/230 V	[%Icu]	75%	100%	75%	75%	100%	100%	100%	100%
(AC) 50-60 Hz 380/415 V	[%Icu]	–	100%	100%	75%	100%	100%	100%	75% (70 kA)
(AC) 50-60 Hz 440 V	[%Icu]	–	100%	75%	50%	100%	100%	100%	75%
(AC) 50-60 Hz 500 V	[%Icu]	–	100%	75%	50%	100%	100%	100%	75%
(AC) 50-60 Hz 690 V	[%Icu]	–	100%	75%	50%	100%	100%	100%	75%
Rated short-circuit making capacity, **Icm**									
(AC) 50-60 Hz 220/230 V	[kA]	52.5	52.5	84	105	143	187	220	264
(AC) 50-60 Hz 380/415 V	[kA]	–	32	52.5	75.6	75.6	105	154	187
(AC) 50-60 Hz 440 V	[kA]	–	17	30	46.2	63	94.5	121	165
(AC) 50-60 Hz 500 V	[kA]	–	13.6	17	30	52.5	63	75.6	105
(AC) 50-60 Hz 690 V	[kA]	–	4.3	5.9	9.2	9.2	11.9	13.6	17
Opening time (415 V)	[ms]	7	7	6	5	3	3	3	3
Utilisation category (IEC 60947-2)		A	A			A			
Reference Standard		IEC 60947-2	IEC 60947-2			IEC 60947-2			
Isolation behaviour		■	■			■			
Interchangeability		–	–			–			
Versions		F	F			F-P			
Mechanical life	[No. operations]	25000	25000			25000			
	[No. Hourly operations]	240	240			240			
Electrical life @ 415 V AC	[No. operations]	8000	8000			8000			
	[No. Hourly operations]	120	120			120			

F = fixed circuit-breakers
P = plug-in circuit-breakers
W = withdrawable circuit-breakers

(*) The breaking capacity for settings In=16 A and In=20 A is 16 kA

3 General characteristics

	Tmax T3		Tmax T4					Tmax T5					Tmax T6				Tmax T7			
Rated uninterrupted current, **Iu** [A]	250		250/320					400/630					630/800/1000				800/1000/1250/1600			
Poles [Nr]	3/4		3/4					3/4					3/4				3/4			
Rated service current, **Ue** (AC) 50-60 Hz [V]	690		690					690					690				690			
(DC) [V]	500		750					750					750				–			
Rated impulse withstand voltage, **Uimp** [kV]	8		8					8					8				8			
Rated insulation voltage, **Ui** [V]	800		1000					1000					1000				1000			
Test voltage at industrial frequency for 1 min. [V]	3000		3500					3500					3500				3500			
Rated ultimate short-circuit breaking capacity, **Icu**	**N**	**S**	**N**	**S**	**H**	**L**	**V**	**N**	**S**	**H**	**L**	**V**	**N**	**S**	**H**	**L**	**S**	**H**	**L**	**V**[(6)]
(AC) 50-60 Hz 220/230 V [kA]	50	85	70	85	100	200	200	70	85	100	200	200	70	85	100	200	85	100	200	200
(AC) 50-60 Hz 380/415 V [kA]	36	50	36	50	70	120	200	36	50	70	120	200	36	50	70	100	50	70	120	150
(AC) 50-60 Hz 440 V [kA]	25	40	30	40	65	100	180	30	40	65	100	180	30	45	50	80	50	65	100	130
(AC) 50-60 Hz 500 V [kA]	20	30	25	30	50	85	150	25	30	50	85	150	25	35	50	65	40	50	85	100
(AC) 50-60 Hz 690 V [kA]	5	8	20	25	40	70	80	20	25	40	70	80	20	22	25	30	30	42	50	60
(DC) 250 V - 2 poles in series [kA]	36	50	36	50	70	100	150	36	50	70	100	150	36	50	70	100	–	–	–	–
(DC) 250 V - 3 poles in series [kA]	40	55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
(DC) 500 V - 2 poles in series [kA]	–	–	25	36	50	70	100	25	36	50	70	100	20	35	50	65	–	–	–	–
(DC) 500 V - 3 poles in series [kA]	36	50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
(DC) 750 V - 3 poles in series [kA]	–	–	16	25	36	50	70	16	25	36	50	70	16	20	36	50	–	–	–	–
Rated service short-circuit breaking capacity, **Ics**																				
(AC) 50-60 Hz 220/230 V [%Icu]	75%	50%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	75%	100%	100%	100%	100%
(AC) 50-60 Hz 380/415 V [%Icu]	75%	50% (27 kA)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	75%	100%	100%	100%	100%
(AC) 50-60 Hz 440 V [%Icu]	75%	50%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	75%	100%	100%	100%	100%
(AC) 50-60 Hz 500 V [%Icu]	75%	50%	100%	100%	100%	100%	100%	100%	100%	100%	100%[(1)]	100%[(2)]	100%	100%	100%	75%	100%	100%	75%	100%
(AC) 50-60 Hz 690 V [%Icu]	75%	50%	100%	100%	100%	100%	100%	100%	100%	100%[(1)]	100%[(2)]	100%[(2)]	75%	75%	75%	75%	100%	75%	75%	75%
Rated short-circuit making capacity, **Icm**																				
(AC) 50-60 Hz 220/230 V [kA]	105	187	154	187	220	440	660	154	187	220	440	660	154	187	220	440	187	220	440	440
(AC) 50-60 Hz 380/415 V [kA]	75.6	105	75.6	105	154	264	440	75.6	105	154	264	440	75.6	105	154	220	105	154	264	330
(AC) 50-60 Hz 440 V [kA]	52.5	84	63	84	143	220	396	63	84	143	220	396	63	94.5	105	176	105	143	220	286
(AC) 50-60 Hz 500 V [kA]	40	63	52.5	63	105	187	330	52.5	63	105	187	330	52.5	73.5	105	143	84	105	187	220
(AC) 50-60 Hz 690 V [kA]	7.7	13.6	40	52.5	84	154	176	40	52.5	84	154	176	40	46	52.5	63	63	88.2	105	132
Opening time (415 V) [ms]	7	6	5	5	5	5	5	6	6	6	6	6	10	9	8	7	15	10	8	8
Utilisation category (IEC 60947-2)	A		A					B (400 A)[(3)] - A (630 A)					B (630A - 800A)[(5)] - A (1000A)				B[(7)]			
Reference Standard	IEC 60947-2		IEC 60947-2					IEC 60947-2					IEC 60947-2				IEC 60947-2			
Isolation behaviour	■		■					■					■				■			
Interchangeability	–		■					■					■				■			
Versions	F-P		F-P-W					F-P-W					F-W[(4)]				F-W			
Mechanical life [No. operations]	25000		20000					20000					20000				10000			
[No. Hourly operations]	240		240					120					120				60			
Electrical life @ 415 V AC [No. operations]	8000		8000 (250 A) - 6000 (320 A)					7000 (400 A) - 5000 (630 A)					7000 (630A) - 5000 (800A) - 4000 (1000A)				2000 (S-H-L versions) - 3000 (V version)			
[No. Hourly operations]	120		120					60					60				60			

(1) 75% for T5 630
(2) 50% for T5 630
(3) Icw = 5 kA
(4) W version is not available on T6 1000 A
(5) Icw = 7.6 kA (630 A) - 10 kA (800 A)
(6) Only for T7 800/1000/1250 A
(7) Icw = 20 kA (S,H,L versions) - 15 kA (V version)

Notes: in the plug-in version of T2,T3,T5 630 and in the withdrawable version of T5 630 the maximum rated current available is derated by 10% at 40 °C

3 General characteristics

Tmax moulded-case circuit-breakers for motor protection

			Tmax T2				Tmax T3	
Rated uninterrupted current, **Iu**		[A]	160				250	
Rated service current, **In**		[A]	1…100				100…200	
Poles		[Nr]	3				3	
Rated service current, **Ue**	(AC) 50-60 Hz	[V]	690				690	
	(DC)	[V]	500				500	
Rated impulse withstand voltage, **Uimp**		[kV]	8				8	
Rated insulation voltage, **Ui**		[V]	800				800	
Test voltage at industrial frequency for 1 min.		[V]	3000				3000	
Rated ultimate short-circuit breaking capacity, **Icu**			**N**	**S**	**H**	**L**	**N**	**S**
(AC) 50-60 Hz 220/230 V		[kA]	65	85	100	120	50	85
(AC) 50-60 Hz 380/415 V		[kA]	36	50	70	85	36	50
(AC) 50-60 Hz 440 V		[kA]	30	45	55	75	25	40
(AC) 50-60 Hz 500 V		[kA]	25	30	36	50	20	30
(AC) 50-60 Hz 690 V		[kA]	6	7	8	10	5	8
Rated service short-circuit breaking capacity, **Ics**								
(AC) 50-60 Hz 220/230 V		[%Icu]	100%	100%	100%	100%	75%	50%
(AC) 50-60 Hz 380/415 V		[%Icu]	100%	100%	100%	75% (70 kA)	75%	50% (27 kA)
(AC) 50-60 Hz 440 V		[%Icu]	100%	100%	100%	75%	75%	50%
(AC) 50-60 Hz 500 V		[%Icu]	100%	100%	100%	75%	75%	50%
(AC) 50-60 Hz 690 V		[%Icu]	100%	100%	100%	75%	75%	50%
Rated short-circuit making capacity, **Icm**								
(AC) 50-60 Hz 220/230 V		[kA]	143	187	220	264	105	187
(AC) 50-60 Hz 380/415 V		[kA]	75.6	105	154	187	75.6	105
(AC) 50-60 Hz 440 V		[kA]	63	94.5	121	165	52.5	84
(AC) 50-60 Hz 500 V		[kA]	52.5	63	75.6	105	40	63
(AC) 50-60 Hz 690 V		[kA]	9.2	11.9	13.6	17	7.7	13.6
Opening time (415 V)		[ms]	3	3	3	3	7	6
Utilisation category (IEC 60947-2)			A				A	
Isolation behaviour			■				■	
Reference Standard			IEC 60947-2				IEC 60947-2	
Protection against short-circuit								
Magnetic only trip unit	MA		■ (MF up to In 12.5 A)				■	
Electronic trip unit	PR221DS-I		–				–	
	PR231/P-I		–				–	
Integrated protection (IEC 60947-4-1)								
Electronic trip unit	PR222MP		–				–	
Interchangeability			–				–	
Versions			F - P				F - P	
Fixing on DIN rail			DIN EN 50022				DIN EN 50022	
Mechanical life		[No. operations]	25000				25000	
		[No. Hourly operations]	240				240	
Electrical life @ 415 V AC		[No. operations]	8000				8000	
		[No. Hourly operations]	120				120	

	Tmax T4					Tmax T5					Tmax T6				Tmax T7			
Rated uninterrupted current, **Iu** [A]	250, 320					400, 630					630, 800				800/1000/1250			
Rated service current, **In** [A]	10…320					320, 400, 630					630				–			
Poles [Nr]	3					3					3				3			
Rated service current, **Ue** (AC) 50-60 Hz [V]	690					690					690				690			
(DC) [V]	750					750					750				–			
Rated impulse withstand voltage, **Uimp** [kV]	8					8					8				8			
Rated insulation voltage, **Ui** [V]	1000					1000					1000				1000			
Test voltage at industrial frequency for 1 min. [V]	3500					3500					3500				3500			
Rated ultimate short-circuit breaking capacity, **Icu**	**N**	**S**	**H**	**L**	**V**	**N**	**S**	**H**	**L**	**V**	**N**	**S**	**H**	**L**	**S**	**H**	**L**	**V**
(AC) 50-60 Hz 220/230 V [kA]	70	85	100	200	200	70	85	100	200	200	70	85	100	200	85	100	200	200
(AC) 50-60 Hz 380/415 V [kA]	36	50	70	120	200	36	50	70	120	200	36	50	70	100	50	70	120	150
(AC) 50-60 Hz 440 V [kA]	30	40	65	100	180	30	40	65	100	180	30	45	50	80	50	65	100	130
(AC) 50-60 Hz 500 V [kA]	25	30	50	85	150	25	30	50	85	150	25	35	50	65	40	50	85	100
(AC) 50-60 Hz 690 V [kA]	20	25	40	70	80	20	25	40	70	80	20	22	25	30	30	42	50	60
Rated service short-circuit breaking capacity, **Ics**																		
(AC) 50-60 Hz 220/230 V [%Icu]	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	75%	100%	100%	100%	100%
(AC) 50-60 Hz 380/415 V [%Icu]	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	75%	100%	100%	100%	100%
(AC) 50-60 Hz 440 V [%Icu]	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	75%	100%	100%	100%	100%
(AC) 50-60 Hz 500 V [%Icu]	100%	100%	100%	100%	100%	100%	100%	100%	100%[1]	100%[2]	100%	100%	100%	75%	100%	100%	75%	100%
(AC) 50-60 Hz 690 V [%Icu]	100%	100%	100%	100%	100%	100%	100%	100%[1]	100%[2]	100%[2]	75%	75%	75%	75%	100%	75%	75%	75%
Rated short-circuit making capacity, **Icm**																		
(AC) 50-60 Hz 220/230 V [kA]	154	187	220	440	660	154	187	220	440	660	154	187	220	440	187	220	440	440
(AC) 50-60 Hz 380/415 V [kA]	75.6	105	154	264	440	75.6	105	154	264	440	75.6	105	154	220	105	154	264	330
(AC) 50-60 Hz 440 V [kA]	63	84	143	220	396	63	84	143	220	396	63	94.5	105	176	105	143	220	286
(AC) 50-60 Hz 500 V [kA]	52.5	63	105	187	330	52.5	63	105	187	330	52.5	73.5	105	143	84	105	187	220
(AC) 50-60 Hz 690 V [kA]	40	52.5	84	154	176	40	52.5	84	154	176	40	46	52.6	63	63	88.2	105	132
Opening time (415 V) [ms]															15	10	8	8
Utilisation category (IEC 60947-2)	A					B (400 A)[3] - A (630 A)					B[4]				B[5]			
Isolation behaviour	■					■					■				■			
Reference Standard	IEC 60947-2/IEC 60947-4					IEC 60947-2/IEC 60947-4					IEC 60947-2/IEC 60947-4				IEC 60947-2			
Protection against short-circuit																		
Magnetic only trip unit MA	■					–					–				–			
Electronic trip unit PR221DS-I	■					■					■				–			
PR231/P-I	–					–					–				■			
Integrated protection (IEC 60947-4-1)																		
Electronic trip unit PR222MP	■					■					■				–			
Interchangeability	■					■					■				■			
Versions	F - P - W					F - P - W					F - W				F-W			
Fixing on DIN rail	–					–					–				–			
Mechanical life [No. operations]	20000					20000					20000				10000			
[No. Hourly operations]	240					120					120				60			
Electrical life @ 415 V AC [No. operations]	8000					7000					5000				2000 (S-H-L versions) - 3000 (V version)			
[No. Hourly operations]	120					60					60				60			

[1] 75% for T5 630
[2] 50% for T5 630
[3] Icw = 5 kA
[4] Icw = 10 kA
[5] Icw = 20 kA (S, H, L version) - 15 kA (V version)

Notes: in the plug-in version of T2,T3,T5 630 and in the withdrawable version of T5 630 the maximum rated current available is derated by 10% at 40 °C

3 General characteristics

3 General characteristics

SACE Emax air circuit-breakers

Common data

Voltages		
Rated operational voltage Ue	[V]	690 ~
Rated insulation voltage Ui	[V]	1000
Rated impulse withstand voltage Uimp	[kV]	12
Service temperature	[°C]	-25....+70
Storage temperature	[°C]	-40....+70
Frequency f	[Hz]	50 - 60
Number of poles		3 - 4
Version		Fixed -Withdrawable

(1) Without intentional delays
(2) Performance at 600 V is 100 kA

3 General characteristics

Performance levels		X1			E1		E2				E3					E4			E6	
		B	N	L	B	N	B	N	S	L	N	S	H	V	L	S	H	V	H	V
Currents: rated uninterrupted current (at 40 °C) Iu	[A]	630	630	630	800	800	1600	1000	800	1250	2500	1000	800	800	2000	4000	3200	3200	4000	3200
	[A]	800	800	800	1000	1000	2000	1250	1000	1600	3200	1250	1000	1250	2500		4000	4000	5000	4000
	[A]	1000	1000	1000	1250	1250		1600	1250			1600	1250	1600					6300	5000
	[A]	1250	1250	1250	1600	1600		2000	1600			2000	1600	2000						6300
	[A]	1600	1600						2000			2500	2000	2500						
	[A]											3200	2500	3200						
	[A]												3200							
Neutral pole current-carrying capacity for 4-pole CBs	[%Iu]	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	50	50	50	50
Rated ultimate breaking capacity under short-circuit **Icu**																				
220/230/380/400/415 V ~	[kA]	42	65	150	42	50	42	65	85	130	65	75	100	130	130	75	100	150	100	150
440 V ~	[kA]	42	65	130	42	50	42	65	85	110	65	75	100	130	110	75	100	150	100	150
500/525 V ~	[kA]	42	50	100	42	50	42	55	65	85	65	75	100	100	85	75	100	130	100	130
660/690 V ~	[kA]	42	50	60	42	50	42	55	65	85	65	75	85 [2]	100	85	75	85 [2]	100	100	100
Rated service breaking capacity under short-circuit **Ics**																				
220/230/380/400/415 V ~	[kA]	42	50	150	42	50	42	65	85	130	65	75	85	100	130	75	100	150	100	125
440 V ~	[kA]	42	50	130	42	50	42	65	85	110	65	75	85	100	110	75	100	150	100	125
500/525 V ~	[kA]	42	42	100	42	50	42	55	65	65	65	75	85	85	65	75	100	130	100	100
660/690 V ~	[kA]	42	42	45	42	50	42	55	65	65	65	75	85	85	65	75	85	100	100	100
Rated short-time withstand current **Icw** (1s)	[kA]	42	42	15	42	50	42	55	65	10	65	75	75	85	15	75	100	100	100	100
(3s)	[kA]				36	36	42	42	50	–	65	65	65	65	–	75	75	75	85	85
Rated making capacity under short-circuit (peak value) **Icm**																				
220/230/380/400/415 V ~	[kA]	88.2	143	330	88.2	105	88.2	143	187	286	143	165	220	286	286	165	220	330	220	330
440 V ~	[kA]	88.2	143	286	88.2	105	88.2	143	187	242	143	165	220	286	242	165	220	330	220	330
500/525 V ~	[kA]	88.2	121	220	88.2	105	88.2	121	143	187	143	165	187	220	187	165	220	286	220	286
660/690 V ~	[kA]	88.2	121	132	88.2	105	88.2	121	143	187	143	165	187	220	187	165	187	220	220	220
Utilisation category (according to IEC 60947-2)		B	B	A	B	B	B	B	B	A	B	B	B	B	A	B	B	B	B	B
Isolation behaviour (according to IEC 60947-2)		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Overcurrent protection																				
Electronic releases for AC applications		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Operating times																				
Closing time (max)	[ms]	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Breaking time for I<Icw (max) [1]	[ms]	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Breaking time for I>Icw (max)	[ms]	30	30	12	30	30	30	30	30	12	30	30	30	30	12	30	30	30	30	30

SACE Emax air circuit-breakers

		X1			E1 B-N		
Rated uninterrupted current (at 40 °C) **Iu**	[A]	800	1250	1600	800	1000-1250	1600
Mechanical life with regular ordinary maintenance	[No. operations x 1000]	12.5	12.5	12.5	25	25	25
Operation frequency	[Operations/hour]	60	60	60	60	60	60
Electrical life	(440 V ~) [No. operations x 1000]	6	4	3	10	10	10
	(690 V ~) [No. operations x 1000]	3	2	1	10	8	8
Operation frequency	[Operations/hour]	30	30	30	30	30	30

	E2 B-N-S				E2 L		E3 N-S-H-V						E3 L		E4 S-H-V		E6 H-V			
Rated uninterrupted current (at 40 °C) **Iu** [A]	800	1000-1250	1600	2000	1250	1600	800	1000-1250	1600	2000	2500	3200	2000	2500	3200	4000	3200	4000	5000	6300
Mechanical life with regular ordinary maintenance [No. operations x 1000]	25	25	25	25	20	20	20	20	20	20	20	20	15	15	15	15	12	12	12	12
Operation frequency [Operations/hour]	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Electrical life (440 V ~) [No. operations x 1000]	15	15	12	10	4	3	12	12	10	9	8	6	2	1.8	7	5	5	4	3	2
Electrical life (690 V ~) [No. operations x 1000]	15	15	10	8	3	2	12	12	10	9	7	5	1.5	1.3	7	4	5	4	2	1.5
Operation frequency [Operations/hour]	30	30	30	30	20	20	20	20	20	20	20	20	20	20	10	10	10	10	10	10

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SACE Emax air circuit-breakers with full-size neutral conductor

		E4S/f	E4H/f	E6H/f
Rated uninterrupted current (at 40 °C) Iu	[A]	**4000**	**3200**	**4000**
	[A]		**4000**	**5000**
				6300
Number of poles		4	4	4
Rated operational voltage **Ue**	[V ~]	690	690	690
Rated ultimate short-circuit breaking capacity **Icu**				
220/230/380/400/415 V ~	[kA]	80	100	100
440 V ~	[kA]	80	100	100
500/525 V ~	[kA]	75	100	100
660/690 V ~	[kA]	75	100	100
Rated service short-circuit breaking capacity **Ics**				
220/230/380/400/415 V ~	[kA]	80	100	100
440 V ~	[kA]	80	100	100
500/525 V ~	[kA]	75	100	100
660/690 V ~	[kA]	75	100	100
Rated short-time withstand current **Icw**				
(1s)	[kA]	75	85	100
(3s)	[kA]	75	75	85
Rated short-circuit making capacity **Icm**				
220/230/380/400/415 V ~	[kA]	176	220	220
440 V ~	[kA]	176	220	220
500/525 V ~	[kA]	165	220	220
660/690 V ~	[kA]	165	220	220
Utilization category (in accordance with IEC 60947-2)		B	B	B
Isolation behavior (in accordance with IEC 60947-2)		■	■	■
Overall dimensions				
Fixed: H = 418 mm - D = 302 mm L	[mm]	746	746	1034
Withdrawable: H = 461 - D = 396.5 mm L	[mm]	774	774	1062
Weight (circuit-breaker complete with releases and CT, not including accessories)				
Fixed	[kg]	120	120	165
Withdrawable (including fixed part)	[kg]	170	170	250

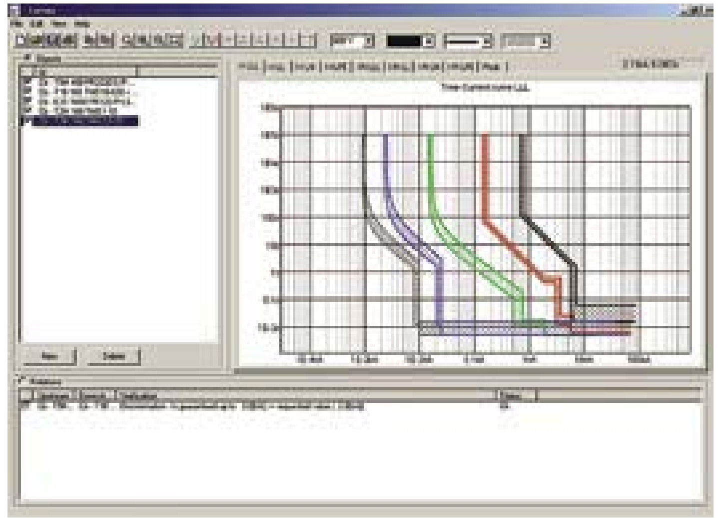
3 General characteristics

3.2 Characteristic curves and the software "Curves"

3.2.1 Curves 1.0

The software "Curves" available in the cd, attached to this edition of the "Electrical Installation Handbook" (5th edition), is a tool dedicated to who works in the electrical engineering field.
This program allows the visualization of :

- I-t LLL: tripping characteristics for three-phase faults;
- I-t LL: tripping characteristics for two-phase faults;
- I-t LN: tripping characteristics for single-phase faults;
- I-t LPE: tripping characteristics for phase-to-earth faults;
- I-I^2t LLL: specific let-through energy for three-phase faults;
- I-I^2t LL: specific let-through energy for two-phase faults;
- I-I^2t LN: specific let-through energy for single-phase faults;
- I-I^2t LPE: specific let-through energy for phase-to-earth faults;
- Peak: current limitation curve;
- Cable and fuse characteristic curves.



Besides, other program features are the verifications of cable protection, of human beings' protection and of discrimination. The algorithms for the verification of the cable protection are described in the international standards. The algorithms for the verification of discrimination are implemented in accordance with the guidelines provided in ABB SACE Technical Application Papers, specifically "QT1: Low voltage selectivity with ABB circuit-breakers" (QT1 from now on). The software "Curves" displays tripping and limiting characteristics according to the catalogues.

3 General characteristics

3.2.2 Trip curves of thermomagnetic and magnetic only releases

The overload protection function must not trip the circuit-breaker in 2 hours for current values which are lower than 1.05 times the set current, and must trip within 2 hours for current values which are lower than 1.3 times the set current.

By “cold trip conditions” it is meant that the overload occurs when the circuit-breaker has not reached the normal working temperature (no current flows through the circuit-breaker before the anomalous condition occurs); on the contrary “hot trip conditions” refers to the circuit-breaker having reached the normal working temperature with the rated current flowing through, before the overload current occurs. For this reason “cold trip conditions” times are always greater than “hot trip conditions” times.

The protection function against short-circuit is represented in the time-current curve by a vertical line, corresponding to the rated value of the trip threshold I3. In accordance with the Standard IEC 60947-2, the real value of this threshold is within the range 0.8·I3 and 1.2·I3. The trip time of this protection varies according to the electrical characteristics of the fault and the presence of other devices: it is not possible to represent the envelope of all the possible situations in a sufficiently clear way in this curve; therefore it is better to use a single straight line, parallel to the current axis.

All the information relevant to this trip area and useful for the sizing and coordination of the plant are represented in the limitation curve and in the curves for the specific let-through energy of the circuit-breaker under short-circuit conditions.

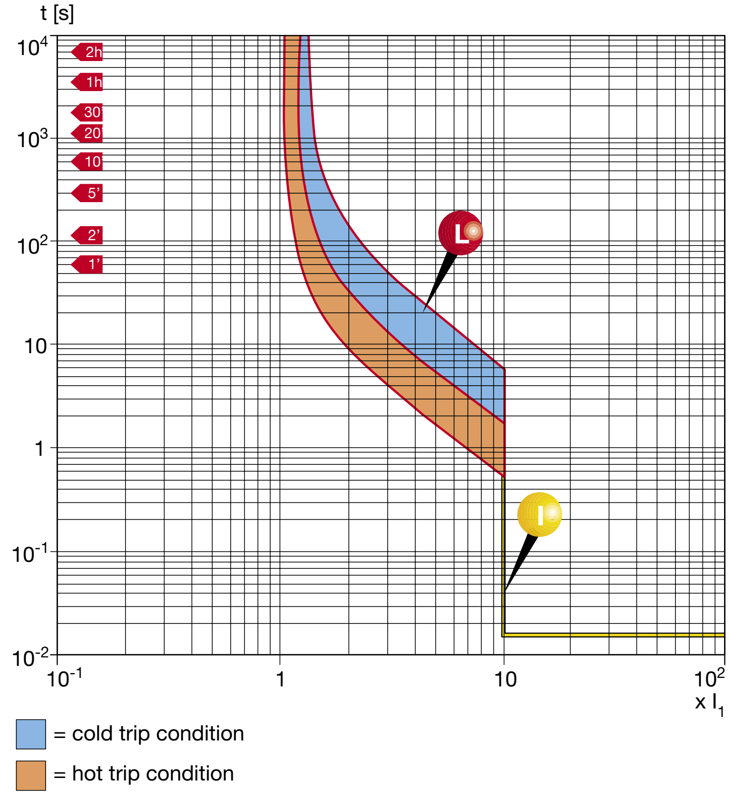
The following pages show some examples reporting the settings of thermomagnetic releases.

To simplify the reading of these examples, the tolerance of the protection functions has not been considered.

For a proper setting it is necessary to consider the tolerances referred to the type of thermomagnetic release used; for these information please refer to the technical catalogues.

3 General characteristics

The following figure shows the time-current tripping curve of a circuit-breaker equipped with thermomagnetic release:



3 General characteristics

Overload protection (L)

To set correctly the function L of the release is necessary to know the load current (Ib) and divide it for the rated current of the thermomagnetic releases, taking the setting available higher or equal to the value obtained.

$$Setting_L = \frac{I_b}{I_n}$$

Besides, in case of protection of a cable, it is necessary to comply with the following relation :

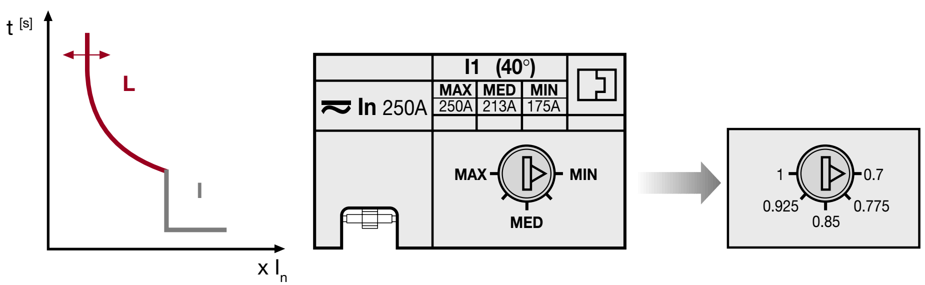
Ib < I1 < Iz where Iz is the conductor carrying capacity and I1 is the current set on the overload protection.

Example:

T4N250 In 250 with thermomagnetic release TMA. (with function L adjustable from 0.7 to 1 x In)

Ib=175A

$$Setting_L = \frac{I_b}{I_n} = \frac{175}{250} = 0.7$$



3 General characteristics

Short-circuit instantaneous protection (I)

To set the magnetic function of the release is necessary to know the minimum value of the short-circuit current that we can have in the plant.

The I3 thresold shall comply with following condition:

$I3 \leq Ikmin$

$I3 = setting_I \times In$

To detect the setting it is necessary to divide the Ikmin by the rated current of the releases and take the setting value immediately lower.

$$Setting_I = \frac{Ik\,min}{In}$$

Example:

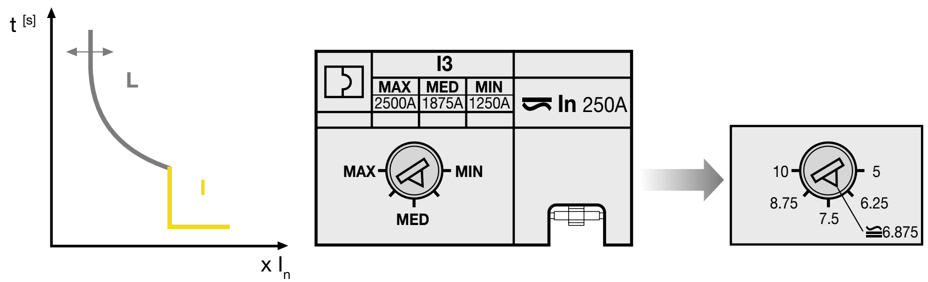
T4N250 In 250 with thermomagnetic release TMA with instantaneous function adjustable from 5 (=1250A) to 10 (=2500A).

Ikmin=1750 A

$$Setting_I = \frac{Ik\,min}{In} = \frac{1750}{250} = 7$$

It is necessary to choose: ≅ 6.875 :

$I3 = 6.875 \times 250 = 1718 \leq 1750$ A



3 General characteristics

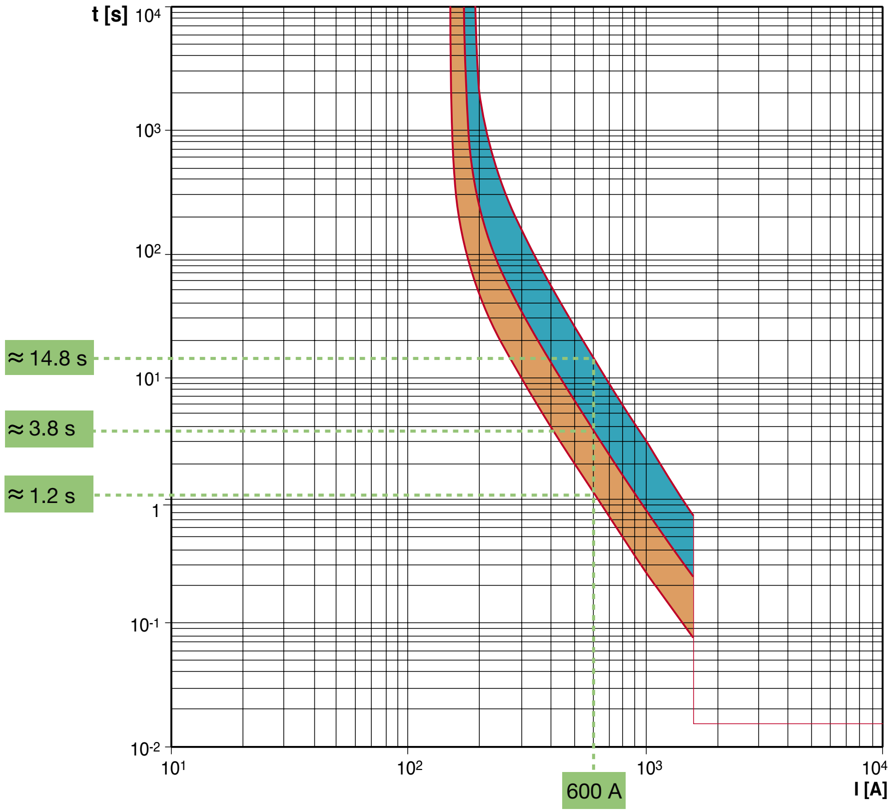
Example of thermomagnetic release setting

Consider a circuit-breaker type T1 160 In 160 and, using the trimmer for the thermal regulation, select the current threshold, for example at 144 A; the magnetic trip threshold, fixed at 10xIn, is equal to 1600 A.

Note that, according to the conditions under which the overload occurs, that is either with the circuit-breaker at full working temperature or not, the trip of the thermal release varies considerably. For example, for an overload current of 600 A, the trip time is between 1.2 and 3.8 s for hot trip, and between 3.8 and 14.8 s for cold trip.

For fault current values higher than 1600 A, the circuit-breaker trips instantaneously through magnetic protection.

T1 160 - In 160 Time-current curves



3 General characteristics

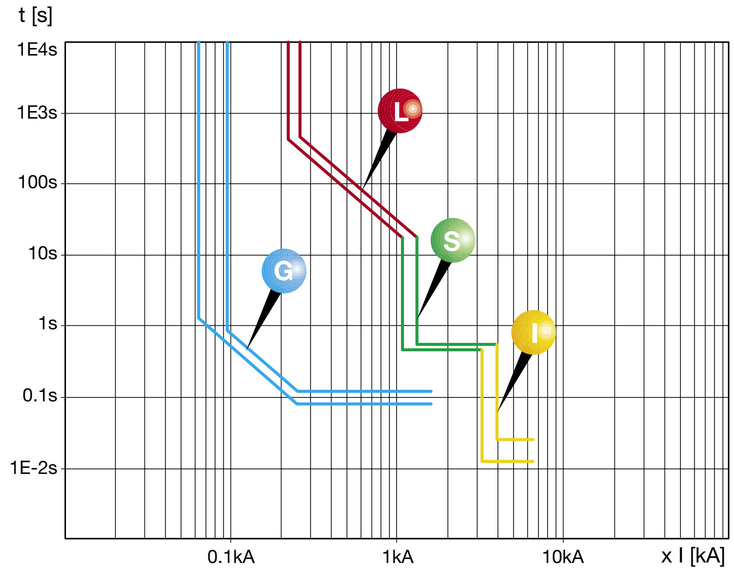
3.2.3 The functions of electronic releases

In the following pages the protection functions of the electronic releases for both moulded-case as well as air circuit breakers are reported; as regards the availability of the protection functions with the different releases, reference shall be made to the table on page 33.

The examples shown in these pages show how it is possible to set the electronic release by means of the dip-switch on the front of the circuit-breaker; this operation can be carried out also through the controls viewing the LED display (for the releases PR122-PR123-PR332-PR333) or electronically through the test unit PRO10T.

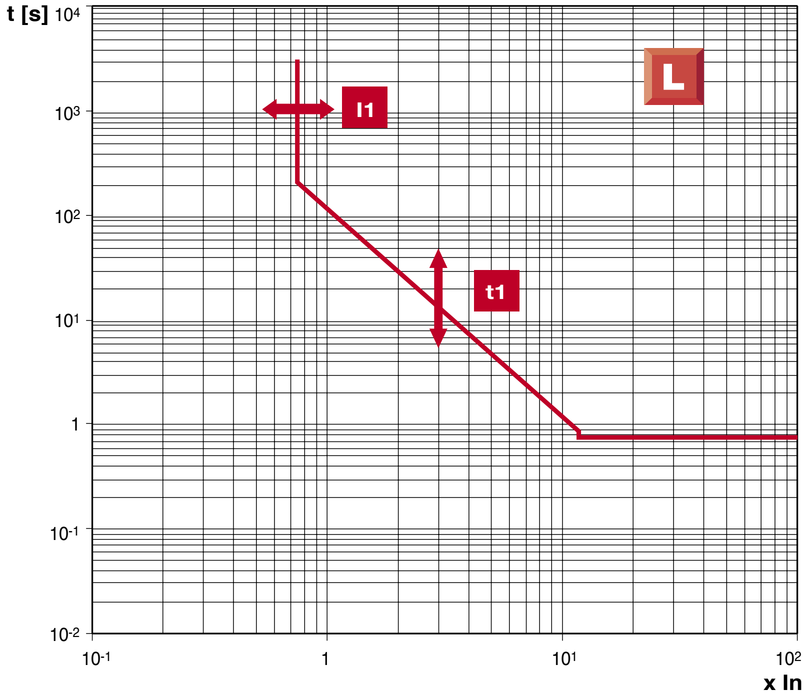
To simplify the reading of the examples, the tolerance of the protection functions has not been considered. For a correct setting it is necessary to take into consideration the tolerances relevant to the different protection functions referred to the electronic trip unit used; for this information please consult the technical catalogue.

The figure below shows the time-current tripping curve of a circuit-breaker equipped with an electronic release having the protection functions LSIG which are described in the following pages :



3 General characteristics

Overload protection (L function)



The application field of this protection function refers to all the installations which can be subject to overloads - usually of low value but of long duration - which are dangerous for the life of apparatus and cables.
These currents usually occur in a sound circuit, where the line results to be overloaded (this event is more likely than a real fault).
The trip curve of this protection (which cannot be excluded) is defined by a current threshold I1 and by a trip time t1. More exactly :

- I1 represents the current value beyond which the protection function commands the opening of the circuit-breaker according to an inverse time trip characteristic, where the time-current connection is given by the relation
  I^2t = constant (constant specific let-through energy);
- t1 represents the trip time of the protection, in seconds, corresponding to a well defined multiple of I1 and it is used to identify a defined curve among those made available by the trip unit.

As regards the settings available please consult the technical catalogues.

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To set properly L threshold, it is necessary to know the current required by the load (Ib), divide it by the In of the trip unit and take the setting immediately higher than or equal to the value obtained :

$$\text{Setting}_L = \frac{I_b}{I_n}$$

Besides, in case of cable protection, the following relation shall be observed Ib < I1 < Iz where Iz is the conductor carrying capacity and I1 is the current value set for the overload protection.

Example :
T5N400 In 320, trip unit type PR222DS-LSIG, function L (I1=0.4 at 1 x In with step 0.02) through manual setting.
Ib=266 A

$$\text{Setting}_L = \frac{I_b}{I_n} = \frac{266}{320} = 0.83$$

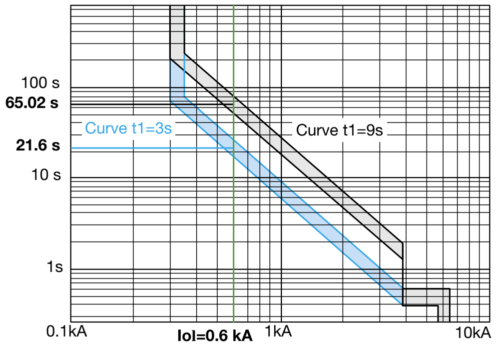
I1=0.84 is chosen.

Through the manual setting, the dip-switches shall be positioned so that a coefficient equal to 0.84 is obtained; this coefficient multiplied by the rated current of the trip unit gives the required current value. The figure below shows the correct combination of dip-switches to obtain the required multiplying factor:
I1= 320 x (0.4*+0.04+0.08+0.32) =268.8A
The trip time of L function for an overload current varies according to the type of curve used.
As regards the release considered in the example, the available curves are 4 and each of them is characterized by the passage by a characteristic multiple (6xI1) to which a different trip time (t1=3s, 6s, 9s, 18s) corresponds; since these are curves with I^2t=const, it is possible to identify multiples different from 6xI1 after the setting of t1.
Being a curve with I^2t constant, the condition
$(6xI1)^2$ x t1 =const =I^2t
must be always verified.

(*) 0.4 is the fixed value, which cannot be excluded

3 General characteristics

where the expression I^2t represents the product of a generic fault current to the square and the time necessary to the protection to extinguish it.



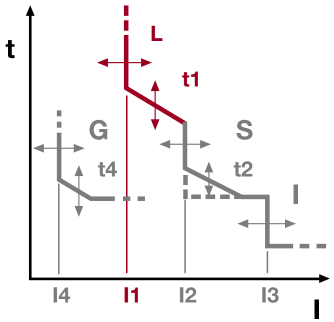
Assuming an overload current of 600A (IoI) and having set t1 at 3s, the following results :

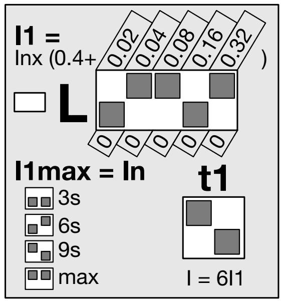
$$(6xI1)^2 \, x \, t1 = IoI^2 \, x \, t \longrightarrow t = \frac{(6x268.8)^2 \, x \, 3}{(600)^2} = 21.6s$$

At the same overload level (IoI)=600A, if t1 had been set at 9s, the trip time would have been :

$$(6xI1)^2 \, x \, t1 = IoI^2 \, x \, t \longrightarrow t = \frac{(6x268.8)^2 \, x \, 9}{(600)^2} = 65.02s$$

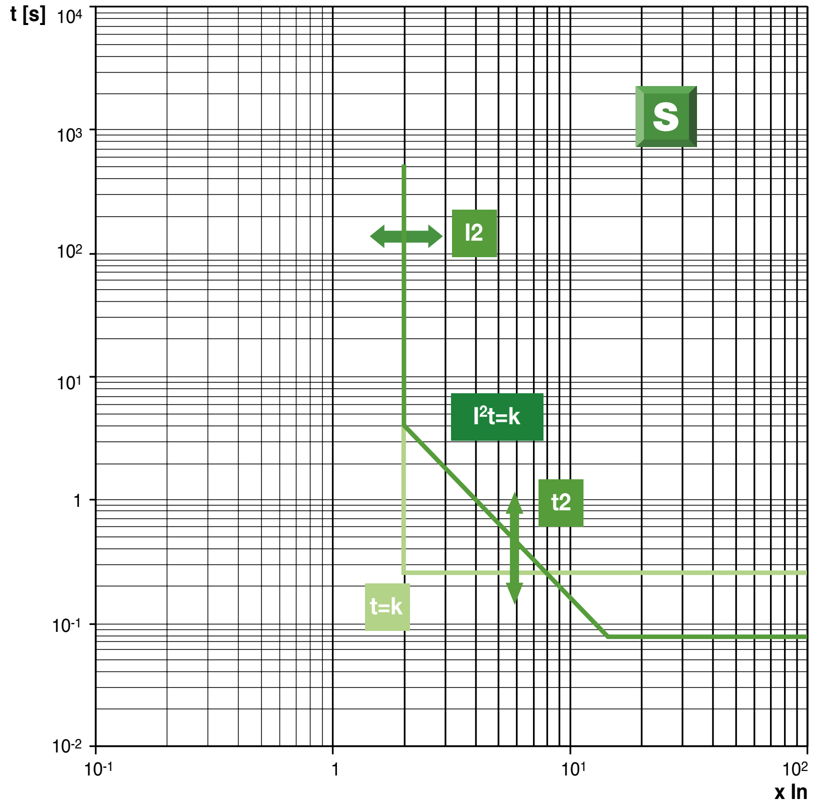
The time t1 shall be chosen keeping into consideration any co-ordination with cables or other devices either on the supply or the load side of the circuit-breaker under consideration.





3 General characteristics

Short-circuit protection with time delay (function S)



This protection function is used to introduce a trip time-delay in case of short-circuit. S function is necessary when time-current discrimination is required so that the tripping is delayed more and more by approaching the supply sources.

The trip curve of this protection (which can be excluded) is defined by a current threshold I2 and by a trip time t2. In details :

- I2 represents the current value beyond which the protection function commands the opening of the circuit-breaker, according to one of the following tripping characteristics:
  - with inverse time delay, where the link time-current is given by the relation $I^2t = k$ (constant let-through energy)
  - with definite time, where the trip time is given by the relation t=k (constant time); in this case the tripping time is equal for any value of current higher than I2;
- t2 represents the trip time of the protection, in seconds, in correspondence with:
  - a well defined multiple of In for the tripping curve at $I^2t = k$;
  - I2 for the tripping curve at t = k.

As regards the availability of the settings with the different trip units, please refer to the technical catalogues.

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In order to adjust properly the function S of a circuit-breaker equipped with an electronic trip unit it is necessary to divide the Ikmin value (the lowest short-circuit current among all the available ones) by the In value of the trip unit and then to take the setting value immediately lower.

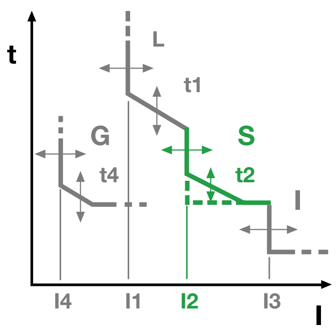
$$\text{Setting}_S = \frac{Ik\,min}{In}$$

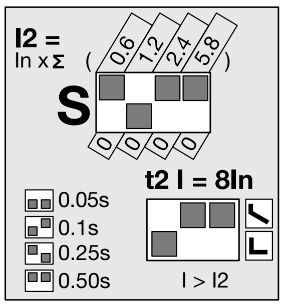
Example :
T4N320 In=100 with trip unit PR222 DS-LSI
function S (I2=0.6-1.2-1.8-2.4-3-3.6-4.2-5.8-6.4-7-7.6-8.2-8.8-9.4-10 x In)
Ikmin=900A

$$\text{Setting}_S = \frac{Ik\,min}{In} = \frac{900}{100} = 9$$

then, the value 8.8 is to be chosen.
As in the previous example, the figure shows the correct positioning of the dip switches so that the required multiplying factor can be obtained:
I2 = 100 x (0.6+2.4+5.8) = 880 A < 900 A

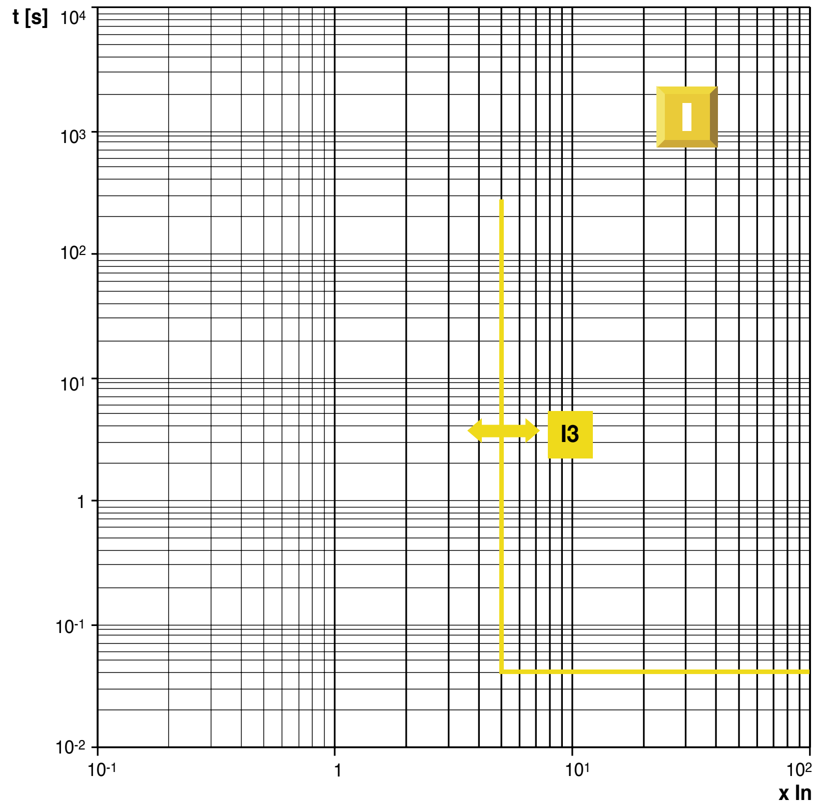
The time delay t2 of function S changes according to the selected characteristic: either t=constant or I^2t=constant.
By selecting t2=const, in case of short-circuit, all the overcurrents higher or equal to I2 (in this case 880 A) shall be extinguished within the set time t2;
instead, by selecting the characteristic curve with I^2t=const, the same considerations made for the determination of the trip time t1 are valid, taking into account the proper thresholds I2.





3 General characteristics

Short-circuit instantaneous protection (I function)



This function allows to have instantaneous protection in case of short-circuit. This protection is active for fault currents exceeding the set threshold I3; the trip time (instantaneous) cannot be set.
Function I can be excluded; the term "excludible" means that the trip threshold of the current is increased in comparison with the maximum threshold which can be adjusted through standard settings.
In order to set properly the threshold I, it is necessary to know the lowest short-circuit current of those which can occur at the installation point.
The threshold I3 shall comply with the following relation:
I3≤Imin
I3=setting_I x In

As regards the availability of the settings with the different trip units, please refer to the technical catalogues.

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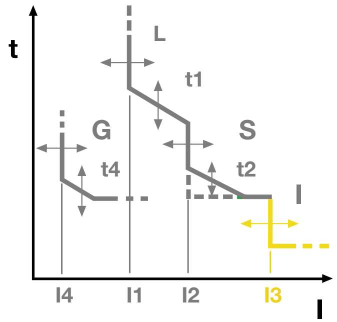
To determine the value to be set, the Ikmin value shall be divided by the In value and the setting value immediately lower shall be taken:

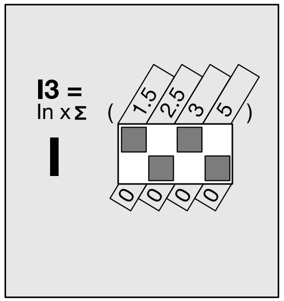
$$Setting_I = \frac{I_{kmin}}{I_n}$$

Example:
T5N400 In 320 trip unit PR222DS-LSIG
function I (I3=1-1.5-2-2.5-3-3.5-4.5-5.5-6.5-7-7.5-8-8.5-9-10 x In)
Ikmin=1500 A

$$Setting_I = \frac{I_{kmin}}{I_n} = \frac{1500}{320} = 4.68$$

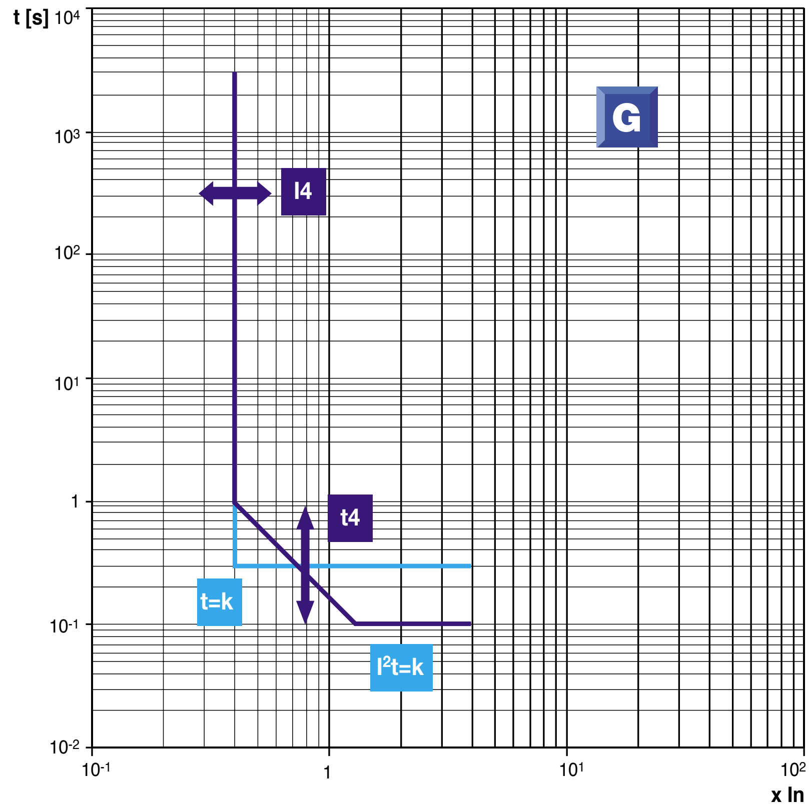
4.5 is to be chosen.
As in the previous example, the figure shows the correct positioning of the dip switches so that the required multiplying factor can be obtained:
I3 = 320 x (1.5+3) = 1440 A < 1500





3 General characteristics

Earth fault protection (function G)



Protection G can assess the vectorial sum of the currents flowing through the live conductors (the three phases and the neutral).
In a sound circuit, this sum is equal to zero, but in the presence of an earth fault, a part of the fault current returns to the source through the protective conductor and/or the earth, without affecting the live conductors. The trip curve of this protection (which can be excluded) is defined by a current threshold I4 and by a trip time t4. More precisely:

- I4 represents the current value beyond which the protection function commands the opening of the circuit-breaker, according to one of the following tripping characteristics:
  - with inverse time delay, where the link time-current is given by the relation $I^2t = k$ (constant let-through energy)
  - with definite time, where the trip time is given by the relation t=k(constant time); in this case the tripping time is equal for any value of current higher than I4;
- t4 represents the trip time of the protection, in seconds, in correspondence with:
  - a well defined multiple of In for the tripping curve at $I^2t = k$;
  - I4 for the tripping curve at t = k.

As regards the availability of the settings with the different trip units, please refer to the technical catalogues.

3 General characteristics

In order to set properly the current I4 and the time t4 of the function G, it is necessary to comply with the requirements reported in the installation Standard (see Chapter 5 of Volume 2 - “Protection of human beings”).

Example:
T4N250 In 250 with trip unit PR222DS-LSIG
function G (I4=0.2-0.25-0.45-0.55-0.75-0.8-1 x In)
Ik_{PE}=220 A
distribution system: TN-S.
In TN systems, a bolted fault to ground on the LV side usually generates a current with a value analogous to that of a short-circuit and the fault current flowing through the phase and/or the protection conductor (or the conductors) does not affect the earthing system at all.
The relation concerning TN-S distribution systems Zs x Ia ≤ Uo can be expressed as follows:

$$Ia \leq \frac{Uo}{Zs} = Ik_{LPE}$$

where:

- Uo is the voltage phase-to-PE;
- Zs is the fault ring impedance;
- Ia is the trip current within the time delay established by the Standard (with U_0=230V the time is 0.4s).
- Ik_{LPE}= is the fault current phase-to-PE

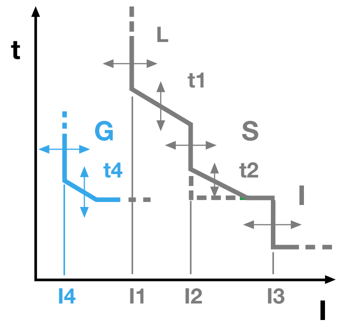
Therefore, it is possible to affirm that the protection against indirect contacts is verified if the trip current Ia is lower than the fault current phase-PE (IkI_{PE}) which is present in correspondence with the exposed conductive part to be protected.
Then:

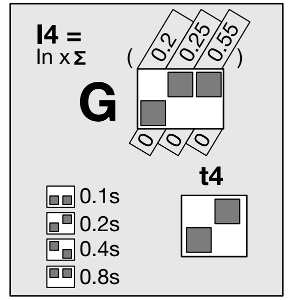
$$\text{Setting}_G = \frac{Ik_{PE}}{I_n} = \frac{220}{250} = 0.88$$

the setting 0.8 is selected.

3 General characteristics

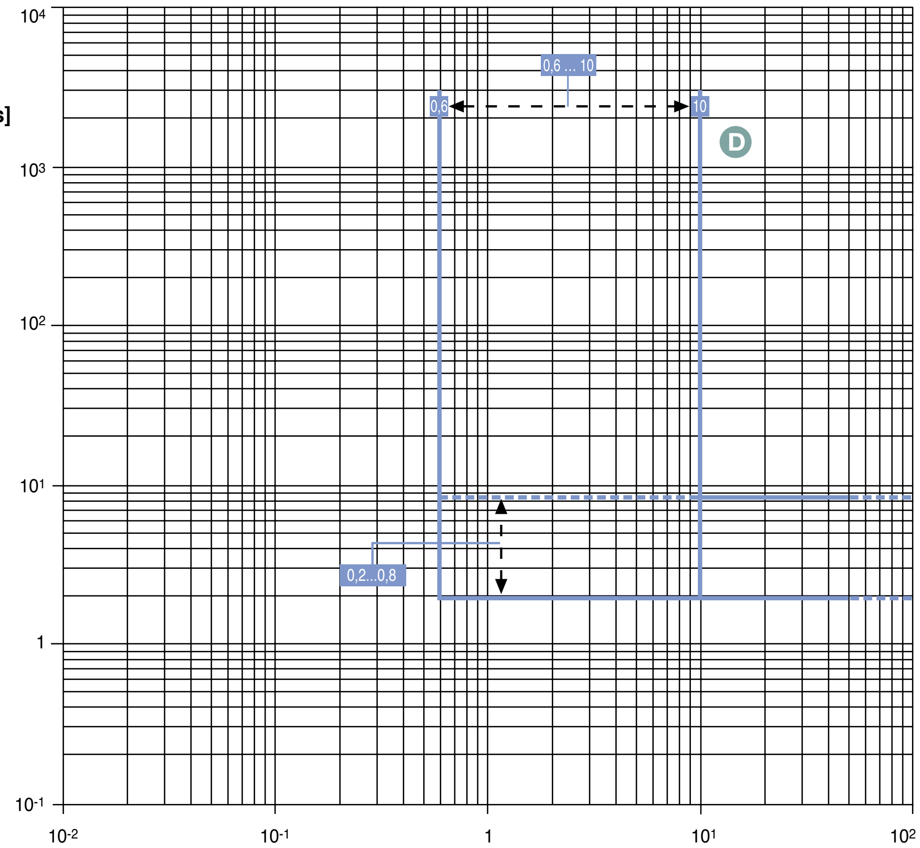
As in the previous example, the figure shows the correct positioning of the dip switches so that the required multiplying factor can be obtained:
I4 = 250 x (0.25+0.55) = 200 A < 220 A
The trip time t4 shall be chosen according to the provisions of the installation standards; with the trip unit under consideration, the available curves which define t4 are with I^2t constant; therefore, in order to define the trip time it is necessary to apply the same considerations made for the determination of the trip time t1, but taking into account the proper thresholds I4 and the relevant characteristic curves (t4).
Assuming to use a release with trip time t4=constant, when the set threshold I4 is reached and exceeded, the circuit-breaker shall trip within the set time t4.





3 General characteristics

Protection against directional short-circuit with adjustable time-delay (function D)



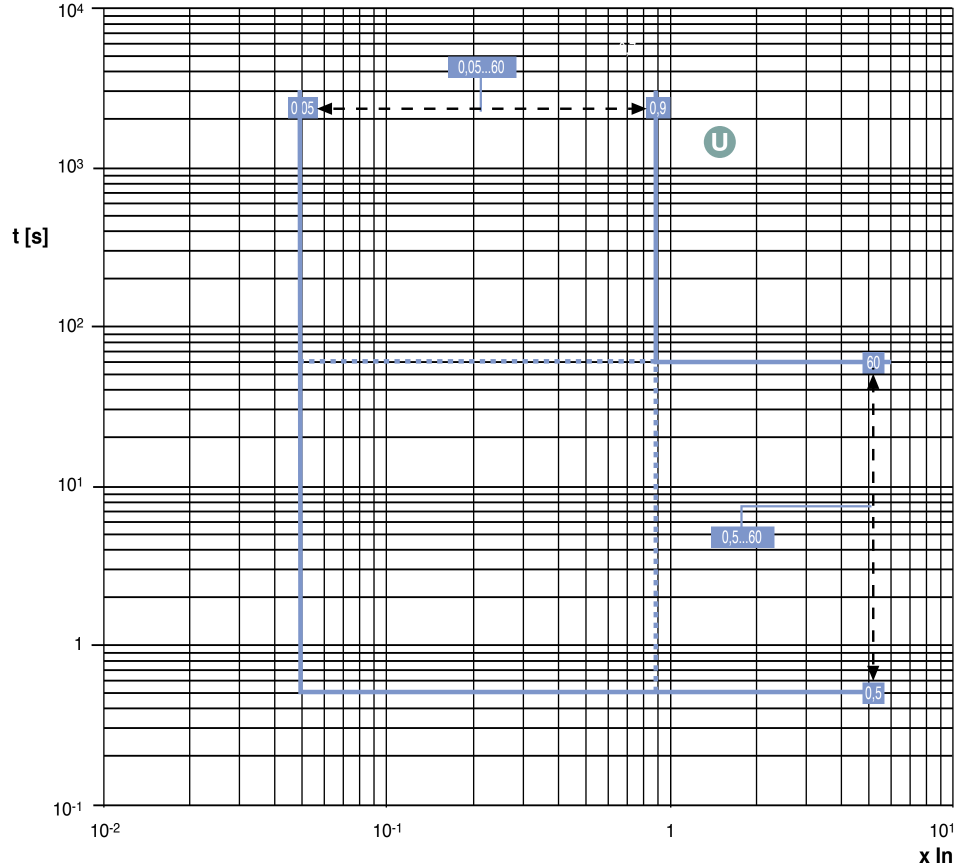
This protection is very similar to function S with definite time. It allows to identify, besides the intensity, also the direction of the fault current and consequently to understand whether the fault is either on the supply or on the load side of the circuit-breaker, thus excluding only the part of the installation affected by the fault. Its use is particularly suitable in the ring distribution systems and in the installations with more supply lines in parallel.

The adjustable current thresholds are in a range from 0.6 to 10xIn and the trip times can be set within a range from 0.2 to 0.8 seconds.

Function D can be excluded.

3 General characteristics

Protection against unbalanced phase (function U)



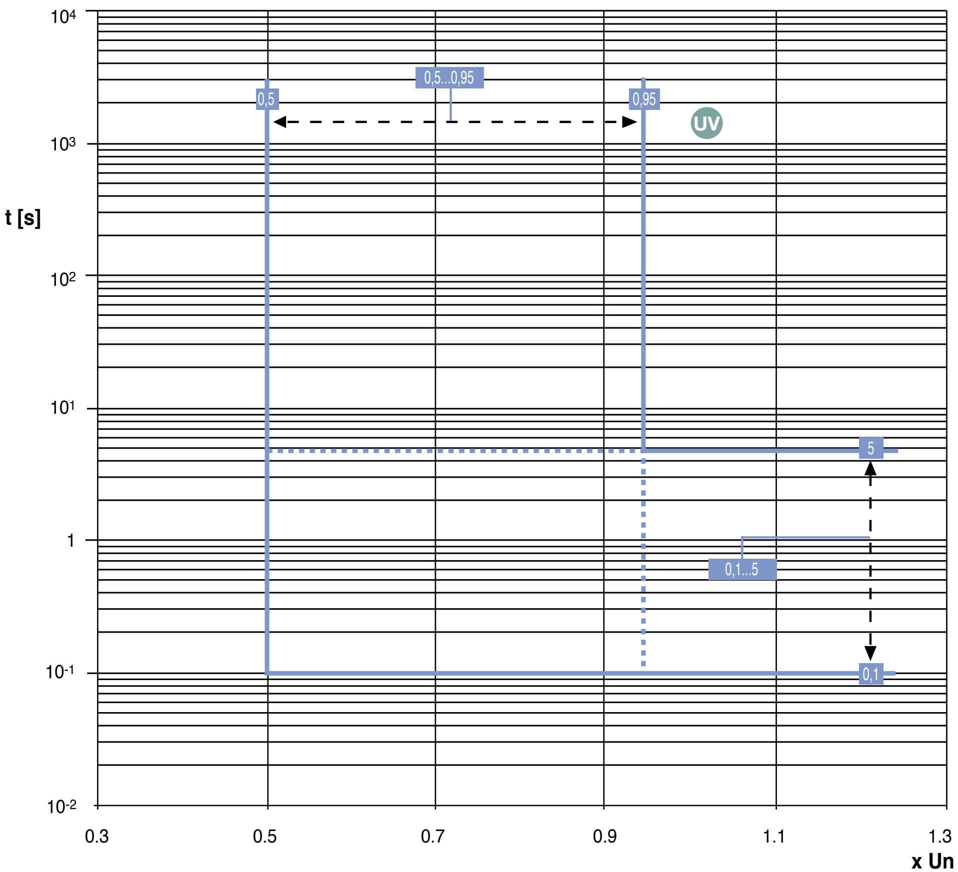
This protection makes the circuit-breaker open when an unbalanced phase current exceeding the set threshold is detected.

The possible settings are 5% to 90% of the rated current, and the trip times can be set in the range from 0.5 to 60 s.

The protection function U is used above all in the installations with the presence of rotary machines, where an unbalanced phase might cause unwanted effects on the same machines. Function U can be excluded.

3 General characteristics

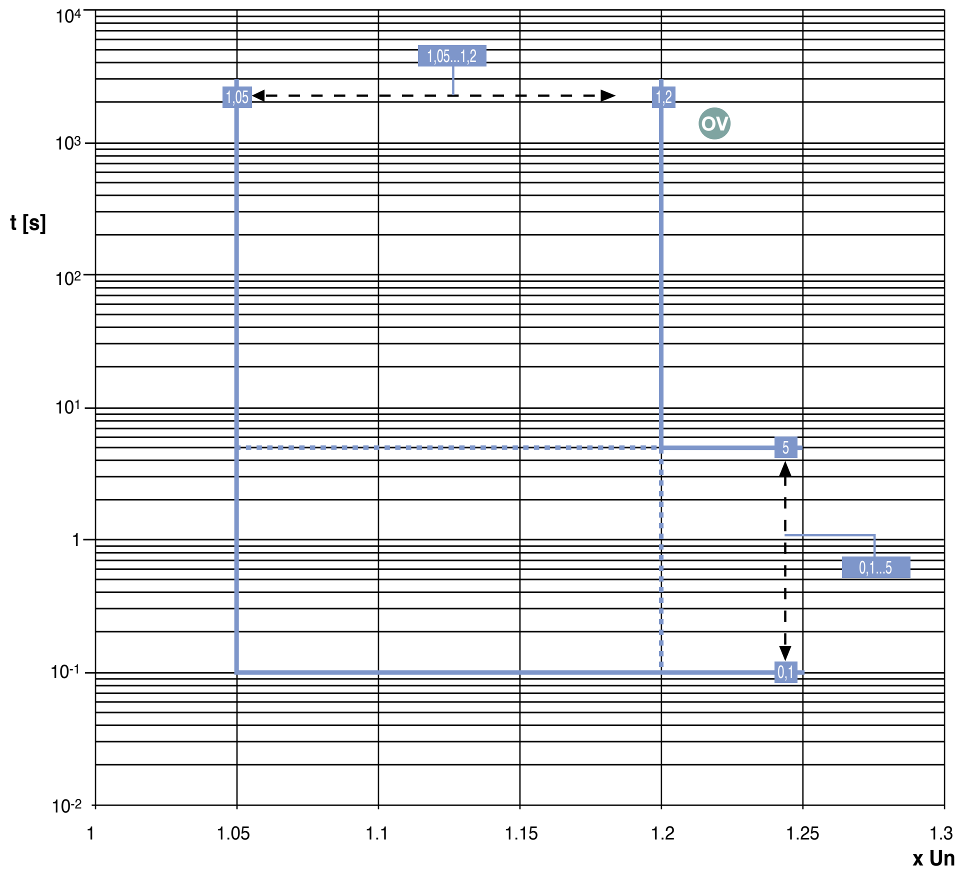
Protection against undervoltage (function UV)



This protection trips after the adjusted time (t8) has elapsed when the phase voltage decreases below the set threshold U8.
The voltage threshold can be set in the range from 0.5 to 0.95xUn and the time threshold from 0.1 to 5 s.
Function UV can be excluded.

3 General characteristics

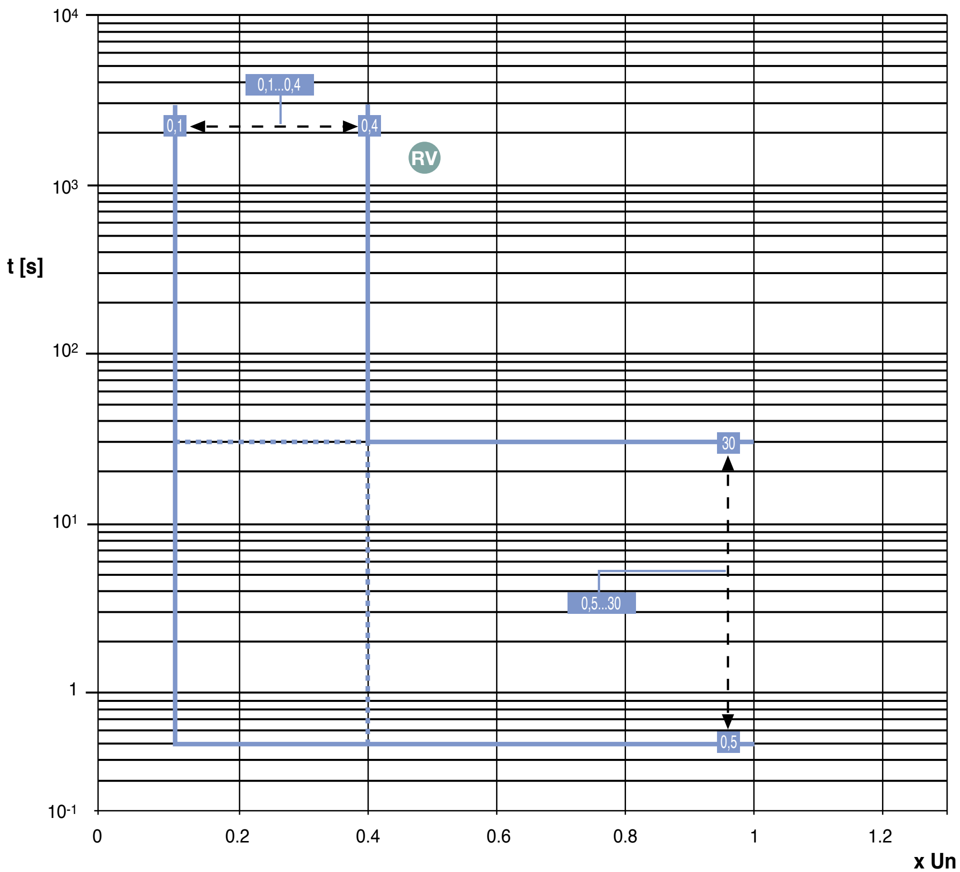
Protection against overvoltage (function OV)



This protection trips after the set time (t9) has elapsed, when the phase voltage exceeds the set threshold U9.
The voltage threshold can be set in the range from 1.05 to 1.2xUn and the time threshold from 0.1 to 5 s.
Function OV can be excluded.

3 General characteristics

Protection against residual voltage (function RV)

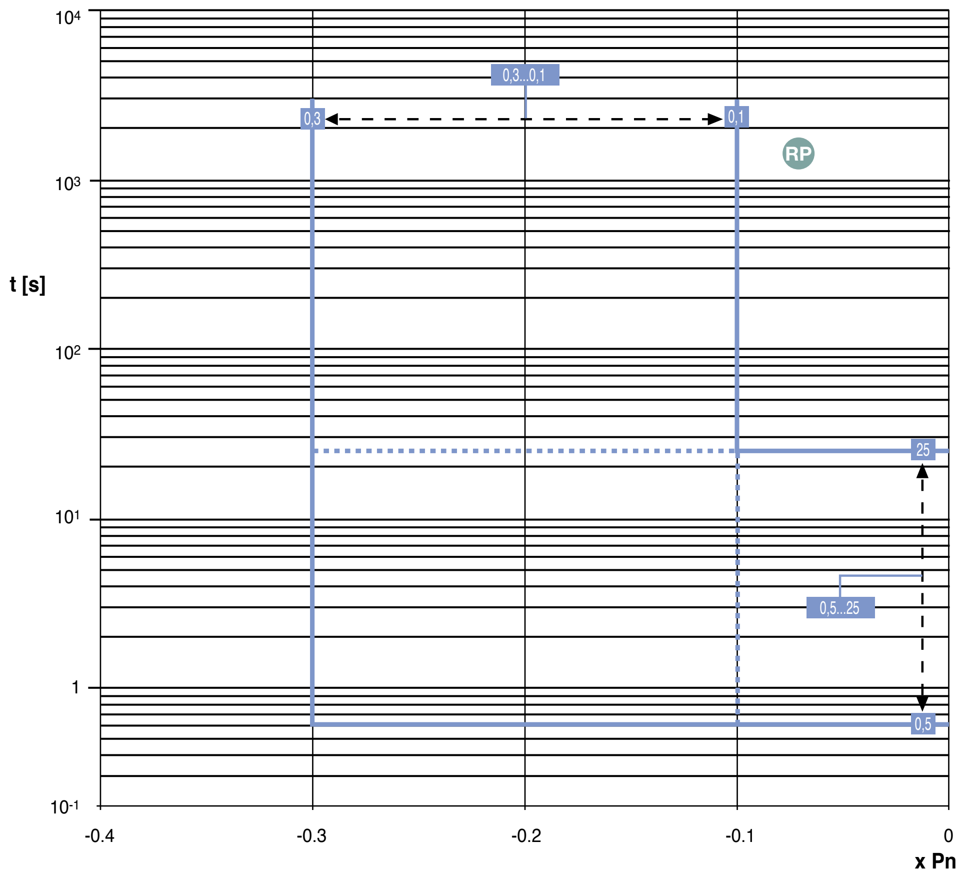


The protection against residual voltage allows to detect the faults which cause the movements of the star centre in case of system with isolated neutral.
This protection trips after the set time when the residual voltage exceeds the threshold U10.
This threshold can be set in a range from 0.1 to 0.4xUn and the time threshold from 0.5s to 30s.
Function RV can be excluded.

3.2 Characteristic curves and the software "Curves"

3 General characteristics

Protection against reversal of power (function RP)



The protection against reversal of power is particularly suitable for protection of large rotary machines (e.g. motors).
Under certain conditions a motor may generate power instead of absorbing it.
When the total reverse active power (sum of the power of the three phases) exceeds the set power threshold P11, the protection function trips after the set time-delay t11 causing the circuit-breaker opening

3 General characteristics

Protection against minimum frequency (function UF)

This protection intervenes by generating an alarm or making the circuit-breaker open after the adjusted time-delay (t9) when the frequency varies below the set threshold f12.
It is used above all for installations supplied by generators and co-generation plants.

Protection against maximum frequency (function OF)

This protection intervenes by generating an alarm or making the circuit-breaker open after the adjusted time-delay (t10) when the frequency exceeds the set threshold f13.
It is used above all for installations supplied by generators and co-generation plants.

Protection against overtemperature (function OT)

This protection allows signaling of the presence of anomalous temperatures which might cause malfunctioning of the electronic components of the trip unit.
If the temperature reaches the first threshold, (70°C), the trip unit shall advise the operator through the lightening up of the “warning” led; should the temperature reach the second threshold (85°C), besides the lightening up of the “warning” and “alarm” leds, the circuit-breaker would be tripped (by enabling the proper parameter).

Overload protection with curves according to IEC60255-3

This protection function against overload finds its application in the co-ordination with MV releases and fuses.
In fact it is possible to obtain a co-ordination among the tripping curves of the circuit-breakers by getting nearer to the slopes of the tripping curves of MV releases or fuses, so that time-current selectivity between LV and MV is obtained. Besides being defined by a current threshold I1 and by a trip time t1, the curves according to Std. IEC 60255 are defined by the parameters “K” and “a” which determine their slope.
The parameters are the following:

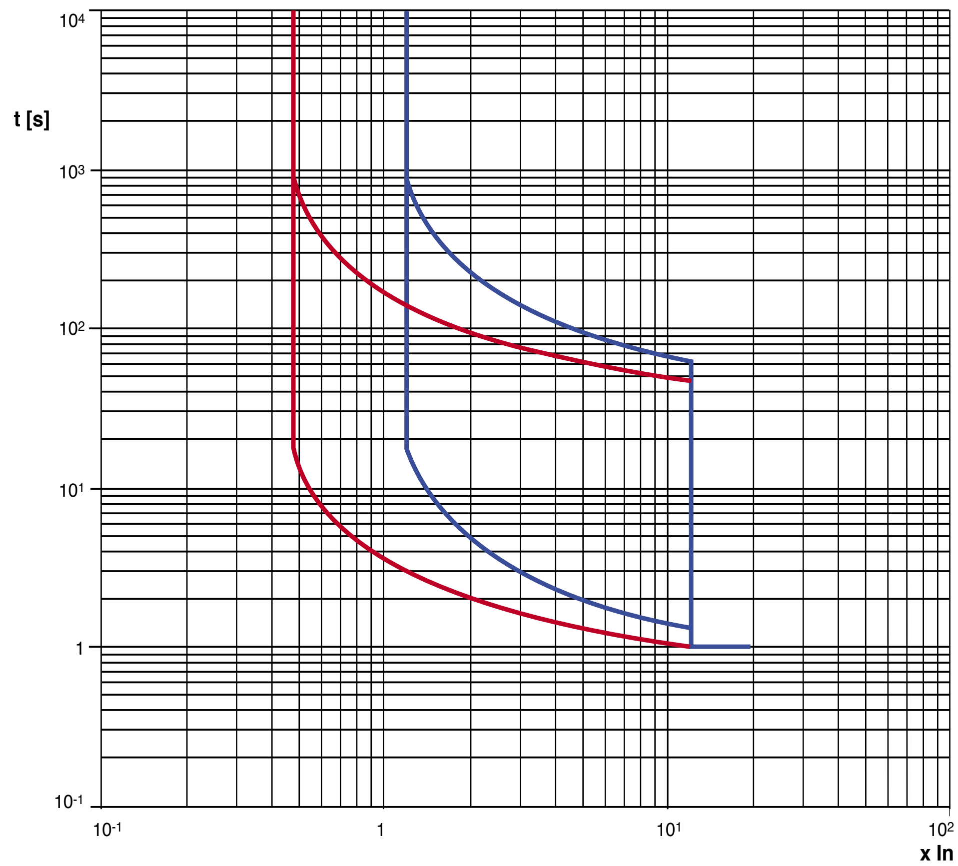
	Curve typology		
Parameters	**A**	**B**	**C**
K	0.14	13.5	80.0
a	0.02	1.0	2.0

The curve L complying with Std. IEC 60255-3 is available both for the electronic trip units type PR332-PR333 for T7 and X1 series circuit-breakers, as well as for the electronic trip units type PR122-PR123 for Emax series circuit-breakers.

3 General characteristics

Curve A

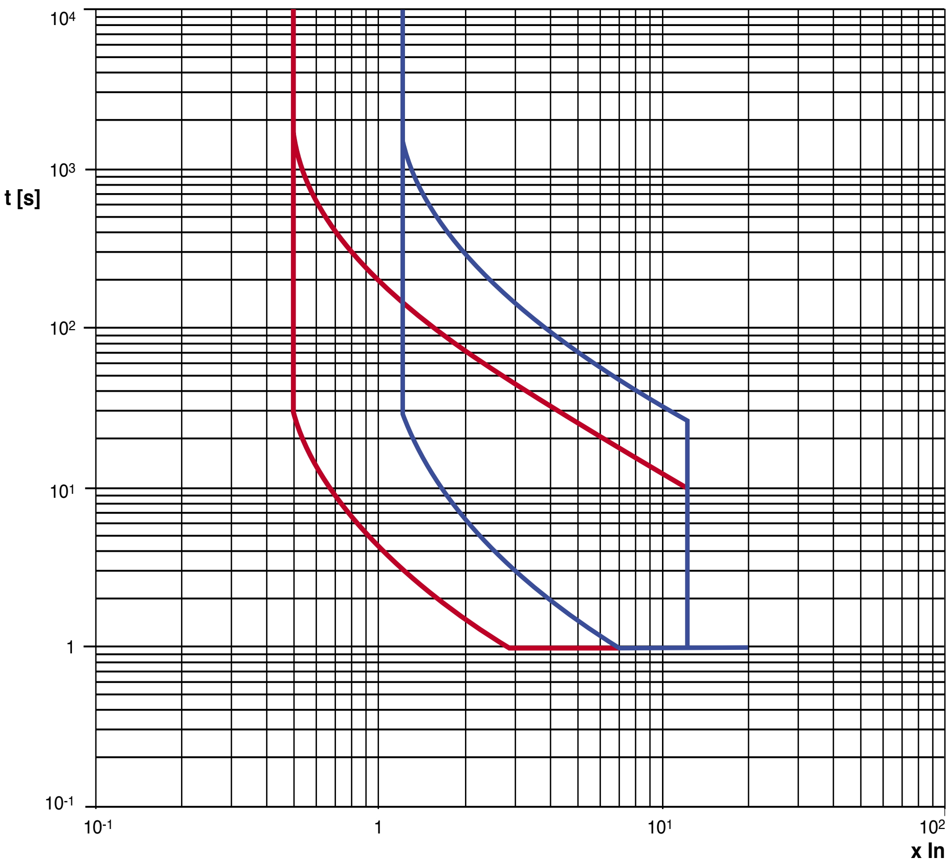
k=0.14 alfa=0.02



3 General characteristics

Curve B

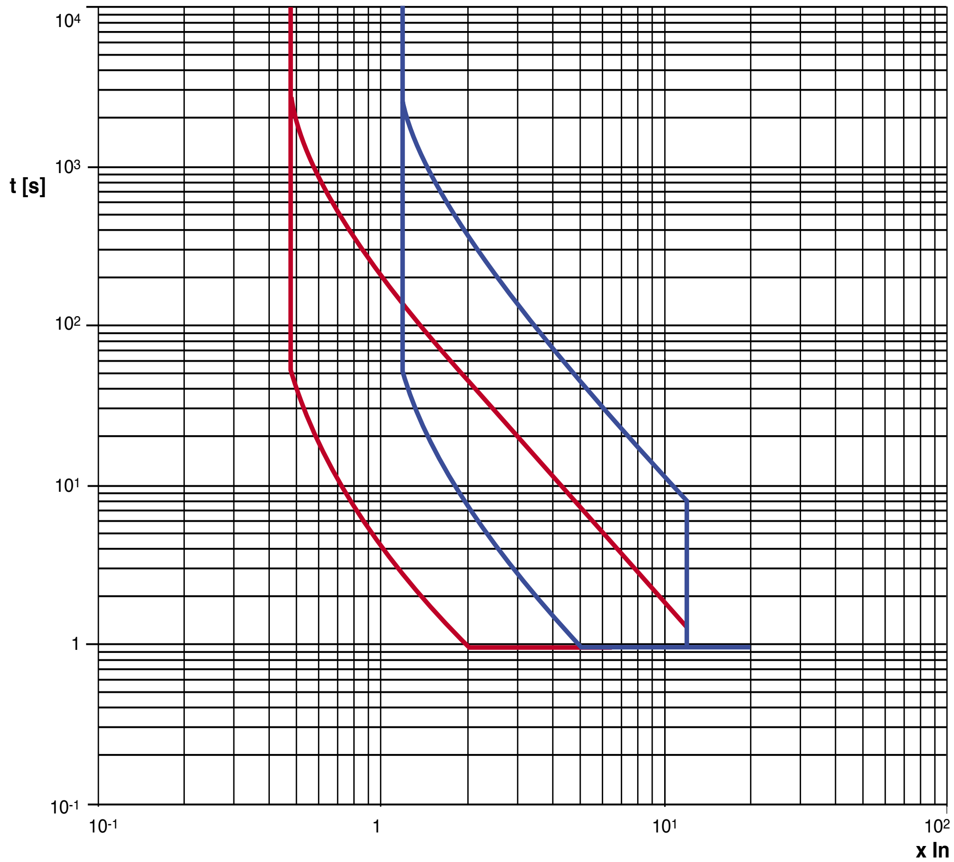
k=13.5 alfa=1



3 General characteristics

Curve C

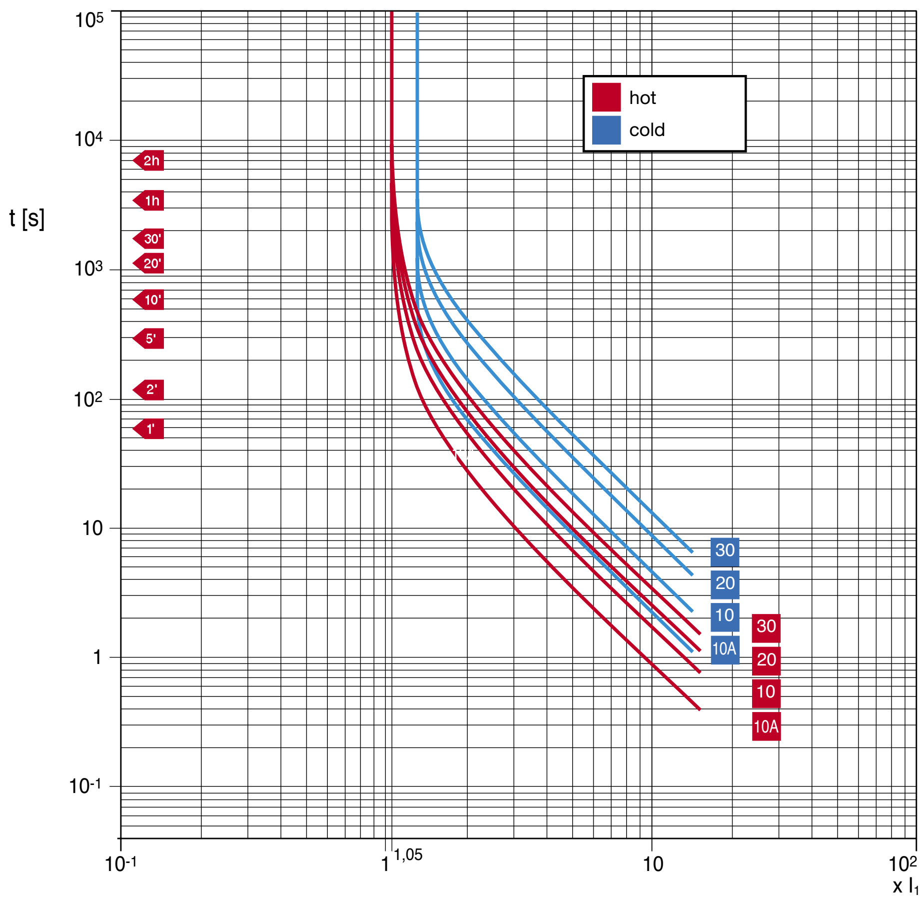
k=80 alfa=2



3 General characteristics

Motor protection

L: motor protection function against overload according to the indications and classes defined by the Std. IEC 60947-4-1



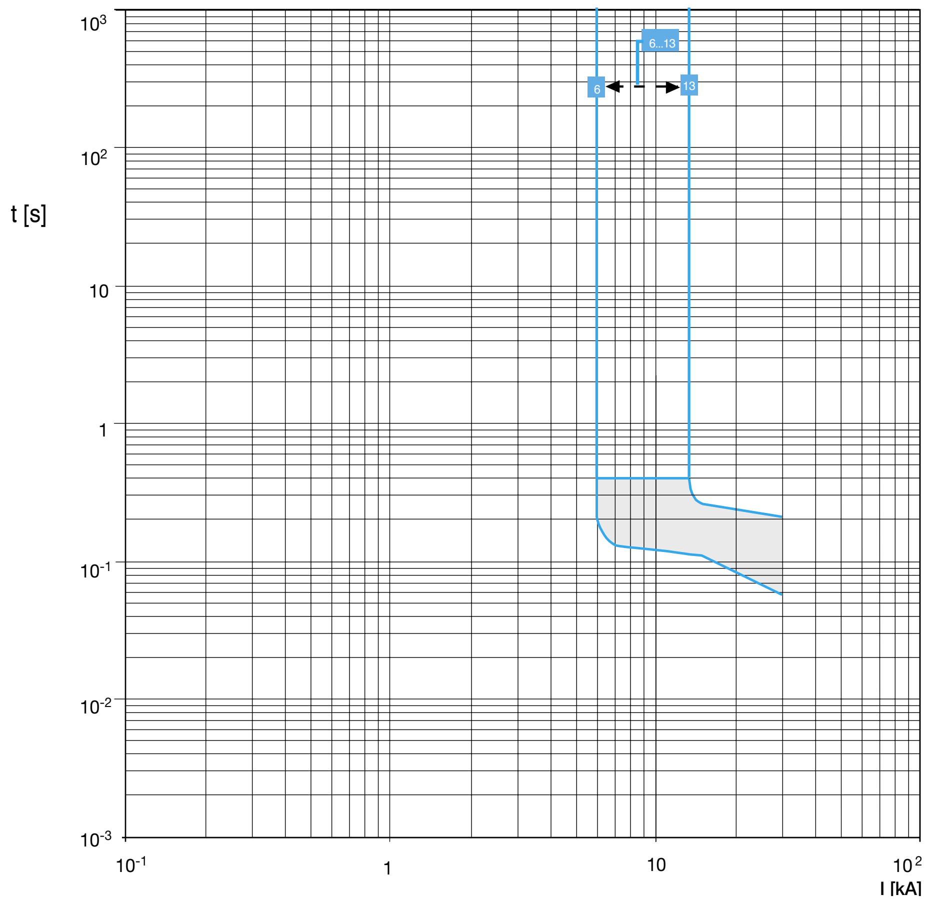
Function L implemented on MP trip units protects the motor against overloads, according to the indications and the classes defined by the Std. IEC 60947-4-1. The protection is based on a pre-defined thermal model, which by simulating the copper and iron overtemperatures inside motors, allows to safeguard properly the motor itself. The trip time-delay is set by selecting the trip class defined in the above mentioned Standard.

The function is temperature-compensated and sensitive to the lack of phase. Function L, which cannot be excluded, can be set manually from a minimum of 0.4 to a maximum of 1x In. Besides, it is necessary to select the starting class of the motor, which determines the trip time with a current equal to 7.2xIe in compliance with the prescriptions of item 4.7.3 of the Std. IEC 60947-4-1 4.7.3. For further details see Chapter 3.3 of Volume 2.

3 General characteristics

Motor protection

I: protection against short-circuit with instantaneous trip



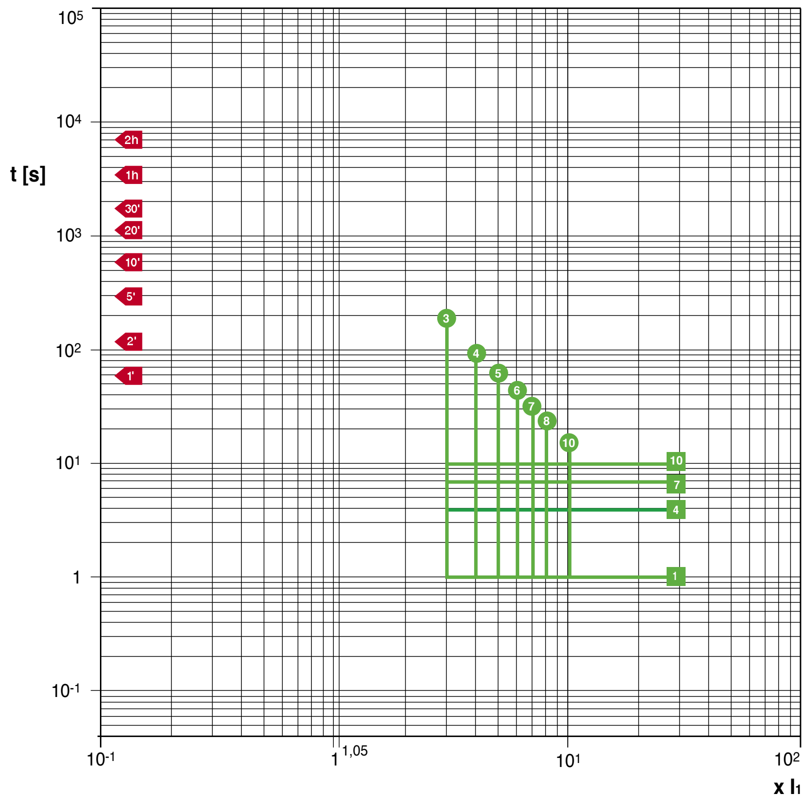
This protection function trips in case of phase-to-phase short-circuit. It is enough that one phase only exceeds the set threshold to cause the instantaneous opening of the circuit-breaker.

The trip current can be set up to 13 times the rated current of the trip unit.

3 General characteristics

Motor protection

R: Protection against rotor block

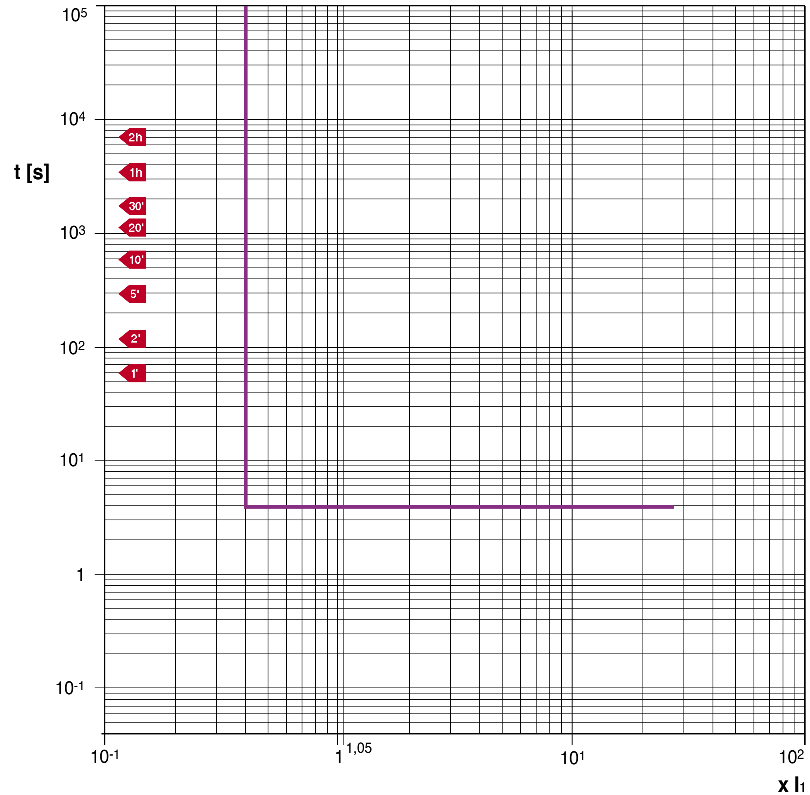


Function R protects the motor against possible rotor block during operation. Protection R has the characteristics of protecting the motor in two different ways, according to whether the fault is present at start-up or whether it occurs during normal service of an already active plant.
In the former case, protection R is linked to protection L for time selection as well: in the presence of a fault during the start-up, protection R is inhibited for a time equal to the time set according to the trip class. Once this time has been exceeded, protection R becomes active causing a trip after the set time t5. In the latter case, protection R is already active and the protection tripping time shall be equal to the set value t5. This protection intervenes when at least one of the phase current exceeds the established value and remains over that threshold for the fixed time t5.

3 General characteristics

Motor protection

U: Protection against phase unbalance

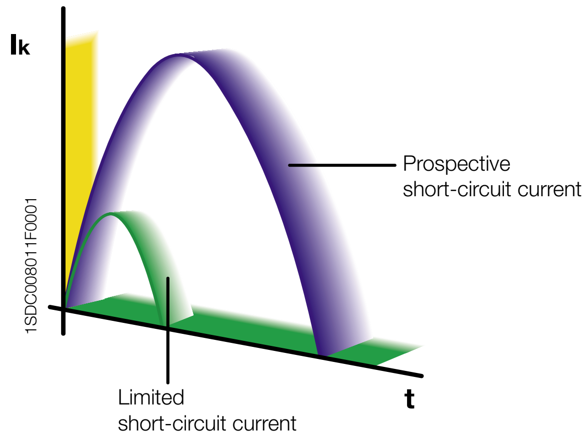


Function U can be used in those cases where a particularly accurate control is needed as regards phase lack/unbalance. This protection intervenes if the r.m.s. value of one or two currents drop below the level equal to 0.4 times the current I1 set for protection L and remain below it for longer than 4 seconds.
This protection can be excluded.

3 General characteristics

3.3 Limitation curves

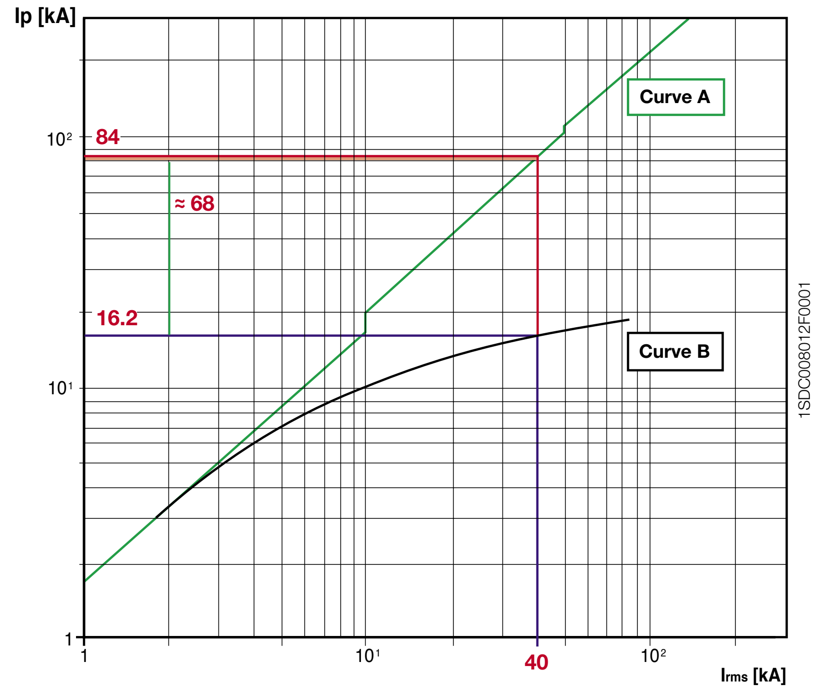
A circuit-breaker in which the opening of the contacts occurs after the passage of the peak of the short-circuit current, or in which the trip occurs with the natural passage to zero, allows the system components to be subjected to high stresses, of both thermal and dynamic type. To reduce these stresses, current-limiting circuit-breakers have been designed (see Chapter 2.2 "Main definitions"), which are able to start the opening operation before the short-circuit current has reached its first peak, and to quickly extinguish the arc between the contacts; the following diagram shows the shape of the waves of both the prospective short-circuit current as well as of the limited short-circuit current.



The following diagram shows the limit curve for Tmax T2L160, In160 circuit-breaker. The x-axis shows the effective values of the symmetrical prospective short-circuit current, while the y-axis shows the relative peak value. The limiting effect can be evaluated by comparing, at equal values of symmetrical fault current, the peak value corresponding to the prospective short-circuit current (curve A) with the limited peak value (curve B).

3 General characteristics

Circuit-breaker T2L160 with thermomagnetic release In160 at 400 V, for a fault current of 40 kA, limits the short-circuit peak to 16.2 kA only, with a reduction of about 68 kA compared with the peak value in the absence of limitation (84 kA).



Considering that the electro-dynamic stresses and the consequent mechanical stresses are closely connected to the current peak, the use of current limiting circuit-breakers allows optimum dimensioning of the components in an electrical plant. Besides, current limitation may also be used to obtain back-up protection between two circuit-breakers in series.

3 General characteristics

In addition to the advantages in terms of design, the use of current-limiting circuit-breakers allows, for the cases detailed by Standard IEC 60439-1, the avoidance of short-circuit withstand verifications for switchboards. Clause 8.2.3.1 of the Standard "Circuits of ASSEMBLIES which are exempted from the verification of the short-circuit withstand strength" states that:

"A verification of the short-circuit withstand strength is not required in the following cases…

For ASSEMBLIES protected by current-limiting devices having a cut-off current not exceeding 17 kA at the maximum allowable prospective short-circuit current at the terminals of the incoming circuit of the ASSEMBLY..."

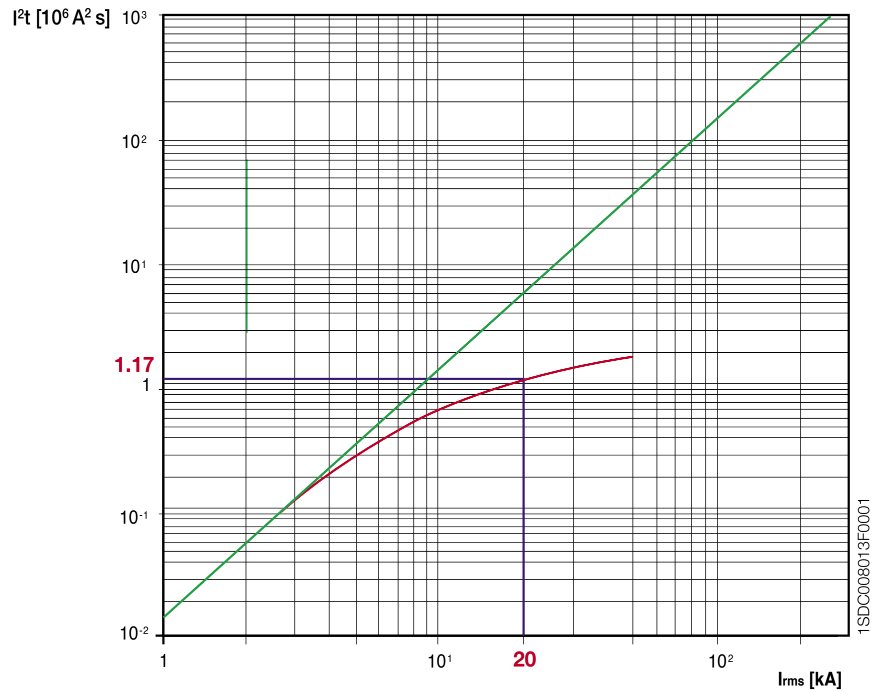
The example in the previous page included among those considered by the Standard: if the circuit-breaker was used as a main breaker in a switchboard to be installed in a point of the plant where the prospective short-circuit current is 40 kA, it would not be necessary to carry out the verification of short-circuit withstand.

3 General characteristics

3.4 Specific let-through energy curves

In case of short-circuit, the parts of a plant affected by a fault are subjected to thermal stresses which are proportional both to the square of the fault current as well as to the time required by the protection device to break the current. The energy let through by the protection device during the trip is termed "specific let-through energy" (I^2t), measured in A^2s. The knowledge of the value of the specific let-through energy in various fault conditions is fundamental for the dimensioning and the protection of the various parts of the installation.
The effect of limitation and the reduced trip times influence the value of the specific let-through energy. For those current values for which the tripping of the circuit-breaker is regulated by the timing of the release, the value of the specific let-through energy is obtained by multiplying the square of the effective fault current by the time required for the protection device to trip; in other cases the value of the specific let-through energy may be obtained from the following diagrams.

The following is an example of the reading from a diagram of the specific let-through energy curve for a circuit-breaker type T3S 250 In160 at 400 V.
The x-axis shows the symmetrical prospective short-circuit current, while the y-axis shows the specific let-through energy values, expressed in MA^2s.
Corresponding to a short-circuit current equal to 20 kA, the circuit-breaker lets through a value of I^2t equal to 1.17 MA^2s (1170000 A^2s).



3 General characteristics

3.5 Temperature derating

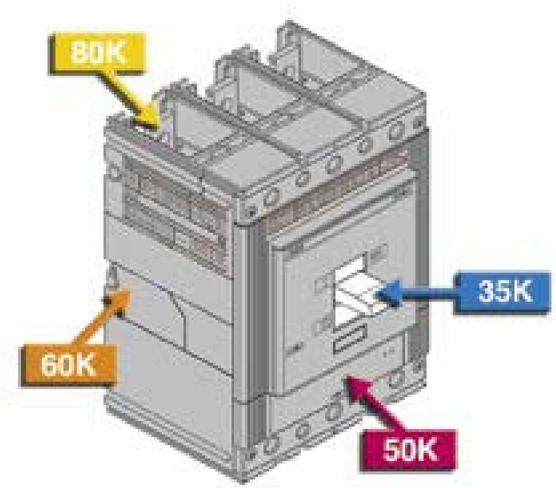
Standard IEC 60947-2 states that the temperature rise limits for circuit-breakers working at rated current must be within the limits given in the following table:

Table 1 - Temperature rise limits for terminals and accessible parts

Description of part*		**Temperature rise limits K**
- Terminal for external connections		80
- Manual operating means:	metallic	25
	non metallic	35
- Parts intended to be touched but not hand-held:	metallic	40
	non metallic	50
- Parts which need not be touched for normal operation:	metallic	50
	non metallic	60

* No value is specified for parts other than those listed but no damage should be caused to adjacent parts of insulating materials.

These values are valid for a maximum reference ambient temperature of 40°C, as stated in Standard IEC 60947-1, clause 6.1.1.



3 General characteristics

Whenever the ambient temperature is other than 40°C, the value of the current which can be carried continuously by the circuit-breaker is given in the following tables:

Circuit-breakers with thermomagnetic release

		10 °C		20 °C		30 °C		40 °C		50 °C		60 °C		70 °C	
	In [A]	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
T1	16	13	18	12	18	12	17	11	16	11	15	10	14	9	13
T1	20	16	23	15	22	15	21	14	20	13	19	12	18	11	16
T1	25	20	29	19	28	18	26	18	25	16	23	15	22	14	20
T1	32	26	37	25	35	24	34	22	32	21	30	20	28	18	26
T1	40	32	46	31	44	29	42	28	40	26	38	25	35	23	33
T1	50	40	58	39	55	37	53	35	50	33	47	31	44	28	41
T1	63	51	72	49	69	46	66	44	63	41	59	39	55	36	51
T1	80	64	92	62	88	59	84	56	80	53	75	49	70	46	65
T1	100	81	115	77	110	74	105	70	100	66	94	61	88	57	81
T1	125	101	144	96	138	92	131	88	125	82	117	77	109	71	102
T1	160	129	184	123	176	118	168	112	160	105	150	98	140	91	130
T2	1,6	1,3	1,8	1,2	1,8	1,2	1,7	1,1	1,6	1	1,5	1	1,4	0,9	1,3
T2	2	1,6	2,3	1,5	2,2	1,5	2,1	1,4	2	1,3	1,9	1,2	1,7	1,1	1,6
T2	2,5	2	2,9	1,9	2,8	1,8	2,6	1,8	2,5	1,6	2,3	1,5	2,2	1,4	2
T2	3,2	2,6	3,7	2,5	3,5	2,4	3,4	2,2	3,2	2,1	3	1,9	2,8	1,8	2,6
T2	4	3,2	4,6	3,1	4,4	2,9	4,2	2,8	4	2,6	3,7	2,4	3,5	2,3	3,2
T2	5	4	5,7	3,9	5,5	3,7	5,3	3,5	5	3,3	4,7	3	4,3	2,8	4
T2	6,3	5,1	7,2	4,9	6,9	4,6	6,6	4,4	6,3	4,1	5,9	3,8	5,5	3,6	5,1
T2	8	6,4	9,2	6,2	8,8	5,9	8,4	5,6	8	5,2	7,5	4,9	7	4,5	6,5
T2	10	8	11,5	7,7	11	7,4	10,5	7	10	6,5	9,3	6,1	8,7	5,6	8,1
T2	12,5	10,1	14,4	9,6	13,8	9,2	13,2	8,8	12,5	8,2	11,7	7,6	10,9	7,1	10,1
T2	16	13	18	12	18	12	17	11	16	10	15	10	14	9	13
T2	20	16	23	15	22	15	21	14	20	13	19	12	17	11	16
T2	25	20	29	19	28	18	26	18	25	16	23	15	22	14	20
T2	32	26	37	25	35	24	34	22	32	21	30	19	28	18	26
T2	40	32	46	31	44	29	42	28	40	26	37	24	35	23	32
T2	50	40	57	39	55	37	53	35	50	33	47	30	43	28	40
T2	63	51	72	49	69	46	66	44	63	41	59	38	55	36	51
T2	80	64	92	62	88	59	84	56	80	52	75	49	70	45	65
T2	100	80	115	77	110	74	105	70	100	65	93	61	87	56	81
T2	125	101	144	96	138	92	132	88	125	82	117	76	109	71	101
T2	160	129	184	123	178	118	168	112	160	105	150	97	139	90	129

3 General characteristics

	In [A]	10 °C MIN	10 °C MAX	20 °C MIN	20 °C MAX	30 °C MIN	30 °C MAX	40 °C MIN	40 °C MAX	50 °C MIN	50 °C MAX	60 °C MIN	60 °C MAX	70 °C MIN	70 °C MAX
T3	63	51	72	49	69	46	66	44	63	41	59	38	55	35	51
	80	64	92	62	88	59	84	56	80	52	75	48	69	45	64
	100	80	115	77	110	74	105	70	100	65	93	61	87	56	80
	125	101	144	96	138	92	132	88	125	82	116	76	108	70	100
	160	129	184	123	176	118	168	112	160	104	149	97	139	90	129
	200	161	230	154	220	147	211	140	200	130	186	121	173	112	161
	250	201	287	193	278	184	263	175	250	163	233	152	216	141	201
T4	20	19	27	18	24	16	23	14	20	12	17	10	15	8	13
	32	26	43	24	39	22	36	19	32	16	27	14	24	11	21
	50	37	62	35	58	33	54	30	50	27	46	25	42	22	39
	80	59	98	55	92	52	86	48	80	44	74	40	66	32	58
	100	83	118	80	113	74	106	70	100	66	95	59	85	49	75
	125	103	145	100	140	94	134	88	125	80	115	73	105	63	95
	160	130	185	124	176	118	168	112	160	106	150	100	104	90	130
	200	162	230	155	220	147	210	140	200	133	190	122	175	107	160
	250	200	285	193	275	183	262	175	250	168	240	160	230	150	220
T5	320	260	368	245	350	234	335	224	320	212	305	200	285	182	263
	400	325	465	310	442	295	420	280	400	265	380	250	355	230	325
	500	435	620	405	580	380	540	350	500	315	450	280	400	240	345
T6	630	520	740	493	705	462	660	441	630	405	580	380	540	350	500
	800	685	965	640	905	605	855	560	800	520	740	470	670	420	610

Examples:

Selection of a moulded-case circuit-breaker, with thermomagnetic release, for a load current of 180 A, at an ambient temperature of 60°C. From the table referring to Tmax T3, it can be seen that the most suitable breaker is the T3 In 250, which can be set from 152 A to 216 A.

3 General characteristics

Circuit-breakers with electronic release

			up to 40°C Imax (A)	up to 40°C I1	50°C Imax (A)	50°C I1	60°C Imax (A)	60°C I1	70°C Imax (A)	70°C I1
T2 160	fixed	F	160	1	153.6	0,96	140.8	0,88	128	0,8
		EF	160	1	153.6	0,96	140.8	0,88	128	0,8
		ES	160	1	153.6	0,96	140.8	0,88	128	0,8
		FC Cu	160	1	153.6	0,96	140.8	0,88	128	0,8
		FC CuAl	160	1	153.6	0,96	140.8	0,88	128	0,8
		R	160	1	153.6	0,96	140.8	0,88	128	0,8
	plug-in	F	144	0,9	138	0,84	126	0,8	112	0,68
		EF	144	0,9	138	0,84	126	0,8	112	0,68
		ES	144	0,9	138	0,84	126	0,8	112	0,68
		FC Cu	144	0,9	138	0,84	126	0,8	112	0,68
		FC CuAl	144	0,9	138	0,84	126	0,8	112	0,68
		R	144	0,9	138	0,84	126	0,8	112	0,68
T4 250	fixed	FC	250	1	250	1	250	1	220	0,88
		F	250	1	250	1	250	1	220	0,88
		R (HR)	250	1	250	1	250	1	220	0,88
		R (VR)	250	1	250	1	250	1	230	0,92
	plug-in	FC	250	1	250	1	230	0,92	210	0,84
		F	250	1	250	1	230	0,92	210	0,84
		HR	250	1	250	1	230	0,92	210	0,84
		VR	250	1	250	1	240	0,96	220	0,88
T4 320	fixed	FC	320	1	294	0,92	269	0,84	243	0,76
		F	320	1	294	0,92	269	0,84	243	0,76
		R (HR)	320	1	294	0,92	269	0,84	243	0,76
		R (VR)	320	1	307	0,96	281	0,88	256	0,8
	plug-in	FC	320	1	294	0,92	268	0,84	242	0,76
		F	320	1	294	0,92	268	0,84	242	0,76
		HR	320	1	294	0,92	268	0,84	242	0,76
		VR	320	1	307	0,96	282	0,88	256	0,8
T5 400	fixed	FC	400	1	400	1	400	1	352	0,88
		F	400	1	400	1	400	1	352	0,88
		R (HR)	400	1	400	1	400	1	352	0,88
		R (VR)	400	1	400	1	400	1	368	0,92
	plug-in	FC	400	1	400	1	368	0,92	336	0,84
		F	400	1	400	1	368	0,92	336	0,84
		R (HR)	400	1	400	1	368	0,92	336	0,84
		R (VR)	400	1	400	1	382	0,96	350	0,88
T5 630	fixed	FC	630	1	580	0,92	529	0,84	479	0,76
		F	630	1	580	0,92	529	0,84	479	0,76
		HR	630	1	580	0,92	529	0,84	479	0,76
		VR	630	1	605	0,96	554	0,88	504	0,80
	plug-in	F	567	0.9	502	0,8	458	0,72	409	0,64
		HR	567	0.9	502	0,8	458	0,72	409	0,64
		VR	567	0.9	526	0,82	480	0,76	429	0,68

Caption

F= Front flat terminals
FC= Front terminals for cables
HR= Rear flat horizontal terminals
VR= Rear flat vertical terminals
R= Rear terminals

EF= Front extended
FC Cu = Front terminals for copper cables
FC CuAl= Front terminals for CuAl cables
ES= Front extended spread terminals

3 General characteristics

			up to 40°C		50°C		60°C		70°C	
			Imax (A)	I1	Imax (A)	I1	Imax (A)	I1	Imax (A)	I1
T6 630	fixed	FC	630	1	630	1	598,1	1	567	0,9
		R (VR)	630	1	630	1	630	1	598,5	0,95
		R (HR)	630	1	630	1	567	0,9	504	0,8
	plug-in	F	630	1	598,5	0,95	567	0,9	567	0,9
		VR	630	1	630	1	598,5	0,95	504	0,8
		HR	630	1	598,5	0,95	567	0,9	504	0,8
T6 800	fixed	FC	800	1	800	1	760	0,95	720	0,9
		R (VR)	800	1	800	1	800	1	760	0,95
		R (HR)	800	1	800	1	720	0,9	640	0,8
	plug-in	F	800	1	760	0,95	720	0,9	640	0,8
		VR	800	1	800	1	760	0,95	720	0,9
		HR	800	1	760	0,95	720	0,9	640	0,8
T6 1000	fixed	FC	1000	1	926	0,93	877	0,88	784	0,78
		R (HR)	1000	1	926	0,93	845	0,85	756	0,76
		R (VR)	1000	1	1000	1	913	0,92	817	0,82
		ES	1000	1	900	0,9	820	0,82	720	0,72
T7 1000 V version	fixed	VR	1000	1	1000	1	1000	1	894	0,89
		EF-HR	1000	1	1000	1	895	0,89	784	0,78
	plug-in	VR	1000	1	1000	1	913	0,91	816	0,82
		EF-HR	1000	1	1000	1	895	0,89	784	0,78
T7 1250 V version	fixed	VR	1250	1	1201	0,96	1096	0,88	981	0,78
		EF-HR	1250	1	1157	0,93	1056	0,85	945	0,76
	plug-in	VR	1250	1	1157	0,93	1056	0,85	945	0,76
		EF-HR	1250	1	1000	0,8	913	0,73	816	0,65
T7 1250 S-H-L version	fixed	VR	1250	1	1250	1	1250	1	1118	0,89
		EF-HR	1250	1	1250	1	1118	0,89	980	0,78
	plug-in	VR	1250	1	1250	1	1141	0,91	1021	0,82
		EF-HR	1250	1	1250	1	1118	0,89	980	0,78
T7 1600 S-H-L version	fixed	VR	1600	1	1537	0,96	1403	0,88	1255	0,78
		EF-HR	1600	1	1481	0,93	1352	0,85	1209	0,76
	plug-in	VR	1600	1	1481	0,93	1352	0,85	1209	0,76
		EF-HR	1600	1	1280	0,8	1168	0,73	1045	0,65

Caption
F= Front flat terminals
FC= Front terminals for cables
HR= Rear flat horizontal terminals
VR= Rear flat vertical terminals
R= Rear terminals
EF= Front extended
FC Cu = Front terminals for copper cables
FC CuAl= Front terminals for CuAl cables
ES= Front extended spread terminals

Example:

Selection of a moulded-case circuit-breaker, with electronic release, in withdrawable version with rear flat horizontal bar terminals, for a load current equal to 720 A, with an ambient temperature of 50 °C. From the table referring to Tmax T6, it can be seen that the most suitable breaker is the T6 800, which can be set from 320 A to 760 A.

3 General characteristics

Emax X1 with horizontal rear terminals

Temperature	X1 630		X1 800		X1 1000		X1 1250		X1 1600	
[°C]	%	[A]	%	[A]	%	[A]	%	[A]	%	[A]
10	100	630	100	800	100	1000	100	1250	100	1600
20	100	630	100	800	100	1000	100	1250	100	1600
30	100	630	100	800	100	1000	100	1250	100	1600
40	100	630	100	800	100	1000	100	1250	100	1600
45	100	630	100	800	100	1000	100	1250	100	1600
50	100	630	100	800	100	1000	100	1250	97	1550
55	100	630	100	800	100	1000	100	1250	94	1500
60	100	630	100	800	100	1000	100	1250	93	1480

Emax X1 with vertical rear terminals

Temperature	X1 630		X1 800		X1 1000		X1 1250		X1 1600	
[°C]	%	[A]	%	[A]	%	[A]	%	[A]	%	[A]
10	100	630	100	800	100	1000	100	1250	100	1600
20	100	630	100	800	100	1000	100	1250	100	1600
30	100	630	100	800	100	1000	100	1250	100	1600
40	100	630	100	800	100	1000	100	1250	100	1600
45	100	630	100	800	100	1000	100	1250	100	1600
50	100	630	100	800	100	1000	100	1250	100	1600
55	100	630	100	800	100	1000	100	1250	98	1570
60	100	630	100	800	100	1000	100	1250	95	1520

Emax E1

Temperature	E1 800		E1 1000		E1 1250		E1 1600	
[°C]	%	[A]	%	[A]	%	[A]	%	[A]
10	100	800	100	1000	100	1250	100	1600
20	100	800	100	1000	100	1250	100	1600
30	100	800	100	1000	100	1250	100	1600
40	100	800	100	1000	100	1250	100	1600
45	100	800	100	1000	100	1250	98	1570
50	100	800	100	1000	100	1250	96	1530
55	100	800	100	1000	100	1250	94	1500
60	100	800	100	1000	100	1250	92	1470
65	100	800	100	1000	99	1240	89	1430
70	100	800	100	1000	98	1230	87	1400

3 General characteristics

Emax E2

Temperature	E2 800		E2 1000		E2 1250		E2 1600		E2 2000	
[°C]	%	[A]	%	[A]	%	[A]	%	[A]	%	[A]
10	100	800	100	1000	100	1250	100	1600	100	2000
20	100	800	100	1000	100	1250	100	1600	100	2000
30	100	800	100	1000	100	1250	100	1600	100	2000
40	100	800	100	1000	100	1250	100	1600	100	2000
45	100	800	100	1000	100	1250	100	1600	100	2000
50	100	800	100	1000	100	1250	100	1600	97	1945
55	100	800	100	1000	100	1250	100	1600	94	1885
60	100	800	100	1000	100	1250	98	1570	91	1825
65	100	800	100	1000	100	1250	96	1538	88	1765
70	100	800	100	1000	100	1250	94	1510	85	1705

Emax E3

Temperature	E3 800		E3 1000		E3 1250		E3 1600		E3 2000		E3 2500		E3 3200	
[C°]	%	[A]	%	[A]	%	[A]	%	[A]	%	[A]	%	[A]	%	[A]
10	100	800	100	1000	100	1250	100	1600	100	2000	100	2500	100	3200
20	100	800	100	1000	100	1250	100	1600	100	2000	100	2500	100	3200
30	100	800	100	1000	100	1250	100	1600	100	2000	100	2500	100	3200
40	100	800	100	1000	100	1250	100	1600	100	2000	100	2500	100	3200
45	100	800	100	1000	100	1250	100	1600	100	2000	100	2500	100	3200
50	100	800	100	1000	100	1250	100	1600	100	2000	100	2500	97	3090
55	100	800	100	1000	100	1250	100	1600	100	2000	100	2500	93	2975
60	100	800	100	1000	100	1250	100	1600	100	2000	100	2500	89	2860
65	100	800	100	1000	100	1250	100	1600	100	2000	97	2425	86	2745
70	100	800	100	1000	100	1250	100	1600	100	2000	94	2350	82	2630

3 General characteristics

Emax E4

Temperature	E4 3200		E4 4000	
[°C]	%	[A]	%	[A]
10	100	3200	100	4000
20	100	3200	100	4000
30	100	3200	100	4000
40	100	3200	100	4000
45	100	3200	100	4000
50	100	3200	98	3900
55	100	3200	95	3790
60	100	3200	92	3680
65	98	3120	89	3570
70	95	3040	87	3460

Emax E6

Temperature	E6 3200		E6 4000		E6 5000		E6 6300	
[°C]	%	[A]	%	[A]	%	[A]	%	[A]
10	100	3200	100	4000	100	5000	100	6300
20	100	3200	100	4000	100	5000	100	6300
30	100	3200	100	4000	100	5000	100	6300
40	100	3200	100	4000	100	5000	100	6300
45	100	3200	100	4000	100	5000	100	6300
50	100	3200	100	4000	100	5000	100	6300
55	100	3200	100	4000	100	5000	98	6190
60	100	3200	100	4000	98	4910	96	6070
65	100	3200	100	4000	96	4815	94	5850
70	100	3200	100	4000	94	4720	92	5600

3 General characteristics

The following table lists examples of the continuous current carrying capacity for circuit-breakers installed in a switchboard with the dimensions indicated below. These values refer to withdrawable switchgear installed in non segregated switchboards with a protection rating up to IP31, and following dimensions:
2000x400x400 (HxLxD) for X1, 2300x800x900 (HxLxD) for X1 - E1 - E2 - E3;
2300x1400x1500 (HxLxD) for E4 - E6.
The values refer to a maximum temperature at the terminals of 120 °C.
For withdrawable circuit-breakers with a rated current of 6300 A, the use of vertical rear terminals is recommended.

For switchboards with the following dimensions (mm): 2000x400x400

Type	Iu [A]	Vertical terminals Continuous capacity [A] 35°C	 45°C	 55°C	 Busbars section [mm²]	Horizontal and front terminals Continuous capacity [A] 35°C	 45°C	 55°C	 Busbars section [mm²]
X1B/N/L 06	630	630	630	630	2x(40x5)	630	630	630	2x(40x5)
X1B/N/L 08	800	800	800	800	2x(50x5)	800	800	800	2x(50x5)
X1B/N/ 10	1000	1000	1000	1000	2x(50x8)	1000	1000	1000	2x(50x10)
X1L 10	1000	1000	1000	960	2x(50x8)	1000	950	890	2x(50x10)
X1B/N/ 12	1250	1250	1250	1250	2x(50x8)	1250	1250	1200	2x(50x10)
X1L 12	1250	1250	1205	1105	2x(50x8)	1250	1125	955	2x(50x10)
X1B/N 16	1600	1520	1440	1340	2x(50x10)	1400	1330	1250	3x(50x8)

For switchboards with the following dimensions (mm): 2300x800x900

Type	Iu [A]	Vertical terminals Continuous capacity [A] 35°C	 45°C	 55°C	 Busbars section [mm²]	Horizontal and front terminals Continuous capacity [A] 35°C	 45°C	 55°C	 Busbars section [mm²]
X1B/N/L 06	630	630	630	630	2x(40x5)	630	630	630	2x(40x5)
X1B/N/L 08	800	800	800	800	2x(50x5)	800	800	800	2x(50x5)
X1B/N/L 10	1000	1000	1000	1000	2x(50x8)	1000	1000	1000	2x(50x10)
X1L 10	1000	1000	1000	1000	2x(50x8)	1000	960	900	2x(50x10)
X1B/N/L 12	1250	1250	1250	1250	2x(50x8)	1250	1250	1200	2x(50x10)
X1L 12	1250	1250	1250	1110	2x(50x8)	1250	1150	960	2x(50x10)
X1B/N 16	1600	1600	1500	1400	2x(50x10)	1460	1400	1300	3x(50x8)

3 General characteristics

Type	Iu [A]	Vertical terminals Continuous capacity [A] 35°C	 45°C	 55°C	 Busbars section [mm²]	Horizontal and front terminals Continuous capacity [A] 35°C	 45°C	 55°C	 Busbars section [mm²]
E1B/N 08	800	800	800	800	1x(60x10)	800	800	800	1x(60x10)
E1B/N 10	1000	1000	1000	1000	1x(80x10)	1000	1000	1000	2x(60x8)
E1B/N 12	1250	1250	1250	1250	1x(80x10)	1250	1250	1200	2x(60x8)
E1B/N 16	1600	1600	1600	1500	2x(60x10)	1550	1450	1350	2x(60x10)
E2S 08	800	800	800	800	1x(60x10)	800	800	800	1x(60x10)
E2N/S 10	1000	1000	1000	1000	1x(60x10)	1000	1000	1000	1x(60x10)
E2N/S 12	1250	1250	1250	1250	1x(60x10)	1250	1250	1250	1x(60x10)
E2B/N/S 16	1600	1600	1600	1600	2x(60x10)	1600	1600	1530	2x(60x10)
E2B/N/S 20	2000	2000	2000	1800	3x(60x10)	2000	2000	1750	3x(60x10)
E2L 12	1250	1250	1250	1250	1x(60x10)	1250	1250	1250	1x(60x10)
E2L 16	1600	1600	1600	1500	2x(60x10)	1600	1500	1400	2x(60x10)
E3H/V 08	800	800	800	800	1x(60x10)	800	800	800	1x(60x10)
E3S/H 10	1000	1000	1000	1000	1x(60x10)	1000	1000	1000	1x(60x10)
E3S/H/V 12	1250	1250	1250	1250	1x(60x10)	1250	1250	1250	1x(60x10)
E3S/H/V 16	1600	1600	1600	1600	1x(100x10)	1600	1600	1600	1x(100x10)
E3S/H/V 20	2000	2000	2000	2000	2x(100x10)	2000	2000	2000	2x(100x10)
E3N/S/H/V 25	2500	2500	2500	2500	2x(100x10)	2500	2450	2400	2x(100x10)
E3N/S/H/V 32	3200	3200	3100	2800	3x(100x10)	3000	2880	2650	3x(100x10)
E3L 20	2000	2000	2000	2000	2x(100x10)	2000	2000	1970	2x(100x10)
E3L 25	2500	2500	2390	2250	2x(100x10)	2375	2270	2100	2x(100x10)
E4H/V 32	3200	3200	3200	3200	3x(100x10)	3200	3150	3000	3x(100x10)
E4S/H/V 40	4000	4000	3980	3500	4x(100x10)	3600	3510	3150	6x(60x10)
E6V 32	3200	3200	3200	3200	3x(100x10)	3200	3200	3200	3x(100x10)
E6H/V 40	4000	4000	4000	4000	4x(100x10)	4000	4000	4000	4x(100x10)
E6H/V 50	5000	5000	4850	4600	6x(100x10)	4850	4510	4250	6x(100x10)
E6H/V 63	6300	6000	5700	5250	7x(100x10)	-	-	-	-

Note: the reference temperature is the ambient temperature

Examples:

Selection of an air circuit-breaker, with electronic release, in withdrawable version, with vertical terminals, for a load current of 2700 A, with a temperature of 55 °C outside of the IP31 switchboard.
From the tables referring to the current carrying capacity inside the switchboard for Emax circuit-breaker (see above), it can be seen that the most suitable breaker is the E3 3200, with busbars section 3x(100x10) mm², which can be set from 1280 A to 2800 A.

3.6 Altitude derating

For installations carried out at altitudes of more than 2000 m above sea level, the performance of low voltage circuit-breakers is subject to a decline.
Basically there are two main phenomena:

- the reduction of air density causes a lower efficiency in heat transfer. The allowable heating conditions for the various parts of the circuit-breaker can only be followed if the value of the rated uninterrupted current is decreased;
- the rarefaction of the air causes a decrease in dielectric rigidity, so the usual isolation distances become insufficient. This leads to a decrease in the maximum rated voltage at which the device can be used.

The correction factors for the different types of circuit-breakers, both moulded-case and air circuit-breakers, are given in the following table:

Rated operational voltage Ue [V]

Altitude	2000[m]	3000[m]	4000[m]	5000[m]
Tmax*	690	600	500	440
Emax	690	600	500	440

Rated uninterrupted current Iu [A]

Altitude	2000[m]	3000[m]	4000[m]	5000[m]
Tmax	100%	98%	93%	90%
Emax	100%	98%	93%	90%

*Excluding Tmax T1P

3.7 Electrical characteristics of switch disconnectors

A switch disconnector as defined by the standard IEC 60947-3 is a mechanical switching device which, when in the open position, carries out a disconnecting function and ensures an isolating distance (distance between contacts) sufficient to guarantee safety. This safety of disconnection must be guaranteed and verified by the positive operation: the operating lever must always indicate the actual position of the mobile contacts of the device.
The mechanical switching device must be able to make, carry and break currents in normal circuit conditions, including any overload currents in normal service, and to carry, for a specified duration, currents in abnormal circuit conditions, such as, for example, short-circuit conditions.

Switch disconnectors are often used as:

- main sub-switchboard devices;
- switching and disconnecting devices for lines, busbars or load units;
- bus-tie.

The switch disconnector shall ensure that the whole plant or part of it is not live, safely disconnecting from any electrical supply. The use of such a switch disconnector allows, for example, personnel to carry out work on the plant without risks of electrical nature.

Even if the use of a single pole devices side by side is not forbidden, the standards recommend the use of multi-pole devices so as to guarantee the simultaneous isolation of all poles in the circuit.

The specific rated characteristics of switch disconnectors are defined by the standard IEC 60947-3, as detailed below:

- **Icw [kA]**: rated short-time withstand current:
  is the current that a switch is capable of carrying, without damage, in the closed position for a specific duration

3 General characteristics

- **Icm [kA]**: rated short-circuit making capacity:

  is the maximum peak value of a short-circuit current which the switch disconnector can close without damages. When this value is not given by the manufacturer it must be taken to be at least equal to the peak current corresponding to Icw. It is not possible to define a breaking capacity Icu [kA] since switch disconnectors are not required to break short-circuit currents
- **utilization categories with alternating current AC and with direct current DC:**

  define the kind of the conditions of using which are represented by two letters to indicate the type of circuit in which the device may be installed (AC for alternating current and DC for direct current), with a two digit number for the type of load which must be operated, and an additional letter (A or B) which represents the frequency in the using.

  With reference to the utilization categories, the product standard defines the current values which the switch disconnector must be able to break and make under abnormal conditions.

The characteristics of the utilization categories are detailed in Table 1 below. The most demanding category in alternating current is AC23A, for which the device must be capable of connecting a current equal to 10 times the rated current of the device, and of disconnecting a current equal to 8 times the rated current of the device.

From the point of view of construction, the switch disconnector is a very simple device. It is not fitted with devices for overcurrent detection and the consequent automatic interruption of the current. Therefore the switch disconnector cannot be used for automatic protection against overcurrent which may occur in the case of failure, protection must be provided by a coordinated circuit-breaker. The combination of the two devices allows the use of switch disconnectors in systems in which the short-circuit current value is greater than the electrical parameters which define the performance of the disconnector (back-up protection see Chapter 4.4. This is valid only for Isomax and Tmax switch-disconnectors. For the Emax/MS air disconnectors, it must be verified that the values for Icw and Icm are higher to the values for short-circuit in the plant and correspondent peak, respectively.

3 General characteristics

Table1: Utilization categories

Nature of current	Utilization categories		
	Utilization category		Typical applications
	Frequent operation	Non-frequent operation	
Alternating Current	AC-20A	AC-20B	Connecting and disconnecting under no-load conditions
	AC-21A	AC-21B	Switching of resistive loads including moderate overloads
	AC-22A	AC-22B	Switching of mixed resistive and inductive loads, including moderate overload
	AC-23A	AC-23B	Switching of motor loads or other highly inductive loads
Direct Current	DC-20A	DC-20B	Connecting and disconnecting under no-load conditions
	DC-21A	DC-21B	Switching of resistive loads including moderate overloads
	DC-22A	DC-22B	Switching of mixed resistive and inductive loads, including moderate overload (e.g. shunt motors)
	DC-23A	DC-23B	Switching of highly inductive loads

3 General characteristics

3.7 Electrical characteristics of switch disconnectors

3 General characteristics

Tables 2, 3 and 4 detail the main characteristics of the disconnectors.

Table 2: Tmax switch disconnectors

				Tmax T1D	Tmax T3D	Tmax T4D	Tmax T5D	Tmax T6D	Tmax T7D
Conventional thermal current, **Ith**			[A]	160	250	250/320	400/630	630/800/1000	1000/1250/1600
Rated service current in category AC22, **Ie**			[A]	160	250	250/320	400/630	630/800/1000	1000/1250/1600
Rated service current in category AC23, **Ie**			[A]	125	200	250	400	630/800/800	1000/1250/1250
Poles			[Nr.]	3/4	3/4	3/4	3/4	3/4	3/4
Rated service voltage, **Ue**	(AC) 50-60 Hz		[V]	690	690	690	690	690	690
	(DC)		[V]	500	500	750	750	750	750
Rated impulse withstand voltage, **Uimp**			[kV]	8	8	8	8	8	8
Rated insulation voltage, **Ui**			[V]	800	800	800	800	1000	1000
Test voltage at industrial frequency for 1 minute			[V]	3000	3000	3000	3000	3500	3000
Rated short-circuit making capacity, Icm	(min) switch-disconnector only		[kA]	2.8	5.3	5.3	11	30	52.5
	(max) with circuit-breaker on supply side		[kA]	187	105	440	440	440	440
Rated short-time withstand current for 1s, **Icw**			[kA]	2	3.6	3.6	6	15	20
Reference Standard				IEC 60947-3	IEC 60947-3	IEC 60947-3	IEC 60947-3	IEC 60947-3	IEC 60947-3
Versions				F	F - P	F - P - W	F - P - W	F-W	F-W
Terminals				FC Cu - EF - FC CuAl	F-FC CuAl-FC Cu-EF-ES-R	F-FC CuAl-FC Cu-EF-ES-R-MC-HR-VR	F-FC CuAl-FC Cu-EF-ES-R-HR-VR	F-FC CuAl-EF-ES-R-RC	F-EF-ES-FC CuAl HR/VR
Mechanical life			[No. operations]	25000	25000	20000	20000	20000	10000
			[No. Hourly operations]	120	120	120	120	120	60
Basic dimensions, fixed		3 poles	W [mm]	76	105	105	140	210	210
		4 poles	W [mm]	102	140	140	184	280	280
			D [mm]	70	70	103.5	103.5	268	154(manual)/178(motorizable)
			H [mm]	130	150	205	205	103.5	268
Weight	fixed	3/4 poles	[kg]	0.9/1.2	1.5/2	2.35/3.05	3.25/4.15	9.5/12	9.7/12.5(manual)/11/14(motorizable)
	plug-in	3/4 poles	[kg]	–	2.1/3.7	3.6/4.65	5.15/6.65	–	–
	withdrawable	3/4 poles	[kg]	–	–	3.85/4.9	5.4/6.9	12.1/15.1	29.7/39.6(manual)/32/42.6(motorizable)

KEY TO VERSIONS
F = Fixed
P = Plug-in
W = Withdrawable

KEY TO TERMINALS
F = Front
EF = Extended front
ES = Extended spreaded front
FC CuAl = Front for copper or aluminium cables
R = Rear threaded
RC = Rear for copper or aluminium cables
HR = Rear horizontal flat bar

3 General characteristics

3.7 Electrical characteristics of switch disconnectors

3 General characteristics

Table 4: Emax switch disconnectors

		X1B/MS	E1B/MS	E1N/MS	E2B/MS	E2N/MS	E2S/MS	E3N/MS	E3S/MS	E3V/MS	E4S/fMS	E4S/MS	E4H/fMS	E4H/MS	E6H/MS	E6H/f MS
Rated uninterrupted current	[A]	**1000**	**800**	**800**	**1600**	**1000**	**1000**	**2500**	**1000**	**800**	**4000**	**4000**	**3200**	**3200**	**4000**	**4000**
(a 40 °C) Iu	[A]	**1250**	**1000**	**1000**	**2000**	**1250**	**1250**	**3200**	**1250**	**1250**			**4000**	**4000**	**5000**	**5000**
	[A]	**1600**	**1250**	**1250**		**1600**	**1600**		**1600**	**1600**					**6300**	**6300**
	[A]		**1600**	**1600**		**2000**	**2000**		**2000**	**2000**						
	[A]								**2500**	**2600**						
	[A]								**3200**	**3200**						
Rated operational voltage **Ue**	[V ~]	690	690	690	690	690	690	690	690	690	690	690	690	690	690	690
	[V –]	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
Rated insulation voltage **Ui**	[V ~]	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Rated impulse withstand voltage **Uimp**	[kV]	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Rated short-time withstand current **Icw** (1s)	[kA]	42	42	50[1]	42	55	65	65	75	85	75	75	85	100[2]	100	100
(3s)	[kA]		36	36	42	42	42	65	65	65	75	75	75	75	85	85
Rated short-circuit making capacity (peak value) **Icm**																
220/230/380/400/415/440 V ~	[kA]	88.2	88.2	105	88.2	121	187	143	165	187	165	165	187	220	220	220
500/660/690 V ~	[kA]	88.2	88.2	105	88.2	121	143	143	165	187	165	165	187	220	220	220

Note: the breaking capacity I_{cu}, at the maximum rated use voltage, by means of external protection relay, with 500 ms maximum timing, is equal to the value of I_{cw} (1s).

(1) I_{cw}=36kA@690V.
(2) I_{cw}=85kA@690V.

4 Protection coordination

4.1 Protection coordination

The design of a system for protecting an electric network is of fundamental importance both to ensure the correct economic and functional operation of the installation as a whole and to reduce to a minimum any problem caused by anomalous operating conditions and/or malfunctions.
The present analysis discusses the coordination between the different devices dedicated to the protection of zones and specific components with a view to:

- guaranteeing safety for people and installation at all times;
- identifying and rapidly excluding only the zone affected by a problem, instead of taking indiscriminate actions and thus reducing the energy available to the rest of the network;
- containing the effects of a malfunction on other intact parts of the network (voltage dips, loss of stability in the rotating machines);
- reducing the stress on components and damage in the affected zone;
- ensuring the continuity of the service with a good quality feeding voltage;
- guaranteeing an adequate back-up in the event of any malfunction of the protective device responsible for opening the circuit;
- providing staff and management systems with the information they need to restore the service as rapidly as possible and with a minimal disturbance to the rest of the network;
- achieving a valid compromise between reliability, simplicity and cost effectiveness.

To be more precise, a valid protection system must be able to:

- understand what has happened and where it has happened, discriminating between situations that are anomalous but tolerable and faults within a given zone of influence, avoiding unnecessary tripping and the consequent unjustified disconnection of a sound part of the system;
- take action as rapidly as possible to contain damage (destruction, accelerated ageing, ...), safeguarding the continuity and stability of the power supply.

The most suitable solution derives from a compromise between these two opposing needs-to identify precisely the fault and to act rapidly - and is defined in function of which of these two requirements takes priority.

Over-current coordination

Influence of the network's electrical parameters (rated current and short-circuit current)

The strategy adopted to coordinate the protective devices depends mainly on the rated current (I_n) and short-circuit current (I_k) values in the considered point of network.
Generally speaking, we can classify the following types of coordination:

- current discrimination;
- time (or time-current) discrimination;
- zone (or logical) discrimination;
- energy discrimination;
- back-up.

4 Protection coordination

Definition of discrimination

The **over-current discrimination** is defined in the Standards as *"coordination of the operating characteristics of two or more over-current protective devices such that, on the incidence of over-currents within stated limits, the device intended to operate within these limits does so, while the others do not operate"* (IEC 60947-1, def. 2.5.23);
It is possible to distinguish between:

- **total discrimination**, which means *"over-current discrimination such that, in the case of two over-current protective devices in series, the protective device on the load side provides protection without tripping the other protective device"* (IEC 60947-2, def. 2.17.2);
- **partial discrimination**, which means *"over-current discrimination such that, in the case of two over-current protective devices in series, the protective device on the load side provides protection up to a given over-current limit without tripping the other"* (IEC 60947-2, def. 2.17.3); this over-current threshold is called *"discrimination limit current I_s"* (IEC 60947-2, def. 2.17.4).

Current discrimination

This type of discrimination is based on the observation that the closer the fault comes to the network's feeder, the greater the short-circuit current will be. We can therefore pinpoint the zone where the fault has occurred simply by calibrating the instantaneous protection of the device upstream to a limit value higher than the fault current which causes the tripping of the device downstream.
We can normally achieve total discrimination only in specific cases where the fault current is not very high (and comparable with the device's rated current) or where a component with high impedance is between the two protective devices (e.g. a transformer, a very long or small cable...) giving rise to a large difference between the short-circuit current values.

This type of coordination is consequently feasible mainly in final distribution networks (with low rated current and short-circuit current values and a high impedance of the connection cables).
The devices' time-current tripping curves are generally used for the study.
This solution is:

- rapid;
- easy to implement;
- and inexpensive.

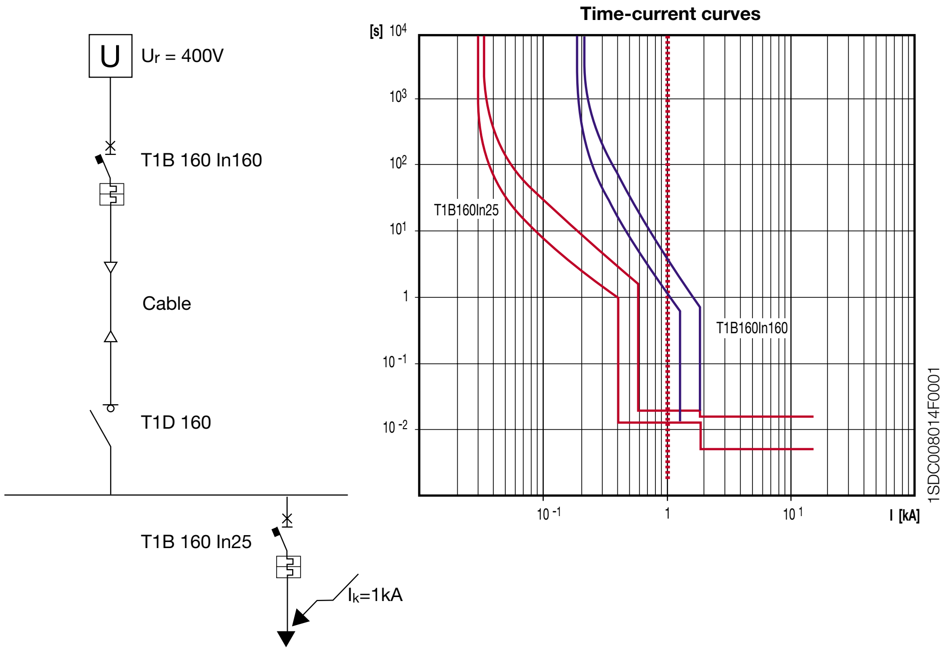
On the other hand:

- the discrimination limits are normally low;
- increasing the discrimination levels causes a rapid growing of the device sizes.

The following example shows a typical application of current discrimination based on the different instantaneous tripping threshold values of the circuit-breakers considered.

4 Protection coordination

With a fault current value at the defined point equal to 1000 A, an adequate coordination is obtained by using the considered circuit-breakers as verified in the tripping curves of the protection devices.
The discrimination limit is given by the minimum magnetic threshold of the circuit-breaker upstream, T1B160 In160.



Time discrimination

This type of discrimination is an evolution from the previous one. The setting strategy is therefore based on progressively increasing the current thresholds and the time delays for tripping the protective devices as we come closer to the power supply source. As in the case of current discrimination, the study is based on a comparison of the time-current tripping curves of the protective devices.

This type of coordination:

- is easy to study and implement;
- is relatively inexpensive;
- enables to achieve even high discrimination levels, depending on the I_{cw} of the upstream device;
- allows a redundancy of the protective functions and can send valid information to the control system,

but has the following disadvantages:

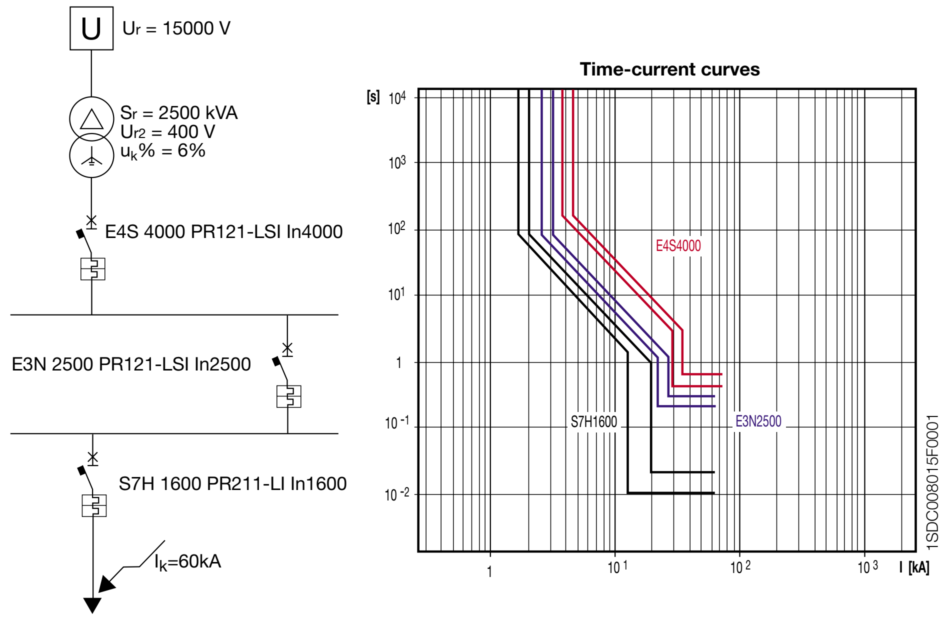
- the tripping times and the energy levels that the protective devices (especially those closer to the sources) let through are high, with obvious problems concerning safety and damage to the components even in zones unaffected by the fault;

4 Protection coordination

- it enables the use of current-limiting circuit-breakers only at levels hierarchically lower down the chain; the other circuit-breakers have to be capable of withstanding the thermal and electro-dynamic stresses related to the passage of the fault current for the intentional time delay. Selective circuit-breakers, often air type, have to be used for the various levels to guarantee a sufficiently high short-time withstand current;
- the duration of the disturbance induced by the short-circuit current on the power supply voltages in the zones unaffected by the fault can cause problems with electronic and electro-mechanical devices (voltage below the electromagnetic releasing value);
- the number of discrimination levels is limited by the maximum time that the network can stand without loss of stability.

The following example shows a typical application of time discrimination obtained by setting differently the tripping times of the different protection devices.

Electronic release:	L (Long delay)	S (Short delay)	I (IST)
E4S 4000 PR121-LSI In4000	Setting: 0.9 Curve: 12s	Setting: 8.5 Curve: 0.5s	Off
E3N 2500 PR121-LSI In2500	Setting: 1 Curve: 3s	Setting: 10 Curve: 0.3s	Off
S7H 1600 PR211-LI In1600	Setting: 1 Curve: A		Setting: 10



4 Protection coordination

Zone (or logical) discrimination

The zone discrimination is available with MCCB (T4 L-T5 L-T6 L with PR223-EF) and ACB (with PR332/P - PR333/P - PR122 - PR 123).
This type of coordination is implemented by means of a dialogue between current measuring devices that, when they ascertain that a setting threshold has been exceeded, give the correct identification and disconnection only of the zone affected by the fault.
In practice, it can be implemented in two ways:

- the releases send information on the preset current threshold that has been exceeded to the supervisor system and the latter decides which protective device has to trip;
- in the event of current values exceeding its setting threshold, each protective device sends a blocking signal via a direct connection or bus to the protective device higher in the hierarchy (i.e. upstream with respect to the direction of the power flow) and, before it trips, it makes sure that a similar blocking signal has not arrived from the protective device downstream; in this way, only the protective device immediately upstream of the fault trips.

The first mode foresees tripping times of about one second and is used mainly in the case of not particularly high short-circuit currents where a power flow is not uniquely defined.
The second mode enables distinctly shorter tripping times: with respect to a time discrimination coordination, there is no longer any need to increase the intentional time delay progressively as we move closer to the source of the power supply. The maximum delay is in relation to the time necessary to detect any presence of a blocking signal sent from the protective device downstream.

Advantages:

- reduction of the tripping times and increase of the safety level;
- reduction of both the damages caused by the fault as well of the disturbances in the power supply network;
- reduction of the thermal and dynamic stresses on the circuit-breakers and on the components of the system;
- large number of discrimination levels;
- redundancy of protections: in case of malfunction of zone discrimination, the tripping is ensured by the settings of the other protection functions of the circuit-breakers. In particular, it is possible to adjust the time-delay protection functions against short-circuit at increasing time values, the closer they are to the network's feeder.

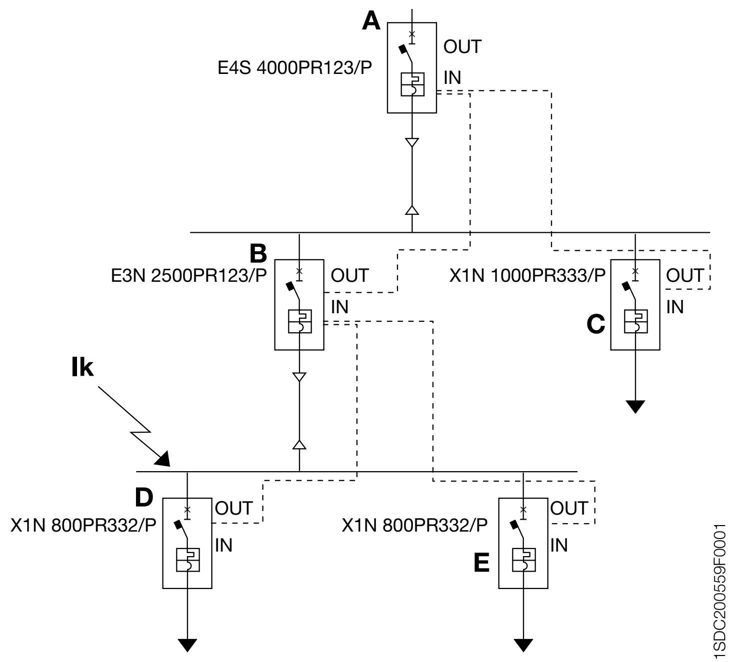
Disadvantages:

- higher costs;
- greater complexity of the system (special components, additional wiring, auxiliary power sources, ...).

This solution is therefore used mainly in systems with high rated current and high short-circuit current values, with precise needs in terms of both safety and continuity of service: in particular, examples of logical discrimination can be often found in primary distribution switchboards, immediately downstream of transformers and generators and in meshed networks.

4 Protection coordination

Zone selectivity with Emax



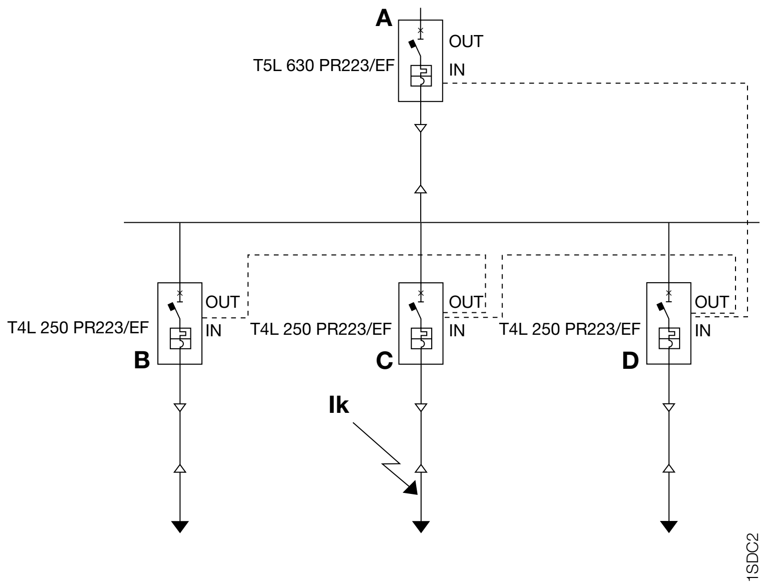
The example above shows a plant wired so as to guarantee zone selectivity with Emax CB equipped with PR332/P-PR333/P-PR122/P-PR123/P releases.
Each circuit-breaker detecting a fault sends a signal to the circuit-breaker immediately on the supply side through a communication wire; the circuit-breaker that does not receive any communication from the circuit-breakers on the load side shall launch the opening command.
In this example, with a fault located in the indicated point, the circuit-breakers D and E do not detect the fault and therefore they do not communicate with the circuit-breaker on the supply side (circuit-breaker B), which shall launch the opening command within the selectivity time set from 40 to 200 ms.

To actuate correctly zone selectivity, the following settings are suggested:

S	$t_2 \geq$ selectivity time + 70 ms
I	I_3 = OFF
G	$t_4 \geq$ selectivity time + 70 ms
Selectivity time	same settings for each circuit-breaker

4 Protection coordination

Zone selectivity for circuit-breakers type Tmax (T4L-T5L-T6L) with PR223 EF releases



The example above shows a plant wired through an interlocking protocol (Interlocking, IL), so as to guarantee zone selectivity through PR223 EF release.
In case of short-circuit, the circuit-breaker immediately on the supply side of the fault sends through the bus a block signal to the protection device hierarchically higher and verifies, before tripping, that an analogous block signal has not been sent by the protection on the load side.
In the example in the figure, the circuit-breaker C, immediately on the supply side of the fault, sends a block signal to the circuit-breaker A, which is hierarchically higher. If, as in the given example, no protection on the load side is present, the circuit-breaker C shall open in very quick times since it has received no block signal.
Everything occurs in shorter times (10 to 15ms) than in the case of zone selectivity with the Emax series air circuit-breaker (40 to 200ms), thus subjecting the plant to lower electrodynamic stresses, and with a consequent cost reduction for the plant.

4 Protection coordination

Energy discrimination

Energy coordination is a particular type of discrimination that exploits the current-limiting characteristics of moulded-case circuit-breakers. It is important to remember that a current-limiting circuit-breaker is *"a circuit-breaker with a break time short enough to prevent the short-circuit current reaching its otherwise attainable peak value"* (IEC 60947-2, def. 2.3).
In practice, ABB SACE moulded-case circuit-breakers Tmax series, under short-circuit conditions, are extremely rapid (tripping times of about some milliseconds) and therefore it is impossible to use the time-current curves for the coordination studies.
The phenomena are mainly dynamic (and therefore proportional to the square of the instantaneous current value) and can be described by using the specific let-through energy curves.
In general, it is necessary to verify that the let-through energy of the circuit-breaker downstream is lower than the energy value needed to complete the opening of the circuit-breaker upstream.
This type of discrimination is certainly more difficult to consider than the previous ones because it depends largely on the interaction between the two devices placed in series and demands access to data often unavailable to the end user. Manufacturers provide tables, rules and calculation programs in which the minimum discrimination limits are given between different combinations of circuit- breakers.

Advantages:
- fast breaking, with tripping times which reduce as the short-circuit current increases;
- reduction of the damages caused by the fault (thermal and dynamic stresses), of the disturbances to the power supply system, of the costs...;
- the discrimination level is no longer limited by the value of the short-time withstand current I_{cw} which the devices can withstand;
- large number of discrimination levels;
- possibility of coordination of different current-limiting devices (fuses, circuit-breakers,..) even if they are positioned in intermediate positions along the chain.

Disadvantage:
- difficulty of coordination between circuit-breakers of similar sizes.

This type of coordination is used above all for secondary and final distribution networks, with rated currents below 1600A.

Back-up protection

The back-up protection is an *"over-current coordination of two over-current protective devices in series where the protective device, generally but not necessarily on the supply side, effects the over-current protection with or without the assistance of the other protective device and prevents any excessive stress on the latter"* (IEC 60947-1, def. 2.5.24).
Besides, IEC 60364-4-43, 434.5.1 states: *"… A lower breaking capacity is admitted if another protective device having the necessary breaking capacity is installed on the supply side. In that case, characteristics of the devices, must be co-ordinated so that the energy let through by these two devices does not exceed that which can be withstood without damage by the device on the load side and the conductors protected by these devices."*

4 Protection coordination

Advantages:
- cost-saving solution;
- extremely rapid tripping.

Disadvantages:
- extremely low discrimination values;
- low service quality, since at least two circuit-breakers in series have to trip.

Coordination between circuit-breaker and switch disconnector

The switch disconnector

The switch disconnectors derive from the corresponding circuit-breakers, of which they keep the overall dimensions, the fixing systems and the possibility of mounting all the accessories provided for the basic versions. They are devices which can make, carry and break currents under normal service conditions of the circuit.
They can also be used as general circuit-breakers in sub-switchboards, as bus-ties, or to isolate installation parts, such as lines, busbars or groups of loads.
Once the contacts have opened, these switches guarantee isolation thanks to their contacts, which are at the suitable distance to prevent an arc from striking in compliance with the prescriptions of the standards regarding aptitude to isolation.

Protection of switch disconnectors

Each switch disconnector shall be protected by a coordinated device which safeguards it against overcurrents, usually a circuit-breaker able to limit the short-circuit current and the let-through energy values at levels acceptable for the switch-disconnector.
As regards overload protection, the rated current of the circuit-breaker shall be lower than or equal to the size of the disconnector to be protected.
Regarding Tmax series switch disconnectors the coordination tables show the circuit-breakers which can protect them against the indicated prospective short-circuit currents values.
Regarding Emax series switch disconnectors it is necessary to verify that the short-circuit current value at the installation point is lower than the short-time withstand current I_{cw} of the disconnector, and that the peak value is lower than the making current value (I_{cm}).

4 Protection coordination

4.2 Discrimination tables

The tables below give the selectivity values of short-circuit currents (in kA) between pre-selected combinations of circuit-breakers, for voltages from 230/240 to 415 V, according annex A of IEC 60947-2. The tables cover the possible combinations of ABB SACE Emax air circuit-breakers series, Tmax moulded-case circuit-breakers series and the series of ABB modular circuit-breakers. The values are obtained following particular rules which, if not respected, may give selectivity values which in some cases may be much lower than those given. Some of these guidelines are generally valid and are indicated below; others refer exclusively to particular types of circuit-breakers and will be subject to notes below the relevant table.

General rules:
- the function I of electronic releases of upstream breakers must be excluded (I3 in OFF);
- the magnetic trip of thermomagnetic (TM) or magnetic only (MA-MF) breakers positioned upstream must be ≥ $10 \cdot I_n$ and set to the maximum threshold;
- it is fundamentally important to verify that the settings adopted by the user for the electronic and thermomagnetic releases of breakers positioned either upstream or downstream result in time-current curves properly spaced.

Notes for the correct reading of the coordination tables:
The limit value of selectivity is obtained considering the lower among the given value, the breaking capacity of the CB on the supply side and the breaking capacity of the CB on the load side.
The letter T indicates total selectivity for the given combination, the corresponding value in kA is obtained considering the lower of the downstream and upstream circuit-breakers' breaking capacities (Icu).

The following tables show the breaking capacities at 415Vac for SACE Emax, Isomax and Tmax circuit-breakers.

Tmax @ 415V ac	
Version	Icu [kA]
B	16
C	25
N	36
S	50
H	70
L (for T2)	85
L (for T4-T5-T7)	120
L (for T6)	100
V (for T7)	150
V	200

Emax @ 415V ac	
Version	Icu [kA]
B	42
N	65*
S	75**
H	100
L	130***
V	150****

* For Emax E1 version N Icu=50kA
** For Emax E2 version S Icu=85kA
*** For Emax X1 version L Icu=150kA
**** For Emax E3 version V Icu=130kA

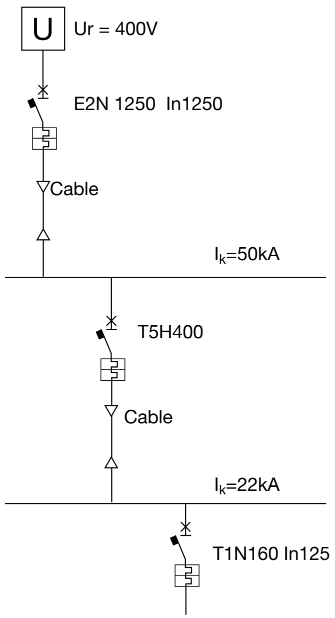
Keys

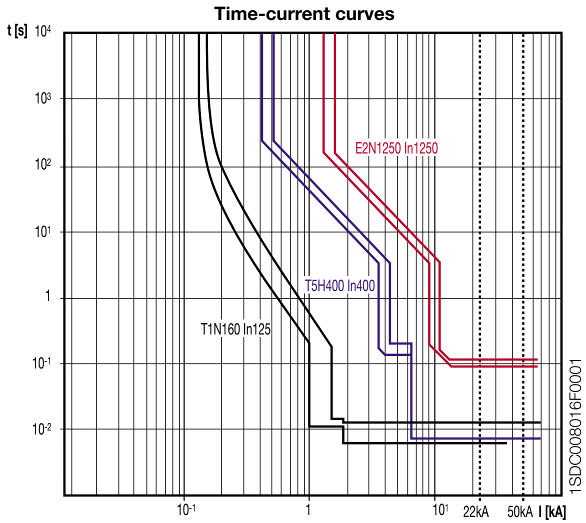
For MCCB (Moulded-case circuit-breaker)	For MCB (Miniature circuit-breaker):
ACB (Air circuit-breaker)	B = charatteristic trip (I3=3...5In)
TM = thermomagnetic release	C = charatteristic trip (I3=5...10In)
– TMD (Tmax)	D = charatteristic trip (I3=10...20In)
– TMA (Tmax)	K = charatteristic trip (I3=8...14In)
M = magnetic only release	Z = charatteristic trip (I3=2...3In)
– MF (Tmax)	
– MA (Tmax)	
EL = elettronic release	

4 Protection coordination

Example:

From the selectivity table on page 138 it can be seen that breakers E2N1250 and T5H400,correctly set, are selective up to 55kA (higher than the short-circuit current at the busbar).
From the selectivity table on page 133 it can be seen that, between T5H400 and T1N160 In125, the total sectivity is granted; as aleady specified on page 107 this means selectivity up to the breaking capacity of T1N and therefore up to 36 kA (higher than the short-circuit current at the busbar).





From the curves it is evident that between breakers E2N1250 and T5H400 time discrimination exists, while between breakers T5H400 and T1N160 there is energy discrimination.

4 Protection coordination

Index of discrimination tables

4.2 Discrimination tables

4 Protection coordination

MCB - S9 @ 230/240 V

	Supply s.[2]			S290					S800 N-S						
Load s.[1]	Char.			C			D		B						
		I_{cu} [kA]		15					36-50						
			I_n [A]	80	100	125	80	100	32	40	50	63	80	100	125
			2	T	T	T	T	T	0,43[3]	0,6	1,3	4	T	T	T
			4	T	T	T	T	T		0,45	0,8	1,5	2,5	4	T
			6	T	T	T	T	T			0,6	1,2	1,6	2,6	3,8
			10	4	T	T	T	T			0,5	1,1	1,4	2	3
S931N	C	4.5	16	2.5	3.5	3.5	4	T				0,8	1,2	1,7	2,5
			20	1.5	2.5	2.5	3	T					1	1,5	2,1
			25	0.5	0.5	1.5	2	4						1,3	1,8
			32	0.5	0.5	0.5	1.5	3.5						1,1	1,7
			40	0.5	0.5	0.5	1.5	3.5							1,6
			2	T	T	T	T	T	0,43[3]	0,6	1,3	4	T	T	T
			4	5	T	T	T	T		0,45	0,8	1,5	2,5	4	T
			6	4,5	5	T	5,5	T			0,6	1,2	1,6	2,6	3,8
			10	4	4,5	5	5	5			0,5	1,1	1,4	2	3
S941N	B, C	6	16	2,5	3,5	3,5	4	4,5				0,8	1,2	1,7	2,5
			20	1,5	2,5	2,5	3	4,5					1	1,5	2,1
			25	0,5	0,5	1,5	2	4						1,3	1,8
			32	0,5	0,5	0,5	1,5	3,5						1,1	1,7
			40	0,5	0,5	0,5	1,5	3,5							1,6
			2	6	8	9	7	8	0,43[3]	0,6	1,3	4	9	T	T
			4	5	6	7,5	6	7		0,45	0,8	1,5	2,5	4	7,3
			6	4,5	5	6	5,5	6			0,6	1,2	1,6	2,6	3,8
			10	4	4,5	5	5	5			0,5	1,1	1,4	2	3
S951N	B, C	10	16	2,5	3,5	3,5	4	4,5				0,8	1,2	1,7	2,5
			20	1,5	2,5	2,5	3	4,5					1	1,5	2,1
			25	0,5	0,5	1,5	2	4						1,3	1,8
			32	0,5	0,5	0,5	1,5	3,5						1,1	1,7
			40	0,5	0,5	0,5	1,5	3,5							1,6
			2	6	8	9	7	8	0,43[3]	0,6	1,3	4	9	T	T
			4	5	6	7,5	6	7		0,45	0,8	1,5	2,5	4	7,3
			6	4,5	5	6	5,5	6			0,6	1,2	1,6	2,6	3,8
			10	4	4,5	5	5	5			0,5	1,1	1,4	2	3
S971N	B, C	10	16	2,5	3,5	3,5	4	4,5				0,8	1,2	1,7	2,5
			20	1,5	2,5	2,5	3	4,5					1	1,5	2,1
			25	0,5	0,5	1,5	2	4						1,3	1,8
			32	0,5	0,5	0,5	1,5	3,5						1,1	1,7
			40	0,5	0,5	0,5	1,5	3,5							1,6

	Supply s.[2]			S800 N-S								S800 N-S							
Load s.[1]	Char.			C								D							
		I_{cu} [kA]		36-50								36-50							
			I_n [A]	25	32	40	50	63	80	100	125	25	32	40	50	63	80	100	125
			2	0,4[3]	0,55	1,2	3	T	T	T	T	1,3	4,1	T	T	T	T	T	T
			4		0,43	0,75	1,3	2,1	3,9	T	T	0,8	1,6	3	T	T	T	T	T
			6			0,55	1,1	1,5	2,5	3,6	T	0,6	1,3	2	3,2	3,9	T	T	T
			10			0,45	1	1,3	1,9	2,8	4,2	0,5	1,2	1,65	2,6	3,1	T	T	T
S931N	C	4.5	16				0,75	1,1	1,6	2,3	3,6		0,9	1,4	1,8	2,6	T	T	T
			20					0,9	1,4	1,9	3,3			1,3	1,6	2,2	4,2	T	T
			25						1,2	1,6	2,7				1,5	1,9	3,5	T	T
			32						1	1,5	2,5					1,8	2,8	4,2	T
			40							1,4	2,1					1,7	2,7	4	T
			2	0,4[3]	0,55	1,2	3	T	T	T	T	1,3	4,1	T	T	T	T	T	T
			4		0,43	0,75	1,3	2,1	3,9	T	T	0,8	1,6	3	5,4	T	T	T	T
			6			0,55	1,1	1,5	2,5	3,6	5,5	0,6	1,3	2	3,2	3,9	T	T	T
			10			0,45	1	1,3	1,9	2,8	4,2	0,5	1,2	1,65	2,6	3,1	T	T	T
S941N	B, C	6	16				0,75	1,1	1,6	2,3	3,6		0,9	1,4	1,8	2,6	5	T	T
			20					0,9	1,4	1,9	3,3			1,3	1,6	2,2	4,2	5,4	T
			25						1,2	1,6	2,7				1,5	1,9	3,5	4,5	T
			32						1	1,5	2,5					1,8	2,8	4,2	5,5
			40							1,4	2,1					1,7	2,7	4	5
			2	0,4[3]	0,55	1,2	3	6,6	T	T	T	1,3	4,1	T	T	T	T	T	T
			4		0,43	0,75	1,3	2,1	3,9	6,6	T	0,8	1,6	3	5,4	7,6	T	T	T
			6			0,55	1,1	1,5	2,5	3,6	5,5	0,6	1,3	2	3,2	3,9	8	T	T
			10			0,45	1	1,3	1,9	2,8	4,2	0,5	1,2	1,65	2,6	3,1	6,2	8,6	T
S951N	B, C	10	16				0,75	1,1	1,6	2,3	3,6		0,9	1,4	1,8	2,6	5	6,3	8,8
			20					0,9	1,4	1,9	3,3			1,3	1,6	2,2	4,2	5,4	7,6
			25						1,2	1,6	2,7				1,5	1,9	3,5	4,5	6,6
			32						1	1,5	2,5					1,8	2,8	4,2	5,5
			40							1,4	2,1					1,7	2,7	4	5
			2	0,4[3]	0,55	1,2	3	6,6	T	T	T	1,3	4,1	T	T	T	T	T	T
			4		0,43	0,75	1,3	2,1	3,9	6,6	T	0,8	1,6	3	5,4	7,6	T	T	T
			6			0,55	1,1	1,5	2,5	3,6	5,5	0,6	1,3	2	3,2	3,9	8	T	T
			10			0,45	1	1,3	1,9	2,8	4,2	0,5	1,2	1,65	2,6	3,1	6,2	8,6	T
S971N	B, C	10	16				0,75	1,1	1,6	2,3	3,6		0,9	1,4	1,8	2,6	5	6,3	8,8
			20					0,9	1,4	1,9	3,3			1,3	1,6	2,2	4,2	5,4	7,6
			25						1,2	1,6	2,7				1,5	1,9	3,5	4,5	6,6
			32						1	1,5	2,5					1,8	2,8	4,2	5,5
			40							1,4	2,1					1,7	2,7	4	5

1 Load side circuit-breaker 1P+N (230/240 V)

2 For networks 230/240 V AC ⇒ two poles circuit-breaker (phase + neutral)
For networks 400/415 V AC ⇒ four poles circuit-breaker (load side circuit branched between one phase and the neutral)

3 Only for curve B

4 Protection coordination

4.2 Discrimination tables

4 Protection coordination

MCCB @ 415 V 4p - S9 @ 240 V

			Supply s.	T1											T2																			T3										
			Version	B, C, N											N, S, H, L																			N, S										
			Release	TMD											TMD, MA														EL					TMD, MA										
			I_u [A]	160											160																			250										
Load s.	Carat.	I_{cu} [kA]	I_n [A]	16	20	25	32	40	50	63	80	100	125	160[2]	16	20	25	32	40	50		63	80	100	125[2]	125	160[2]	160	10	25	63	100	160	63	80	100	125[2]	125	160[2]	160	200[2]	200	250[2]	250
S931N	C			T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T		T	T	T	T	T	T	T		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
						3	3	3	T	T	T	T	T	T		3[1]	3	3	3	T		T	T	T	T	T	T	T		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
								3	T	T	T	T	T	T				3[1]	3	T		T	T	T	T	T	T	T			T	T	T	T	T	T	T	T	T	T	T	T	T	T
									3	T	T	T	T	T				3[1]		3		T	T	T	T	T	T	T			T	T	T	T	T	T	T	T	T	T	T	T	T	T
										T	T	T	T	T						3[1]		T	T	T	T	T	T	T			T	T	T	T	T	T	T	T	T	T	T	T	T	T
											T	T	T	T						3[1]			T	T	T	T	T	T			T	T	T		T	T	T	T	T	T	T	T	T	T
												T	T	T									T[1]	T		T	T	T				T	T		T[1]	T		T	T	T	T	T	T	T
S941N	B, C	6	≤4	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
			6	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T		T	T	T	T	T	T	T		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
			10			3	3	3	4,5	T	T	T	T	T		3[1]	3	3	3	4,5		T	T	T	T	T	T	T		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
			16					3	4,5	5	T	T	T	T				3[1]	3	4,5		5	T	T	T	T	T	T			T	T	T	5	T	T	T	T	T	T	T	T	T	T
			20						3	5	T	T	T	T				3[1]		3		5	T	T	T	T	T	T			T	T	T	5	T	T	T	T	T	T	T	T	T	T
			25							5	T	T	T	T						3[1]		5	T	T	T	T	T	T			T	T	T	5	T	T	T	T	T	T	T	T	T	T
			32								T	T	T	T						3[1]			T	T	T	T	T	T			T	T	T		T	T	T	T	T	T	T	T	T	T
			40									T	T	T									T[1]	T		T	T	T				T	T		T[1]	T		T	T	T	T	T	T	T
S951N	B, C	10	≤4	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
			6	6	6	6	6	6	6	T	T	T	T	T	T	T	T	T	T	T		T	T	T	T	T	T	T		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
			10			3	3	3	4,5	7,5	8,5	T	T	T		3[1]	3	3	3	4,5		7,5	8,5	T	T	T	T	T		T	T	T	T	7,5	8,5	T	T	T	T	T	T	T	T	T
			16					3	4,5	5	7,5	T	T	T				3[1]	3	4,5		5	7,5	T	7,5	T	T	T			T	T	T	5	7,5	T	7,5	T	T	T	T	T	T	T
			20						3	5	6	T	T	T				3[1]		3		5	6	T	6	T	T	T			T	T	T	5	6	T	6	T	T	T	T	T	T	T
			25							5	6	T	T	T						3[1]		5	6	T	6	T	T	T			T	T	T	5	6	T	6	T	T	T	T	T	T	T
			32								6	7,5	T	T						3[1]			6	7,5	6	T	T	T			T	T	T		6	7,5	6	T	T	T	T	T	T	T
			40									7,5	T	T									6[1]	7,5		T	T	T				T	T		6[1]	7,5		T	T	T	T	T	T	T
S971N	B, C	10	≤4	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
			6	6	6	6	6	6	6	12	T	T	T	T	T	T	T	T	T	T		T	T	T	T	T	T	T		T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
			10			3	3	3	4,5	7,5	8,5	T	T	T		3[1]	3	3	3	4,5		7,5	8,5	T	T	T	T	T		T	T	T	T	7,5	8,5	T	T	T	T	T	T	T	T	T
			16					3	4,5	5	7,5	T	T	T				3[1]	3	4,5		5	7,5	T	7,5	T	T	T			T	T	T	5	7,5	T	7,5	T	T	T	T	T	T	T
			20						3	5	6	T	T	T				3[1]		3		5	6	T	6	T	T	T			T	T	T	5	6	T	6	T	T	T	T	T	T	T
			25							5	6	T	T	T						3[1]		5	6	T	6	T	T	T			T	T	T	5	6	T	6	T	T	T	T	T	T	T
			32								6	T	T	T						3[1]			6	7,5	6	T	T	T			T	T	T		6	7,5	6	T	T	T	T	T	T	T
			40									T	T	T									6[1]	7,5		T	T	T				T	T		6[1]	7,5		T	T	T	T	T	T	T

Supply side circuit-breaker 4P (load side circuit branched between one phase and the neutral)
Load side circuit-breaker 1P+N (230/240)

[1] Value valid only for magnetic only supply side circuit-breaker

[2] Value valid also with neutral 50%

4 Protection coordination

4.2 Discrimination tables

4 Protection coordination

MCB - S2.. B @ 415 V

					Supply s.	S290		S800N-S							S800N-S						S800N-S							
	Char.					D		B							C						D							
		I_{cu} [kA]				15		36-50							36-50						36-50							
		10	15	25	I_n [A]	80	100	40	50	63	80	100	125		40	50	63	80	100	125	25	32	40	50	63	80	100	125
Load s.	B	-	-	-	≤2																							
		-	-	-	3																							
		-	-	-	4																							
		S200	S200M	S200P	6	10,5	T	0,4	0,5	0,7	1	1,5	2,6		0,4	0,5	0,7	1	1,5	2,6	0,5	1	1,2	2	2,8	9,9	21,3	T
		S200	S200M	S200P	8	10,5	T		0,4	0,6	0,7	1	1,4			0,4	0,6	0,7	1	1,4	0,4	0,6	0,8	1,1	1,4	2,8	3,9	7,4
		S200	S200M	S200P	10	5	8		0,4	0,6	0,7	1	1,4			0,4	0,6	0,7	1	1,4	0,4	0,6	0,8	1,1	1,4	2,8	3,9	7,4
		S200	S200M	S200P	13	4,5	7			0,5	0,7	0,9	1,3				0,5	0,7	0,9	1,3	0,4	0,6	0,8	1,1	1,4	2,5	3,3	5,6
		S200	S200M	S200P	16	4,5	7				0,7	0,9	1,3					0,7	0,9	1,3		0,6	0,8	1,1	1,4	2,5	3,3	5,6
		S200	S200M	S200P	20	3,5	5					0,9	1,3						0,9	1,3			0,8	1,1	1,3	2,3	3	4,7
		S200	S200M	S200P	25	3,5	5					0,9	1,3						0,9	1,3			0,8	1,1	1,3	2,3	3	4,7
		S200	S200M-S200P	-	32		4,5					0,8	1,1						0,8	1,1				0,9	1,1	1,9	2,4	3,7
		S200	S200M-S200P	-	40							0,8	1,1						0,8	1,1					1,1	1,9	2,4	3,7
		S200	S200M-S200P	-	50								1							1						1,5	1,9	2,3
		S200	S200M-S200P	-	63								0,9							0,9							1,7	2,3

MCB - S2.. C @ 415 V

					Supply s.	S290		S800N-S								S800N-S							S800N-S							
	Char.					D		B								C							D							
		I_{cu} [kA]				15		36-50								36-50							36-50							
		10	15	25	I_n [A]	80	100	32	40	50	63	80	100	125		32	40	50	63	80	100	125	25	32	40	50	63	80	100	125
Load s.	C	S200	S200M	S200P	≤2	T	T	0,7	1,3	T	T	T	T	T		0,7	1,3	T	T	T	T	T	T	T	T	T	T	T	T	T
		S200	S200M	S200P	3	T	T		0,6	0,7	1,1	2,6	8,8	T			0,6	0,7	1,1	2,6	8,8	T	0,7	2,2	4,4	T	T	T	T	T
		S200	S200M	S200P	4	T	T		0,6	0,7	1	1,7	3,1	7			0,6	0,7	1	1,7	3,1	7	0,7	1,3	2,2	4,4	7,7	T	T	T
		S200	S200M	S200P	6	10,5	T		0,4	0,5	0,7	1	1,5	2,6			0,4	0,5	0,7	1	1,5	2,6	0,5	1	1,2	2	2,8	9,9	22	T
		S200	S200M	S200P	8	10,5	T			0,4	0,6	0,7	1	1,4				0,4	0,6	0,7	1	1,4	0,4	0,6	0,8	1,1	1,4	2,8	3,9	7,4
		S200	S200M	S200P	10	5	8			0,4	0,6	0,7	1	1,4				0,4	0,6	0,7	1	1,4	0,4	0,6	0,8	1,1	1,4	2,8	3,9	7,4
		S200	S200M	S200P	13	4,5	7				0,5	0,7	0,9	1,3					0,5	0,7	0,9	1,3	0,4	0,6	0,8	1,1	1,4	2,5	3,3	5,6
		S200	S200M	S200P	16	4,5	7					0,7	0,9	1,3						0,7	0,9	1,3		0,6	0,8	1,1	1,4	2,5	3,3	5,6
		S200	S200M	S200P	20	3,5	5						0,9	1,3							0,9	1,3			0,8	1,1	1,3	2,3	3	4,7
		S200	S200M	S200P	25	3,5	5						0,9	1,3							0,9	1,3			0,8	1,1	1,3	2,3	3	4,7
		S200	S200M-S200P	-	32		4,5						0,8	1,1							0,8	1,1				0,9	1,1	1,9	2,4	3,7
		S200	S200M-S200P	-	40								0,8	1,1							0,8	1,1					1,1	1,9	2,4	3,7
		S200	S200M-S200P	-	50									1								1						1,5	1,9	2,3
		S200	S200M-S200P	-	63									0,9								0,9							1,7	2,3

MCB - S2.. D @ 415 V

					Supply s.	S290		S800N-S								S800N-S							S800N-S							
	Char.					D		B								C							D							
		I_{cu} [kA]				15		36-50								36-50							36-50							
		10	15	25	I_n [A]	80	100	32	40	50	63	80	100	125		32	40	50	63	80	100	125	25	32	40	50	63	80	100	125
Load s.	D	S200	-	S200P	≤2	T	T	0,5	0,7	2,1	T	T	T	T		0,5	0,7	2,1	T	T	T	T	2,3	T	T	T	T	T	T	T
		S200	-	S200P	3	T	T		0,5	0,7	1,2	2,5	8,6	T			0,5	0,7	1,2	2,5	8,6	T	0,7	1,3	4,4	T	T	T	T	T
		S200	-	S200P	4	T	T		0,4	0,7	1	1,7	3	7,7			0,4	0,7	1	1,7	3	7,7	0,7	1	2,2	4,4	7,7	T	T	T
		S200	-	S200P	6	10,5	T			0,6	0,8	1,2	2	3,6				0,6	0,8	1,2	2	3,6	0,6	0,8	1,5	2,5	3,6	12,1	24,2	T
		S200	-	S200P	8	10,5	T				0,7	0,9	1,3	2					0,7	0,9	1,3	2	0,5	0,7	1,1	1,5	2	4	5,5	9,9
		S200	-	S200P	10	5	8					0,9	1,3	2						0,9	1,3	2	0,5	0,7	1,1	1,5	2	4	5,5	9,9
		S200	-	S200P	13	3	5						1	1,5							1	1,5		0,6	0,9	1,2	1,5	2,6	3,4	5,2
		S200	-	S200P	16	3	5							1,5								1,5			0,9	1,2	1,5	2,6	3,4	5,2
		S200	-	S200P	20	3	5																			0,9	1,1	1,8	2,2	3,2
		S200	-	S200P	25		4																				1,1	1,8	2,2	3,2
		S200	S200P	-	32																							1,7	2	2,9
		S200	S200P	-	40																								1,9	2,6
		S200	S200P	-	50																									2,2
		S200	S200P	-	63																									

MCB - S2.. K @ 415 V

					Supply s.	S290		S800N-S								S800N-S							S800N-S							
	Char.					D		B								C							D							
		I_{cu} [kA]				15		36-50								36-50							36-50							
		10	15	25	I_n [A]	80	100	32	40	50	63	80	100	125		32	40	50	63	80	100	125	25	32	40	50	63	80	100	125
Load s.	K	S200	-	S200P	≤2	T	T	0,5	0,7	2,1	T	T	T	T		0,5	0,7	2,1	T	T	T	T	2,3	T	T	T	T	T	T	T
		S200	-	S200P	3	T	T		0,5	0,7	1,2	2,5	8,6	T			0,5	0,7	1,2	2,5	8,6	T	0,7	1,3	4,4	T	T	T	T	T
		S200	-	S200P	4	T	T		0,4	0,7	1	1,7	3	7,7			0,4	0,7	1	1,7	3	7,7	0,7	1	2,2	4,4	7,7	T	T	T
		S200	-	S200P	6	10,5	T			0,6	0,8	1,2	2	3,6				0,6	0,8	1,2	2	3,6	0,6	0,8	1,5	2,5	3,6	12,1	24,2	T
		S200	-	S200P	8	10,5	T				0,7	0,9	1,3	2					0,7	0,9	1,3	2	0,5	0,7	1,1	1,5	2	4	5,5	9,9
		S200	-	S200P	10	5	8					0,9	1,3	2						0,9	1,3	2	0,5	0,7	1,1	1,5	2	4	5,5	9,9
		-	-	S200P	13	3	5						1	1,5							1	1,5		0,6	0,9	1,2	1,5	2,6	3,4	5,2
		S200	-	S200P	16	3	5							1,5								1,5			0,9	1,2	1,5	2,6	3,4	5,2
		S200	-	S200P	20	3	5																			0,9	1,1	1,8	2,2	3,2
		S200	-	S200P	25		4																				1,1	1,8	2,2	3,2
		S200	S200P	-	32																							1,7	2	2,9
		S200	S200P	-	40																								1,9	2,6
		S200	S200P	-	50																									2,2
		S200	S200P	-	63																									

4.2 Discrimination tables

4 Protection coordination

MCB - S2.. Z @ 415 V

					Supply s.	S290		S800N-S								S800N-S							S800N-S							
	Char.					D		B								C							D							
		Icu [kA]				15		36-50								36-50							36-50							
		10	15	25	In [A]	80	100	32	40	50	63	80	100	125		32	40	50	63	80	100	125	25	32	40	50	63	80	100	125
Load s.	Z	S200	-	S200P	≤2	T	T	0,7	1,3	T	T	T	T	T		0,7	1,3	T	T	T	T	T	T	T	T	T	T	T	T	T
		S200	-	S200P	3	T	T		0,6	0,7	1,1	2,6	8,8	T			0,6	0,7	1,1	2,6	8,8	T	0,7	2,2	4,4	T	T	T	T	T
		S200	-	S200P	4	T	T		0,6	0,7	1	1,7	3,1	7			0,6	0,7	1	1,7	3,1	7	0,7	1,3	2,2	4,4	7,7	T	T	T
		S200	-	S200P	6	10,5	T		0,4	0,5	0,7	1	1,5	2,6			0,4	0,5	0,7	1	1,5	2,6	0,5	1	1,2	2	2,8	9,9	22	T
		S200	-	S200P	8	10,5	T			0,4	0,6	0,7	1	1,4				0,4	0,6	0,7	1	1,4	0,4	0,6	0,8	1,1	1,4	2,8	3,9	7,4
		S200	-	S200P	10	5	8			0,4	0,6	0,7	1	1,4				0,4	0,6	0,7	1	1,4	0,4	0,6	0,8	1,1	1,4	2,8	3,9	7,4
		-	-	S200P	13	4,5	7					0,7	0,9	1,3						0,7	0,9	1,3		0,6	0,8	1,1	1,4	2,5	3,3	5,6
		S200	-	S200P	16	4,5	7					0,7	0,9	1,3						0,7	0,9	1,3		0,6	0,8	1,1	1,4	2,5	3,3	5,6
		S200	-	S200P	20	3,5	5						0,9	1,3							0,9	1,3			0,8	1,1	1,3	2,3	3	4,7
		S200	-	S200P	25	3,5	5						0,9	1,3							0,9	1,3			0,8	1,1	1,3	2,3	3	4,7
		S200	S200P	-	32	3	4,5						0,8	1,1							0,8	1,1				0,9	1,1	1,9	2,4	3,7
		S200	S200P	-	40	3	4,5						0,8	1,1							0,8	1,1					1,1	1,9	2,4	3,7
		S200	S200P	-	50		3							1								1						1,5	1,9	2,3
		S200	S200P	-	63									0,9								0,9							1,7	2,3

4 Protection coordination

MCCB - S800 @ 415 V

			Supply s.	T1				T1 - T3				T1	T3		
			Version	B, C, N, S, H, L, V											
			Release	TM											
Load s.	Carat.	I_{cu} [kA]	I_n [A]	25	32	40	50	63	80	100	125	160	160	200	250
S800N	B C D	36	10	4,5	4,5	4,5	4,5	8	10	20[1]	25[1]	T	T	T	T
			13		4,5	4,5	4,5	7,5	10	15	25[1]	T	T	T	T
			16			4,5	4,5	7,5	10	15	25[1]	T	T	T	T
			20				4,5	7,5	10	15	25[1]	T	T	T	T
			25					6	10	15	20[1]	T	T	T	T
			32						7,5	10	20[1]	T	T	T	T
			40							10	20[1]	T	T	T	T
			50								15	T	T	T	T
			63									T	T	T	T
			80									T		T	T
			100									T			T
			125												T
S800S	B C D K	50	10	4,5	4,5	4,5	4,5	8	10	20[1]	25[1]	36[1]	36[1]	36[1]	T
			13		4,5	4,5	4,5	7,5	10	15	25[1]	36[1]	36[1]	36[1]	T
			16			4,5	4,5	7,5	10	15	25[1]	36[1]	36[1]	36[1]	T
			20				4,5	7,5	10	15	25[1]	36[1]	36[1]	36[1]	T
			25					6	10	15	20[1]	36[1]	36[1]	36[1]	T
			32						7,5	10	20[1]	36[1]	36[1]	36[1]	T
			40							10	20[1]	36[1]	36[1]	36[1]	T
			50								15	36[1]	36[1]	36[1]	T
			63									36[1]	36[1]	36[1]	T
			80									36[1]		36[1]	T
			100									36[1]			T
			125												T

[1] Select the lowest value between what is indicated and the breaking capacity of the supply side circuit-breaker

4 Protection coordination

MCCB-S800 @ 415 V

			Supply s.	T4									T4 - T5
			Version	N, S, H, L, V									
			Release	TM									EL
Load s.	Carat.	I_{cu} [kA]	I_n [A]	20	25	32	50	80	100	125	160	200÷250	100÷630
S800N/S	B	36-50	10	6,5	6,5[1]	6,5	6,5	11	T	T	T	T	T
			13	6,5	5[1]	6,5	6,5	11	T	T	T	T	T
			16		5[1]	6,5	6,5	11	T	T	T	T	T
			20		4[1]	6,5	6,5	11	T	T	T	T	T
			25				6,5	11	T	T	T	T	T
			32				6,5	8	T	T	T	T	T
			40				5[1]	6,5	T	T	T	T	T
			50					5[1]	7,5	T	T	T	T
			63						5[1]	7	T	T	T
			80								T	T	T[2]
			100									T	T[2]
			125										T[2,3]
	C	36-50	10	6,5	6,5[1]	6,5	6,5	11	T	T	T	T	T
			13	6,5	5[1]	6,5	6,5	11	T	T	T	T	T
			16		5[1]	6,5	6,5	11	T	T	T	T	T
			20		4[1]	6,5	6,5	11	T	T	T	T	T
			25		4[1]		6,5	11	T	T	T	T	T
			32				6,5	8	T	T	T	T	T
			40				5[1]	6,5	T	T	T	T	T
			50				4[1]	5[1]	7,5	T	T	T	T
			63					4[1]	6,5[1]	7	T	T	T
			80					4[1]	5[1]	6,5[1]	6,5	T	T[2]
			100						4[1]	5[1]	5[1]	6,5	T[2]
			125							4[1]	4[1]	5[1]	T[2,3]
	D	36-50	10	6,5	6,5[1]	6,5	6,5	11	T	T	T	T	T
			13		5[1]		6,5	11	T	T	T	T	T
			16				6,5	11	T	T	T	T	T
			20				6,5[1]	11	T	T	T	T	T
			25				6,5[1]	11	T	T	T	T	T
			32					8[1]	T	T	T	T	T
			40					6,5[1]	T	T	T	T	T
			50						7,5[1]	T	T	T	T
			63							7[1]	T	T	T
			80								5[1]	T	T[2]
			100									5[1]	T[2]
			125										T[2,3]
	K	36-50	10		6,5[1]	6,5	6,5	11	T	T	T	T	T
			13		5[1]	5	6,5	11	T	T	T	T	T
			16		5[1]		6,5	11	T	T	T	T	T
			20		4[1]		6,5	11	T	T	T	T	T
			25				6,5[1]	11[1]	T	T	T	T	T
			32				5[1]	8[1]	T[1]	T	T	T	T
			40					6,5[1]	T[1]	T[1]	T	T	T
			50					5[1]	7,5[1]	T[1]	T[1]	T	T
			63					4[1]	6,5[1]	7[1]	T[1]	T[1]	T
			80						5[1]	6,5[1]	7[1]	T[1]	T[2]
			100							5[1]	6,5[1]	7[1]	T[2]
			125								5[1]	6,5[1]	T[2,3]

[1] Value valid only for magnetic only supply side circuit-breaker (for In = 50 A, please consider MA52 circuit-breaker)

[2] For T4 In = 100 A, value valid only for magnetic only supply

[3] For T4 In = 160 A, value valid only for magnetic only supply

4.2 Discrimination tables

4 Protection coordination

MCCB - S2.. B @ 415 V

					Supply s.	T2	T1 - T2						T1 - T2 - T3						T3		T4										T5	T2					T4		T5
					Version	B, C, N, S, H, L							B, C, N, S, H, L, V																										
	Carat.	I_{cu} [kA]			Release	TM														TM												EL							
		10	15	25	I_n [A]	12,5	16	20	25	32	40	50	63	80	100	125	160		200	250	20	25	32	50	80	100	125	160	200	250	320÷500	10	25	63	100	160	100, 160	250, 320	320÷630
		-	-	-	≤2																																		
		-	-	-	3																																		
		-	-	-	4																																		
		S200	S200M	S200P	6	5,5[1]	5,5	5,5	5,5	5,5	5,5	5,5	10,5	T	T	T	T		T	T	7,5	7,5[4]	7,5	7,5	T	T	T	T	T	T	T		T	T	T	T	T	T	T
		S200	S200M	S200P	8			5,5	5,5	5,5	5,5	5,5	10,5	T	T	T	T		T	T	7,5	7,5[4]	7,5	7,5	T	T	T	T	T	T	T		T	T	T	T	T	T	T
		S200	S200M	S200P	10			3[1]	3	3	3	4,5	7,5	8,5	17	T	T		T	T	5	5[4]	5	6,5	9	T	T	T	T	T	T		T	T	T	T	T	T	T
		S200	S200M	S200P	13			3[1]		3	3	4,5	7,5	7,5	12	20	T		T	T		5[4]	5	6,5	8	T	T	T	T	T	T		T	T	T	T	T	T	T
		S200	S200M	S200P	16					3[1]	3	4,5	5	7,5	12	20	T		T	T		3[4]	5	6,5	8	T	T	T	T	T	T			T	T	T	T	T	T
Load s.	B	S200	S200M	S200P	20					3[1]		3	5	6	10	15	T		T	T				5	7,5	T	T	T	T	T	T			T	T	T	T	T	T
		S200	S200M	S200P	25							3[1]	5	6	10	15	T		T	T				5	7,5	T	T	T	T	T	T			T	T	T	T	T	T
		S200	S200M-S200P	-	32							3[1]		6	7,5	12	T		T	T				5[4]	7,5	T	T	T	T	T	T			T	T	T	T	T	T
		S200	S200M-S200P	-	40									5,5[1]	7,5	12	T		T	T					6,5	T	T	T	T	T	T				T	T	T	T	T
		S200	S200M-S200P	-	50									3[1]	5[2]	7,5	10,5		T	T					5[4]	T	T	T	T	T	T				10,5	10,5	T	T	T
		S200	S200M-S200P	-	63										5[2]	6[3]	10,5		T	T						T[4]	T[4]	T	T	T	T					10,5	T	T	T
		-	-	-	80																																		
		-	-	-	100																																		
		-	-	-	125																																		

[1] Value valid only for T2 magnetic only supply side circuit-breaker
[2] Value valid only for T2-T3 magnetic only supply side circuit-breaker
[3] Value valid only for T3 magnetic only supply side circuit-breaker
[4] Value valid only for T4 magnetic only supply side circuit-breaker

4.2 Discrimination tables
4 Protection coordination

MCCB - S2.. C @ 415 V

					Supply s.	T2	T1 - T2						T1 - T2 - T3					
					Version	B, C, N, S, H, L							B, C, N, S, H, L, V					
	Carat.	I_{cu} [kA]			Release	TM												
		10	15	25	I_n [A]	12,5	16	20	25	32	40	50	63	80	100	125	160	
Load s.	C	S200	S200M	S200P	≤2	T	T	T	T	T	T	T	T	T	T	T	T	
		S200	S200M	S200P	3	T	T	T	T	T	T	T	T	T	T	T	T	
		S200	S200M	S200P	4	T	T	T	T	T	T	T	T	T	T	T	T	
		S200	S200M	S200P	6	5,5[1]	5,5	5,5	5,5	5,5	5,5	5,5	10,5	T	T	T	T	
		S200	S200M	S200P	8			5,5	5,5	5,5	5,5	5,5	10,5	T	T	T	T	
		S200	S200M	S200P	10			3[1]	3	3	3	4,5	7,5	8,5	17	T	T	
		S200	S200M	S200P	13			3[1]		3	3	4,5	7,5	7,5	12	20	T	
		S200	S200M	S200P	16					3[1]	3	4,5	5	7,5	12	20	T	
		S200	S200M	S200P	20					3[1]		3	5	6	10	15	T	
		S200	S200M	S200P	25							3[1]	5	6	10	15	T	
		S200	S200M-S200P	-	32							3[1]		6	7,5	12	T	
		S200	S200M-S200P	-	40									5,5[1]	7,5	12	T	
		S200	S200M-S200P	-	50									3[1]	5[2]	7,5	10,5	
		S200	S200M-S200P	-	63										5[2]	6[3]	10,5	
		-	S290	-	80												4[3]	
		-	S290	-	100												4[3]	
		-	S290	-	125													

					Supply s.	T3		T4										T5	T2					T4		T5
					Version	B, C, N, S, H, L, V																				
	Carat.	I_{cu} [kA]			Release	TM													EL							
		10	15	25	I_n [A]	200	250	20	25	32	50	80	100	125	160	200	250	320÷500	10	25	63	100	160	100, 160	250, 320	320÷630
Load s.	C	S200	S200M	S200P	≤2	T	T	T	T[4]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
		S200	S200M	S200P	3	T	T	T	T[4]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
		S200	S200M	S200P	4	T	T	T	T[4]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
		S200	S200M	S200P	6	T	T	7,5	7,5[4]	7,5	7,5	T	T	T	T	T	T	T		T	T	T	T	T	T	T
		S200	S200M	S200P	8	T	T	7,5	7,5[4]	7,5	7,5	T	T	T	T	T	T	T		T	T	T	T	T	T	T
		S200	S200M	S200P	10	T	T	5	5[4]	5	6,5	9	T	T	T	T	T	T		T	T	T	T	T	T	T
		S200	S200M	S200P	13	T	T		5[4]	5	6,5	8	T	T	T	T	T	T		T	T	T	T	T	T	T
		S200	S200M	S200P	16	T	T		3[4]	5	6,5	8	T	T	T	T	T	T			T	T	T	T	T	T
		S200	S200M	S200P	20	T	T				5	7,5	T	T	T	T	T	T			T	T	T	T	T	T
		S200	S200M	S200P	25	T	T				5	7,5	T	T	T	T	T	T			T	T	T	T	T	T
		S200	S200M-S200P	-	32	T	T				5[4]	7,5	T	T	T	T	T	T			T	T	T	T	T	T
		S200	S200M-S200P	-	40	T	T					6,5	T	T	T	T	T	T				T	T	T	T	T
		S200	S200M-S200P	-	50	T	T					5[4]	T	T	T	T	T	T				10,5	10,5	T	T	T
		S200	S200M-S200P	-	63	T	T						T[4]	T[4]	T	T	T	T					10,5	T	T	T
		-	S290	-	80	10	15								5	11	T	T					4	T[5]	T	T
		-	S290	-	100	7,5[3]	15								5[4]	8	T	T					4	12[4]	T	T
		-	S290	-	125	7,5[3]										8[4]	12	T					4		T	T

[1] Value valid only for T2 magnetic only supply side circuit-breaker
[2] Value valid only for T2-T3 magnetic only supply side circuit-breaker
[3] Value valid only for T3 magnetic only supply side circuit-breaker
[4] Value valid only for T4 magnetic only supply side circuit-breaker
[5] Value valid only for T4 In160 supply side circuit-breaker

4 Protection coordination

4.2 Discrimination tables

4 Protection coordination

MCCB - S2.. D @ 415 V

					Supply s.	T2	T1 - T2						T1 - T2 - T3				
					Version	B, C, N, S, H, L											
	Carat.	I_{cu} [kA]			Release	TM											
		10	15	25	I_n [A]	12,5	16	20	25	32	40	50	63	80	100	125	160
Load s.	D	S200	-	S200P	≤2	T	T	T	T	T	T	T	T	T	T	T	T
		S200	-	S200P	3	T	T	T	T	T	T	T	T	T	T	T	T
		S200	-	S200P	4	T	T	T	T	T	T	T	T	T	T	T	T
		S200	-	S200P	6	5,5[1]	5,5	5,5	5,5	5,5	5,5	5,5	10,5	T	T	T	T
		S200	-	S200P	8			5,5	5,5	5,5	5,5	5,5	10,5	12	T	T	T
		S200	-	S200P	10			3[1]	3	3	3	3	5	8,5	17	T	T
		S200	-	S200P	13					2[1]	2	2	3	5	8	13,5	T
		S200	-	S200P	16					2[1]	2	2	3	5	8	13,5	T
		S200	-	S200P	20					2[1]		2	3	4,5	6,5	11	T
		S200	-	S200P	25							2[1]	2,5	4	6	9,5	T
		S200	S200P	-	32									4	6	9,5	T
		S200	S200P	-	40									3[1]	5	8	T
		S200	S200P	-	50									2[1]	3[2]	5	9,5
		S200	S200P	-	63										3[2]	5[3]	9,5
		-	S290	-	80												4[3]
		-	S290	-	100												4[3]
		-	-	-	125												

					Supply s.	T3		T4										T5	T2					T4		T5
					Version	B, C, N, S, H, L, V																				
	Carat.	I_{cu} [kA]			Release	TM													EL							
		10	15	25	I_n [A]	200	250	20	25	32	50	80	100	125	160	200	250	320÷500	10	25	63	100	160	100, 160	250, 320	320÷630
Load s.	D	S200	-	S200P	≤2	T	T	T	T[4]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
		S200	-	S200P	3	T	T	T	T[4]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
		S200	-	S200P	4	T	T	T	T[4]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
		S200	-	S200P	6	T	T	7,5	7,5[4]	7,5	7,5	T	T	T	T	T	T	T		T	T	T	T	T	T	T
		S200	-	S200P	8	T	T	7,5	7,5[4]	7,5	7,5	T	T	T	T	T	T	T		T	T	T	T	T	T	T
		S200	-	S200P	10	T	T	5	5[4]	5	5	9	T	T	T	T	T	T		T	T	T	T	T	T	T
		S200	-	S200P	13	T	T		5[4]		4	5,5	T	T	T	T	T	T			T	T	T	T	T	T
		S200	-	S200P	16	T	T				4	5,5	T	T	T	T	T	T			T	T	T	T	T	T
		S200	-	S200P	20	T	T				4[4]	5	T	T	T	T	T	T			T	T	T	T	T	T
		S200	-	S200P	25	T	T				4[4]	4,5	T	T	T	T	T	T			T	T	T	T	T	T
		S200	S200P	-	32	T	T					4,5[4]	T	T	T	T	T	T			T	T	T	T	T	T
		S200	S200P	-	40	T	T					4,5[4]	T	T	T	T	T	T				T	T	T	T	T
		S200	S200P	-	50	T	T						T[4]	T	T	T	T	T				9,5	9,5	T	T	T
		S200	S200P	-	63	T	T							T[4]	T[4]	T	T	T					9,5	T	T	T
		-	S290	-	80	10	15								5	11	T	T					4	T[5]	T	T
		-	S290	-	100	7,5[3]	15									8	T	T					4	12[5]	T	T
		-	-	-	125																					

1 Value valid only for T2 magnetic only supply side circuit-breaker
2 Value valid only for T2-T3 magnetic only supply side circuit-breaker
3 Value valid only for T3 magnetic only supply side circuit-breaker
4 Value valid only for T4 magnetic only supply side circuit-breaker
5 Value valid only for T4 In160 supply side circuit-breaker

4.2 Discrimination tables

4 Protection coordination

MCCB - S2.. K @ 415 V

					Supply s.	T2	T1 - T2						T1 - T2 - T3						T3	
					Version	B, C, N, S, H, L							B, C, N, S, H, L, V							
	Carat.	I_{cu} [kA]			Release	TM													TM	
		10	15	25	I_n [A]	12,5	16	20	25	32	40	50	63	80	100	125	160		200	250
Load s.	K	S200	-	S200P	≤2	T	T	T	T	T	T	T	T	T	T	T	T		T	T
		S200	-	S200P	3	T	T	T	T	T	T	T	T	T	T	T	T		T	T
		S200	-	S200P	4	T	T	T	T	T	T	T	T	T	T	T	T		T	T
		S200	-	S200P	6	5,5[1]	5,5	5,5	5,5	5,5	5,5	5,5	10,5	T	T	T	T		T	T
		S200	-	S200P	8			5,5	5,5	5,5	5,5	5,5	10,5	12	T	T	T		T	T
		S200	-	S200P	10			3[1]	3	3	3	3	6	8,5	17	T	T		T	T
		-	-	S200P	13					2[1]	3	3	5	7,5	10	13,5	T		T	T
		S200	-	S200P	16					2[1]	3	3	4,5	7,5	10	13,5	T		T	T
		S200	-	S200P	20					2[1]		3	3,5	5,5	6,5	11	T		T	T
		S200	-	S200P	25							2[1]	3,5	5,5	6	9,5	T		T	T
		S200	S200P	-	32									4,5	6	9,5	T		T	T
		S200	S200P	-	40									3[1]	5	8	T		T	T
		S200	S200P	-	50									2[1]	3[2]	6	9,5		T	T
		S200	S200P	-	63										3[2]	5,5[3]	9,5		T	T
		-	S290	-	80												4[3]		10	15
		-	S290	-	100												4[3]		7,5[3]	15
		-	-	-	125															

Supply s.	T4										T5	T2					T4		T5
Version	B, C, N, S, H, L, V																		
Release	TM											EL							
I_n [A]	20	25	32	50	80	100	125	160	200	250	320÷500	10	25	63	100	160	100, 160	250, 320	320÷630
≤2	T	T[4]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
3	T	T[4]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
4	T	T[4]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
6	7,5	7,5[4]	7,5	7,5	T	T	T	T	T	T	T		T	T	T	T	T	T	T
8	7,5	7,5[4]	7,5	7,5	T	T	T	T	T	T	T		T	T	T	T	T	T	T
10		5[4]	5	5	9	T	T	T	T	T	T		T	T	T	T	T	T	T
13		5[4]	5	5	8	T	T	T	T	T	T		T	T	T	T	T	T	T
16		5[4]		5	8	T	T	T	T	T	T			T	T	T	T	T	T
20				5	6	T	T	T	T	T	T			T	T	T	T	T	T
25				5[4]	6[4]	T	T	T	T	T	T			T	T	T	T	T	T
32				5[4]	6[4]	T[4]	T	T	T	T	T			T	T	T	T	T	T
40					5,5[4]	T[4]	T[4]	T	T	T	T				T	T	T	T	T
50					5[4]	T[4]	T[4]	T[4]	T	T	T				9,5	9,5	T	T	T
63						T[4]	T[4]	T[4]	T[4]	T	T					9,5	T	T	T
80								5	11	T	T					4	T[5]	T	T
100								5[4]	8	T	T					4	12[5]	T	T
125																			

[1] Value valid only for T2 magnetic only supply side circuit-breaker
[2] Value valid only for T2-T3 magnetic only supply side circuit-breaker
[3] Value valid only for T3 magnetic only supply side circuit-breaker
[4] Value valid only for T4 magnetic only supply side circuit-breaker
[5] Value valid only for T4 In160 supply side circuit-breaker

4 Protection coordination

4.2 Discrimination tables

4 Protection coordination

MCCB - S2.. Z @ 415 V

					Supply s.	T2	T1 - T2						T1 - T2 - T3					
					Version	B, C, N, S, H, L							B, C, N, S, H, L, V					
	Carat.	Icu [kA]			Release	TM												
		10	15	25	In [A]	12,5	16	20	25	32	40	50	63	80	100	125	160	
Load s.	Z	S200	-	S200P	≤2	T	T	T	T	T	T	T	T	T	T	T	T	
		S200	-	S200P	3	T	T	T	T	T	T	T	T	T	T	T	T	
		S200	-	S200P	4	T	T	T	T	T	T	T	T	T	T	T	T	
		S200	-	S200P	6	5,5[1]	5,5	5,5	5,5	5,5	5,5	5,5	10,5	T	T	T	T	
		S200	-	S200P	8			5,5	5,5	5,5	5,5	5,5	10,5	T	T	T	T	
		S200	-	S200P	10			3[1]	3	3	3	4,5	8	8,5	17	T	T	
		-	-	S200P	13			3[1]		3	3	4,5	7,5	7,5	12	20	T	
		S200	-	S200P	16					3[1]	3	4,5	5	7,5	12	20	T	
		S200	-	S200P	20					3[1]		3	5	6	10	15	T	
		S200	-	S200P	25							3[1]	5	6	10	15	T	
		S200	S200P	-	32							3[1]		6	7,5	12	T	
		S200	S200P	-	40									5,5[1]	7,5	12	T	
		S200	S200P	-	50									4[1]	5[2]	7,5	10,5	
		S200	S200P	-	63										5[2]	6[3]	10,5	
		-	-	-	80													
		-	-	-	100													
		-	-	-	125													

Supply s.	T3		T4										T5	T2					T4		T5
Version	B, C, N, S, H, L, V																				
Release	TM													EL							
In [A]	200	250	20	25	32	50	80	100	125	160	200	250	320÷500	10	25	63	100	160	100, 160	250, 320	320÷630
≤2	T	T	T	T[4]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
3	T	T	T	T[4]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
4	T	T	T	T[4]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
6	T	T	7,5	7,5[4]	7,5	7,5	T	T	T	T	T	T	T		T	T	T	T	T	T	T
8	T	T	7,5	7,5[4]	7,5	7,5	T	T	T	T	T	T	T		T	T	T	T	T	T	T
10	T	T	5	5[4]	5	6,5	9	T	T	T	T	T	T		T	T	T	T	T	T	T
13	T	T		5[4]	5	6,5	8	T	T	T	T	T	T		T	T	T	T	T	T	T
16	T	T		5[4]	4,5	6,5	8	T	T	T	T	T	T			T	T	T	T	T	T
20	T	T				5	6,5	T	T	T	T	T	T			T	T	T	T	T	T
25	T	T				5	6,5	T	T	T	T	T	T			T	T	T	T	T	T
32	T	T				5[4]	6,5	T	T	T	T	T	T			T	T	T	T	T	T
40	T	T					5	T	T	T	T	T	T				T	T	T	T	T
50	T	T					3,5[4]	T	T	T	T	T	T				10,5	10,5	T	T	T
63	T	T						T[4]	T	T	T	T	T					10,5	T	T	T
80																					
100																					
125																					

[1] Value valid only for T2 magnetic only supply side circuit-breaker
[2] Value valid only for T2-T3 magnetic only supply side circuit-breaker
[3] Value valid only for T3 magnetic only supply side circuit-breaker
[4] Value valid only for T4 magnetic only supply side circuit-breaker
[5] Value valid only for T4 In160 supply side circuit-breaker

4 Protection coordination

4.2 Discrimination tables

4 Protection coordination

MCCB - T1 @ 415 V

				Supply s.	T1	T2					T3			T4								T4				T5						T6					T7			
	Version				B C N	N, S, H, L					N, S			N, S, H, L, V								N, S, H, L, V				N, S, H, L, V						N, S, H, L					S, H, L, V[3]			
		Release			TM	TM,M	EL				TM, M			TM, M								EL				TM			EL			TM, M		EL			EL			
			I_u [A]		160	160					250			250								250			320	400		630	400		630	630	800	630	800	1000	800	1000	1250	1600
Load s.				I_n [A]	160	160	25	63	100	160	160	200	250	50	80	100	125	160	200	250		100	160	250	320	320	400	500	320	400	630	630	800	630	800	1000	800[2]	1000[2]	1250	1600
				16	3	3		3	3	3	3	4	5	10[2]	10	10	10	10	10	10		10	10	10	10	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				20	3	3		3	3	3	3	4	5	10[2]	10	10	10	10	10	10		10	10	10	10	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				25	3	3		3	3	3	3	4	5	10[2]	10	10	10	10	10	10		10	10	10	10	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				32	3	3			3	3	3	4	5		10[1]	10	10	10	10	10		10	10	10	10	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	B			40	3	3			3	3	3	4	5		10[1]	10	10	10	10	10		10	10	10	10	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
T1	C	TM	160	50	3	3			3	3	3	4	5			10[1]	10	10	10	10		10	10	10	10	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	N			63	3	3				3	3	4	5				10[1]	10	10	10		10	10	10	10	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				80						3		4	5					10	10	10			10	10	10	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				100									5					10[1]	10	10			10	10	10	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				125															10[1]	10				10	10	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				160																				10	10	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T

[1] Value valid only for magnetic only supply side circuit-breaker
[2] Value valid only for PR232/P, PR331/P and PR332/P trip units
[3] Available only with Iu ≤ 1250A

4 Protection coordination

4.2 Discrimination tables

4 Protection coordination

MCCB - T2 @ 415 V

Load s.	Version	Release	I_u [A]	I_n [A]	T1	T2					T3			T4									
				Version	B C N	N, S, H, L					N, S			N, S, H, L, V									
				Release	TM	TM,M	EL				TM, M			TM, M									
				I_u [A]	160	160					250			250									
				I_n [A]	160	160	25	63	100	160	160	200	250	20	25	32	50	80	100	125	160	200	250
T2	N S H L	TM	160	1,6-2,5	T	T	T	T	T	T	T	T	T	T	T[1]	T	T	T	T	T	T	T	T
				3,2	T	T	T	T	T	T	T	T	T	T	T[1]	T	T	T	T	T	T	T	T
				4-5	T	T	T	T	T	T	T	T	T	T	T[1]	T	T	T	T	T	T	T	T
				6,3	10	10	10	10	10	10	10	15	40	T	T[1]	T	T	T	T	T	T	T	T
				8	10	10	10	10	10	10	10	15	40		T[1]	T	T	T	T	T	T	T	T
				10	10	10	10	10	10	10	10	15	40		T[1]	T	T	T	T	T	T	T	T
				12,5	3	3		3	3	3	3	4	5			T	T	T	T	T	T	T	T
				16	3	3		3	3	3	3	4	5					70	70	70	70	70	70
				20	3	3		3	3	3	3	4	5					55[1]	55	55	55	55	55
				25	3	3		3	3	3	3	4	5					40[1]	40	40	40	40	40
				32	3	3			3	3	3	4	5					40[1]	40	40	40	40	40
				40	3	3			3	3	3	4	5					30[1]	30[1]	30	30	30	30
				50	3	3			3	3	3	4	5					30[1]	30[1]	30	30	30	30
				63	3	3				3	3	4	5					30[1]	30[1]	30[1]	30	30	30
				80						3	3[1]	4	5						25[1]	25[1]	25[1]	25	25
				100								4	5							25[1]	25[1]	25[1]	25
				125																	25[1]	25[1]	
				160																		25[1]	
		EL	160	10								3	4				25	25	25	25	25	25	25
				25								3	4					25	25	25	25	25	25
				63								3	4								25	25	25
				100								3	4										25
				160								3	4										

Load s.	Version	Release	I_u [A]	I_n [A]	T4				T5						T6					T7			
				Version	N, S, H, L, V				N, S, H, L, V						N, S, H, L					S, H, L, V[3]			
				Release	EL				TM			EL			TM, M		EL			EL			
				I_u [A]	250			320	400		630	400		630	630	800	630	800	1000	800	1000	1250	1600
				I_n [A]	100	160	250	320	320	400	500	320	400	630	630	800	630	800	1000	800[2]	1000[2]	1250	1600
T2	N S H L	TM	160	1,6-2,5	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				3,2	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				4-5	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				6,3	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				8	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				10	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				12,5	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				16	70	70	70	70	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				20	55	55	55	55	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				25	40	40	40	40	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				32	40	40	40	40	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				40	30	30	30	30	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				50	30	30	30	30	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				63	30	30	30	30	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				80		25	25	25	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				100		25	25	25	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				125			25	25	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				160			25	25	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
		EL	160	10	25	25	25	25	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				25	25	25	25	25	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				63	25	25	25	25	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				100		25	25	25	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				160			25	25	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T

1 Value valid only for magnetic only supply side circuit-breaker
2 Value valid only for PR232/P, PR331/P and PR332/P trip units
3 Available only with Iu ≤ 1250A

4 Protection coordination

4 Protection coordination

MCCB - T3 @ 415 V

				Supply s.	T3			T4				T4					T5						T6					T7			
	Version				N, S			N, S, H, L, V				N, S, H, L, V					N, S, H, L, V						N, S, H, L					S, H, L, V[3]			
		Release			TM, M			TM, M				EL					TM			EL			TM, M		EL			EL			
			I_u [A]		250			250				250			320		400		630	400		630	630	800	630	800	1000	800	1000	1250	1600
Load s.				I_n [A]	160	200	250	125	160	200	250	100	160	250	320		320	400	500	320	400	630	630	800	630	800	1000	800[2]	1000[2]	1250	1600
T3	N S	TM	250	63	3	4	5	7[1]	7	7	7	7	7	7	7		25	25	25	25	25	25	T	T	T	T	T	T	T	T	T
				80	3[1]	4	5		7[1]	7	7		7	7	7		25	25	25	25	25	25	T	T	T	T	T	T	T	T	T
				100		4[1]	5		7[1]	7[1]	7		7	7	7		25	25	25	25	25	25	40	T	40	T	T	T	T	T	T
				125						7[1]				7	7		20	20	20	20	20	20	36	T	36	T	T	T	T	T	T
				160										7	7				20	20	20	20	36	T	36	T	T	T	T	T	T
				200											7					20	20	20	30	T	30	T	T	T	T	T	T
				250																20	20	20	30	40	30	40	40	T	T	T	T

[1] Value valid only for magnetic only supply side circuit-breaker
[2] Value valid only for PR232/P, PR331/P and PR332/P trip units
[3] Available only with Iu ≤ 1250A

MCCB - T4 @ 415 V

				Supply s.	T5						T6					T7			
	Version				N, S, H, L, V						N, S, H, L					S, H, L, V[1]			
		Release			TM			EL			TM, M		EL			EL			
			I_u [A]		400		630	400		630	630	800	630	800	1000	800	1000	1250	1600
Load s.				I_n [A]	320	400	500	320	400	630	630	800	630	800	1000	800[2]	1000[2]	1250	1600
T4	N S H L V	TM	250	20	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				25	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				32	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				50	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				80	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
				100		50	50	50	50	50	T	T	T	T	T	T	T	T	T
				125			50	50	50	50	T	T	T	T	T	T	T	T	T
				160				50	50	50	T	T	T	T	T	T	T	T	T
				200				50	50	50	T	T	T	T	T	T	T	T	T
				250					50	50	T	T	T	T	T	T	T	T	T
		EL	250	100	50	50	50	50	50	50	T	T	T	T	T	T	T	T	T
				160	50	50	50	50	50	50	T	T	T	T	T	T	T	T	T
				250			50		50	50	T	T	T	T	T	T	T	T	T
			320	320						50	T	T	T	T	T	T	T	T	T

[1] Available only with Iu ≤ 1250A
[2] Value valid only for PR232/P, PR331/P and PR332/P trip units

MCCB - T5 @ 415 V

				Supply s.	T6					T7			
	Version				N, S, H, L					S, H, L, V[1]			
		Release			TM, M		EL			EL			
			I_u [A]		630	800	630	800	1000	800	1000	1250	1600
Load s.				I_n [A]	630	800	630	800	1000	800[2]	1000[2]	1250	1600
T5	N S H L V	TM	400	320	30	30	30	30	30	T	T	T	T
				400		30		30	30	T	T	T	T
			630	500				30	30	T	T	T	T
		EL	400	320	30	30	30	30	30	T	T	T	T
				400	30	30	30	30	30	T	T	T	T
			630	630					30	T	T	T	T

[1] Available only with Iu ≤ 1250A
[2] Value valid only for PR232/P, PR331/P and PR332/P trip units

MCCB - T6 @ 415 V

				Supply s.	T7			
	Version				S, H, L, V[1]			
		Release			EL			
			I_u [A]		800	1000	1250	1600
Load s.				I_n [A]	800[2]	1000[2]	1250	1600
T6	N S H L V	TM	630	630			40	40
			800	800			40	40
		EL	630	630	40	40	40	40
			800	800	40	40	40	40
			1000	1000			40	40

[1] Available only with Iu ≤ 1250A, maximum selectivity value is: 15kA
[2] Value valid only for PR232/P, PR331/P and PR332/P trip units

4 Protection coordination

ACB - MCCB @ 415 V

			Supply s.	X1			E1		E2				E3					E4			E6	
	Version			B	N	L	B	N	B	N	S	L[1]	N	S	H	V	L[1]	S	H	V	H	V
		Release		EL			EL		EL				EL					EL				
Load s.			I_u [A]	800 1000 1250 1600	800 1000 1250 1600	800 1000 1250	800 1000 1250 1600	800 1000 1250 1600	1600 2000	1000 1250 1600 2000	800 1000 1250 1600 2000	1250 1600	2500 3200	1000 1250 1600 2000 2500 3200	800 1000 1250 1600 2000 2500 3200	800 1000 1250 1600 2000 2500 3200	2000 2500	4000	3200 4000	3200 4000	4000 5000 6300	3200 4000 5000 6300
T1	B	TM	160	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	C			T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	N			T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
T2	N	TM,EL	160	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	S			T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	H			T	T	T	T	T	T	55	65	T	T	T	T	T	T	T	T	T	T	T
	L			T	T	T	T	T	T	55	65	T	T	T	75	T	T	T	T	T	T	T
T3	N	TM	250	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	S			T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
T4	N	TM,EL	250 320	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	S			T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	H			T	T	T	T	T	T	55	65	T	T	T	T	T	T	T	T	T	T	T
	L			T	T	T	T	T	T	55	65	100	T	T	75	85	100	T	T	100	T	100
	V			T	T	T	T	T	T	55	65	100	T	T	75	85	100	T	T	100	T	100
T5	N	TM,EL	400 630	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	S			T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	H			T	T	T	T	T	T	55	65	T	T	T	T	T	T	T	T	T	T	T
	L			T	T	T	T	T	T	55	65	100	T	T	75	85	100	T	T	100	T	100
	V			T	T	T	T	T	T	55	65	100	T	T	75	85	100	T	T	100	T	100
T6	N	TM,EL	630 800 1000	T	T	15	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	S			T	T	15	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	H			T	T	15	T	T	T	55	65	T	T	T	T	T	T	T	T	T	T	T
	L			T	T	15	T	T	T	55	65	T	T	T	75	85	T	T	T	T	T	T
T7	S	EL	800 1000 1250 1600	T	42	15	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	H			T	42	15	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	L			T	42	15	T	T	T	55	T	T	T	T	T	T	T	T	T	T	T	T
	V[2]			T	42	15	T	T	T	55	65	T	T	T	75	85	T	T	T	T	T	T

Table valid for Emax circuit-breaker only with PR121/P, PR122/P and PR123/P releases

[1] Emax L circuit-breaker only with PR122/P and PR123/P releases

[2] Available only with Iu ≤ 1250A

4.2 Discrimination tables

4 Protection coordination

MCCB - Tmax T1, T2 @ 400/415 V

				Supply s.	T4		T5			T6	
	Version				L						
		Release			PR223EF[1]					PR223EF	
			I_u [A]		250	320	400		630	800	
Load s.				I_n [A]	250	320	320	400	630	630	800
T1	B, C, N	TM	160	16-100	T	T	T	T	T	T	T
				125	T	T	T	T	T	T	T
				160	T	T	T	T	T	T	T
T2	N,S,H,L	TM, EL	160	10-100	75[2]	75[2]	T	T	T	T	T
				125	75[2]	75[2]	T	T	T	T	T
				160	75[2]	75[2]	T	T	T	T	T

[1] Release in auxiliary power supply and trip delayed parameter set ON

[2] Select the lowest value between what is indicated and the breaking capacity of the supply side circuit-breaker

MCCB - Tmax T4, T5, T6 @ 400/415 V

				Supply s.	T4		T5			T6	
	Version				L						
		Release			PR223EF						
			I_u [A]		250	320	400		630	800	
Load s.				I_n [A]	250	320	320	400	630	630	800
T4	L	PR223EF	250	160	T	T	T	T	T	T	T
				250	T	T	T	T	T	T	T
			320	320		T	T	T	T	T	T
T5	L	PR223EF	400	320			T	T	T	T	T
				400				T	T	T	T
			630	630					T	T	T
T6	L	PR223EF	630	630						T	T
			800	800							T

Table valid for release with auxiliary power supply connected through a shielded twisted-pair wire as shown in the installing instructions 1SDH000538R0002

4.3 Back-up tables

The tables shown give the short-circuit current value (in kA) for which the back-up protection is verified for the chosen circuit-breaker combination, at voltages from 240 up to 415 V. These tables cover all the possible combinations between ABB SACE moulded-case circuit-breakers Tmax and those between the above mentioned circuit-breakers and ABB MCBs.

Notes for a correct interpretation of the coordination tables:

Tmax @ 415V ac	
Version	Icu [kA]
B	16
C	25
N	36
S	50
H	70
L (for T2)	85
L (for T4-T5)	120
L (for T6)	100
V (for T7)	150
V	200

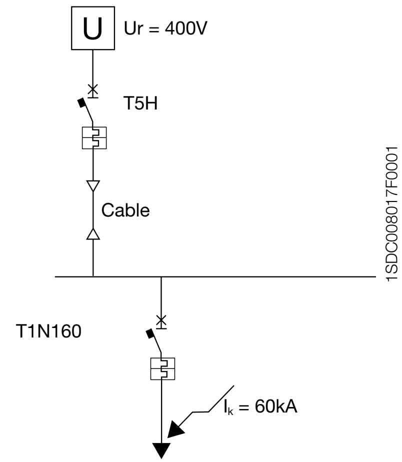
Emax @ 415V ac	
Version	Icu [kA]
B	42
N	65*
S	75**
H	100
L	130***
V	150****

* For Emax E1 version N Icu=50kA
** For Emax E2 version S Icu=85kA
*** For Emax X1 version L Icu=150kA
**** For Emax E3 version V Icu=130kA

Keys

For MCCB (Moulded-case circuit-breaker) ACB (Air circuit-breaker) TM = thermomagnetic release – TMD (Tmax) – TMA (Tmax) M = magnetic only release – MF (Tmax) – MA (Tmax) EL = elettronic release	For MCB (Miniature circuit-breaker): B = charateristic trip (I3=3...5In) C = charateristic trip (I3=5...10In) D = charateristic trip (I3=10...20In) K = charateristic trip (I3=8...14In) Z = charateristic trip (I3=2...3In)

Example:
From the coordination table on page 135 the following conclusion is derived: the circuit-breakers type T5H and T1N are coordinated in back-up protection up to a value of 65 kA (higher than the short-circuit current measured at the installation point), although the maximum breaking capacity of T1N, at 415 V, is 36 kA.



MCB - MCB @ 240 V (Two-pole circuit-breakers)

			Supply s.	S200	S200M	S200P		S280	S290	S800
	Char.			B-C	B-C	B-C		B-C	C	B-C
Load s.		I_{cu} [kA]		20	25	40	25	20	25	100
			I_n [A]	0,5..63	0,5..63	0,5..25	32..63	80, 100	80..125	10..125
S931N	C	4.5	2..40	20	25	40	25	15	15	100
S941N	B,C	6	2..40	20	25	40	25	15	15	100
S951N	B,C	10	2..40	20	25	40	25	15	15	100
S971N	B,C	10	2..40	20	25	40	25	15	15	100
S200	B,C,K,Z	20	0,5..63		25	40	25			100
S200M	B,C	25	0,5..63			40				100
S200P	B,C, D,K,Z	40	0,5..25							100
		25	32..63							100
S280	B,C	20	80, 100							
S290	C,D	25	80..125							

4 Protection coordination

MCCB @ 415 V - MCB @ 240 V

			Supply s.[1]	T1	T1	T1	T2	T3	T2	T3	T2	T2
			Version	B	C	N			S		H	L
Load s.	Carat.	I_n [A]	I_{cu} [kA]	16	25	36			50		70	85
S931 N	C	2..25	4.5	16	16	16	20	10	20	10	20	20
		32, 40		10	10	10	16		16		16	16
S941 N	B,C	2..25	6	16	16	16	20	10	20	10	20	20
		32, 40		10	10	10	16		16		16	16
S951 N	B,C	2..25	10	16	16	16	25	16	25	16	25	25
		32, 40					16		16		16	16
S971 N	B,C	2..25	10	16	16	16	25	16	25	16	25	25
		32, 40					16		16		16	16

[1] Supply side circuit-breaker 4P (load side circuit branched between one phase and the neutral)

MCB - MCB @ 415 V

			Supply s.	S200	S200M	S200P		S280	S290	S800N	S800S
	Char.			B-C	B-C	B-C		B-C	C	B-C-D	B-C-D-K
Load s.		I_{cu} [kA]		10	15	25	15	6	15	36	50
			I_n [A]	0,5..63	0,5..63	0,5..25	32..63	80, 100	80..125	25..125	25..125
S200	B,C,K,Z	10	0,5..63		15	25	15		15	36	50
S200M	B,C	15	0,5..63			25				36	50
S200P	B,C,D,K,Z	25	0,5..25							36	50
		15	32..63							36	50
S280	B,C	6	80, 100								
S290	C,D	15	80..125								
S800N	B,C,D	36	25..125								
S800S	B,C,D,K	50	25..125								

4 Protection coordination

MCCB - MCB @ 415 V

			Supply s.	T1	T1	T1	T2	T3	T4	T2	T3	T4	T2	T4	T2	T4	T4
			Version	B	C	N				S			H		L	L	V
Load s.	Carat.	I_n [A]	I_{cu} [kA]	16	25	36				50			70		85	120	200
S200	B,C,K,Z	0,5..10	10	16	25	30	36	36	36	36	40	40	40	40	40	40	40
		13..63						16			16						
S200M	B,C	0,5..10	15	16	25	30	36	36	36	50	40	40	70	40	85	40	40
		13..63						25			25		60		60		
S200P	B,C, D,K,Z	0,5..10	25			30	36	36	36	50	40	40	70	40	85	40	40
		13..25				30	36	30	36	50	30	40	60	40	60	40	40
		32..63	15	16	25	30	36	25	36	50	25	40	60	40	60	40	40
S280	B,C	80, 100	6	16	16	16	36	16	30	36	16	30	36	30	36	30	30
S290	C,D	80..125	15	16	25	30	36	30	30	50	30	30	70	30	85	30	30
S800N	B,C,D	36	25..125										70	70	85	120	200
S800S	B,C,D,K	50	25..125										70	70	85	120	200

MCCB - MCCB @ 415 V

		Supply s.	T1	T1	T2	T3	T4	T5	T6	T2	T3	T4	T5	T6	T7	T2	T4	T5	T6	T7	T2	T4	T5	T6	T7	T4	T5
		Version	C	N						S						H					L	L		L		V	
Load s.	Carat.	I_{cu} [kA]	25	36						50						70					85	120		100[1]		200	
T1	B	16	25	36	36	36	30	30	30	50	50	36	36	36		70	40	40	40		85	50	50	50		85	65
T1	C	25		36	36	36	36	36	36	50	50	40	40	50	50	70	65	65	65	50	85	85	85	70	50	130	100
T1	N	36								50	50	50	50	50	50	70	65	65	65	50	85	100	100	70	50	200	120
T2										50	50	50	50	50	50	70	65	65	65	65	85	100	100	85	85	200	120
T3											50	50	50	50	50		65	65	65	50		100	100	100	50	200	120
T4												50	50	50	50		65	65	65	50		100	100	65	65	200	120
T5													50	50	50			65	65	50			100	85	65		120
T6														50	40				65	40				70	50		
T2	S	50															70	70	70	70	85	100	100	85	85	200	130
T3																	70	70	70			100	100	100		200	150
T4																	70	70	70	70		100	100	85	85	200	150
T5																		70	70	70			100	85	85		150
T6																			70					85	85		
T2	H	70																			85	120	120	85	85	200	150
T4																						120	120	100	100	200	180
T5																							120	100	100		180
T6																								100	85		
T2	L	85																				120	120			200	180
T4		120																								200	200
T5																											200

[1] 120 kA per T7

4 Protection coordination

4.4 Coordination tables between circuit-breakers and switch disconnectors

The tables shown give the values of the short-circuit current (in kA) for which back-up protection is verified by the pre-selected combination of circuit-breaker and switch disconnector, for voltages between 380 and 415 V. The tables cover the possible combinations of moulded-case circuit-breakers in the ABB SACE Tmax series, with the switch disconnectors detailed above.

4 Protection coordination

Notes for the correct reading of the coordination tables:

Tmax @ 415V ac	
Version	Icu [kA]
B	16
C	25
N	36
S	50
H	70
L (for T2)	85
L (for T4-T5)	120
L (for T6)	100
V (for T7)	150
V	200

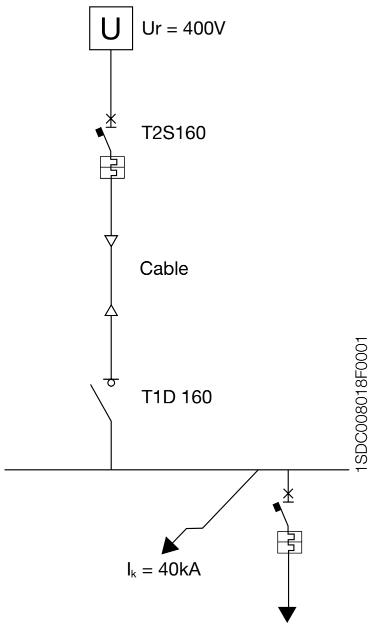
<table>
<tr><th rowspan="2">415 V</th><th colspan="11">SWITCH DISCONNECTOR</th></tr>
<tr><th>T1D 160</th><th>T3D 250</th><th>T4D 320</th><th>T5D 400</th><th>T5D 630</th><th>T6D 630</th><th>T6D 800</th><th>T6D 1000</th><th>T7D 1000</th><th>T7D 1250</th><th>T7D 1600</th></tr>
<tr><td>T1B</td><td colspan="11">16</td></tr>
<tr><td>T1C</td><td colspan="11">25</td></tr>
<tr><td>T1N</td><td colspan="11">36</td></tr>
<tr><td>T2N</td><td colspan="11">36</td></tr>
<tr><td>T2S</td><td colspan="11">50</td></tr>
<tr><td>T2H</td><td colspan="11">70</td></tr>
<tr><td>T2L</td><td colspan="11">85</td></tr>
<tr><td>T3N</td><td></td><td colspan="10">36</td></tr>
<tr><td>T3S</td><td></td><td colspan="10">50</td></tr>
<tr><td>T4N</td><td></td><td>36*</td><td colspan="9">36</td></tr>
<tr><td>T4S</td><td></td><td>50*</td><td colspan="9">50</td></tr>
<tr><td>T4H</td><td></td><td>70*</td><td colspan="9">70</td></tr>
<tr><td>T4L</td><td></td><td>120*</td><td colspan="9">120</td></tr>
<tr><td>T4V</td><td></td><td>200*</td><td colspan="9">200</td></tr>
<tr><td>T5N</td><td></td><td></td><td></td><td colspan="8">36</td></tr>
<tr><td>T5S</td><td></td><td></td><td></td><td colspan="8">50</td></tr>
<tr><td>T5H</td><td></td><td></td><td></td><td colspan="8">70</td></tr>
<tr><td>T5L</td><td></td><td></td><td></td><td colspan="8">120</td></tr>
<tr><td>T5V</td><td></td><td></td><td></td><td colspan="8">200</td></tr>
<tr><td>T6N</td><td></td><td></td><td></td><td></td><td></td><td colspan="6">36</td></tr>
<tr><td>T6S</td><td></td><td></td><td></td><td></td><td></td><td colspan="6">50</td></tr>
<tr><td>T6H</td><td></td><td></td><td></td><td></td><td></td><td colspan="6">65</td></tr>
<tr><td>T6L</td><td></td><td></td><td></td><td></td><td></td><td colspan="6">100</td></tr>
<tr><td>T7S</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">50</td></tr>
<tr><td>T7H</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">70</td></tr>
<tr><td>T7L</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">120</td></tr>
<tr><td>T7V</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">150</td></tr>
</table>

1SDC008037F0201

* for T4 250 or T4 320 only with I1 setting at 250 A.

4 Protection coordination

Example:
From the coordination table on page 144-145 it can be seen that circuit-breaker T2S160 is able to protect the switch disconnector T1D160 up to a short-circuit current of 50 kA (higher than the short-circuit current at the installation point). Overload protection is also verified, as the rated current of the breaker is not higher than the size of the disconnector.



4.4 Coordination tables between circuit-breakers and switch disconnectors

4 Protection coordination

Example:
For the correct selection of the components, the disconnector must be protected from overloads by a device with a rated current not greater than the size of the disconnector, while in short-circuit conditions it must be verified that:

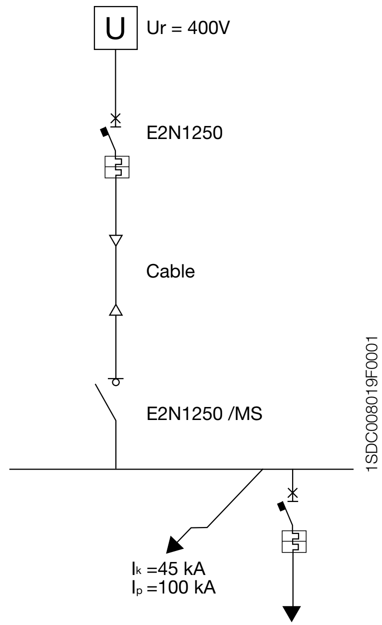
$I_{cw} \geq I_k$

$I_{cm} \geq I_p$.

Therefore, with regard to the electrical parameters of the single devices, Emax E2N1250/MS disconnector is selected, and a E2N1250 breaker. That is:

I_{cw}(E2N /MS) = 55 kA > 45 kA

I_{cm} (E2N /MS) = 143 kA > 100 kA.



5 Special applications

5.1 Direct current networks

Main applications of direct current:

- Emergency supply or auxiliary services:
  the use of direct current is due to the need to employ a back-up energy source which allows the supply of essential services such as protection services, emergency lighting, alarm systems, hospital and industrial services, data-processing centres etc., using accumulator batteries, for example.
- Electrical traction:
  the advantages offered by the use of dc motors in terms of regulation and of single supply lines lead to the widespread use of direct current for railways, underground railways, trams, lifts and public transport in general.
- Particular industrial installations:
  there are some electrolytic process plants and applications which have a particular need for the use of electrical machinery.

Typical uses of circuit-breakers include the protection of cables, devices and the operation of motors.

Considerations for the interruption of direct current

Direct current presents larger problems than alternating current does in terms of the phenomena associated with the interruption of high currents. Alternating currents have a natural passage to zero of the current every half-cycle, which corresponds to a spontaneous extinguishing of the arc which is formed when the circuit is opened.
This characteristic does not exist in direct currents, and furthermore, in order to extinguish the arc, it is necessary that the current lowers to zero.
The extinguishing time of a direct current, all other conditions being equal, is proportional to the time constant of the circuit T = L/R.
It is necessary that the interruption takes place gradually, without a sudden switching off of the current which could cause large over-voltages. This can be carried out by extending and cooling the arc so as to insert an ever higher resistance into the circuit.
The energetic characteristics which develop in the circuit depend upon the voltage level of the plant and result in the installation of breakers according to connection diagrams in which the poles of the breaker are positioned in series to increase their performance under short-circuit conditions. The breaking capacity of the switching device becomes higher as the number of contacts which open the circuit increases and, therefore, when the arc voltage applied is larger.
This also means that when the supply voltage of the installation rises, so must the number of current switches and therefore the poles in series.

5 Special applications

Calculation of the short-circuit current of an accumulator battery

The short-circuit current at the terminals of an accumulator battery may be supplied by the battery manufacturer, or may be calculated using the following formula:

$$I_k = \frac{U_{Max}}{R_i}$$

where:
- U_{Max} is the maximum flashover voltage (no-load voltage);
- R_i is the internal resistance of the elements forming the battery.

The internal resistance is usually supplied by the manufacturer, but may be calculated from the discharge characteristics obtained through a test such as detailed by IEC 60896 – 1 or IEC 60896 – 2.
For example, a battery of 12.84 V and internal resistance of 0.005 Ω gives a short-circuit current at the terminals of 2568 A.
Under short-circuit conditions the current increases very rapidly in the initial moments, reaches a peak and then decreases with the discharge voltage of the battery. Naturally, this high value of the fault current causes intense heating inside the battery, due to the internal resistance, and may lead to explosion. Therefore it is very important to prevent and / or minimize short-circuit currents in direct currents systems supplied by accumulator batteries.

Criteria for the selection of circuit-breakers

For the correct selection of a circuit-breaker for the protection of a direct current network, the following factors must be considered:
1. the load current, according to which the size of the breaker and the setting for the thermo-magnetic over-current release can be determined;
2. the rated plant voltage, according to which the number of poles to be connected in series is determined, thus the breaking capacity of the device can also be increased;
3. the prospective short-circuit current at the point of installation of the breaker influencing the choice of the breaker;
4. the type of network, more specifically the type of earthing connection.

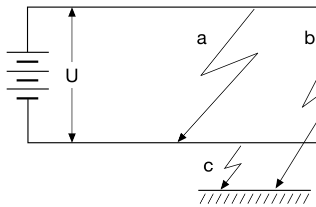
Note: in case of using of four pole circuit-breakers, the neutral must be at 100%

Direct current network types

Direct current networks may be carried out:
- with both polarities insulated from earth;
- with one polarity connected to earth;
- with median point connected to earth.

5 Special applications

Network with both polarities insulated from earth



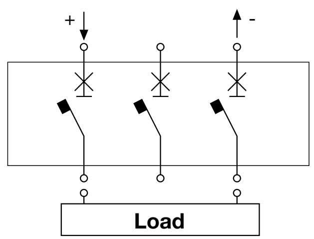
- Fault a: the fault, with negligible impedance, between the two polarities sets up a short-circuit current to which both polarities contribute to the full voltage, according to which the breaking capacity of the breaker must be selected.
- Fault b: the fault between the polarity and earth has no consequences from the point of view of the function of the installation.
- Fault c: again, this fault between the polarity and earth has no consequences from the point of view of the function of the installation.

In insulated networks it is necessary to install a device capable of signalling the presence of the first earth fault in order to eliminate it. In the worst conditions, when a second earth fault is verified, the breaker may have to interrupt the short-circuit current with the full voltage applied to a single polarity and therefore with a breaking capacity which may not be sufficient.
In networks with both polarities insulated from earth it is appropriate to divide the number of poles of the breaker necessary for interruption on each polarity (positive and negative) in such a way as to obtain separation of the circuit.

The diagrams to be used are as follows:

Diagram A

Three-pole breaker with one pole per polarity



5 Special applications

Diagram B

Three-pole breaker with two poles in series for one polarity and one pole for the other polarity (1)

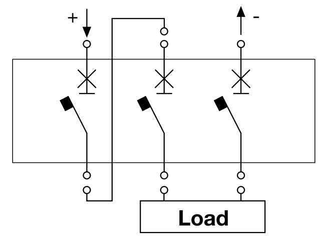


Diagram G

Four-pole breaker with two poles in parallel per polarity

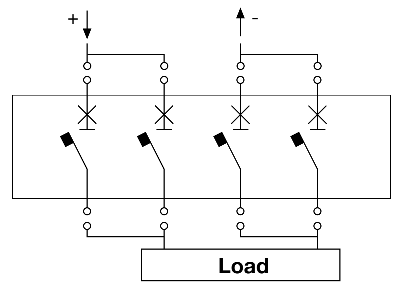
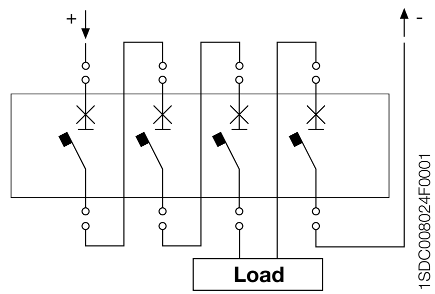


Diagram E

Four-pole breaker with three poles in series on one polarity and one pole on the remaining polarity (1)

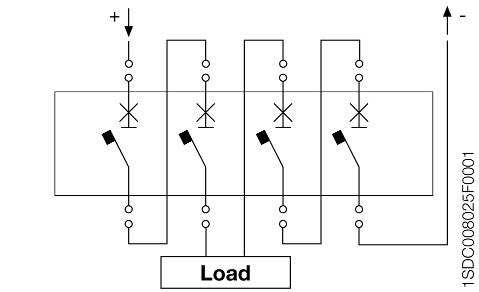


(1) It is not advisable to divide the poles of the breaker unequally as, in this type of network, a second earth fault may lead to the single pole working under fault conditions at full voltage. In these circumstances, it is essential to install a device capable of signalling the earth fault or the loss of insulation of one polarity.

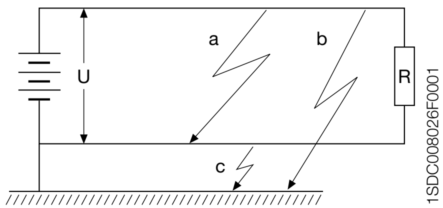
5 Special applications

Diagram F

Four-pole breaker with two poles in series per polarity



Network with one polarity connected to earth



- Fault a: the fault between the two polarities sets up a short-circuit current to which both polarities contribute to the full voltage U, according to which the breaking capacity of the breaker is selected.
- Fault b: the fault on the polarity not connected to earth sets up a current which involves the over-current protection according to the resistance of the ground.
- Fault c: the fault between the polarity connected to earth and earth has no consequences from the point of view of the function of the installation.

In a network with one polarity connected to earth, all the poles of the breaker necessary for protection must be connected in series on the non-earthed polarity. If isolation is required, it is necessary to provide another breaker pole on the earthed polarity.

5 Special applications

Diagrams to be used with circuit isolation are as follows:

Diagram A

Three-pole breaker with one pole per polarity

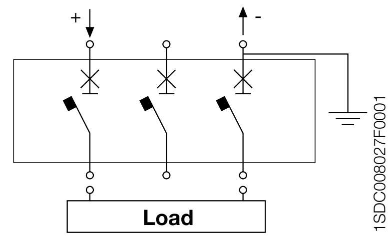


Diagram B

Three-pole breaker with two poles in series on the polarity not connected to earth, and one pole on the remaining polarity

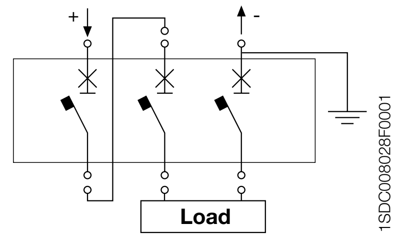
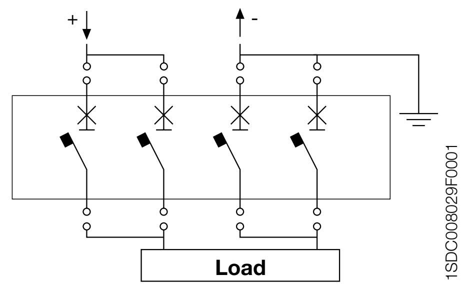


Diagram G

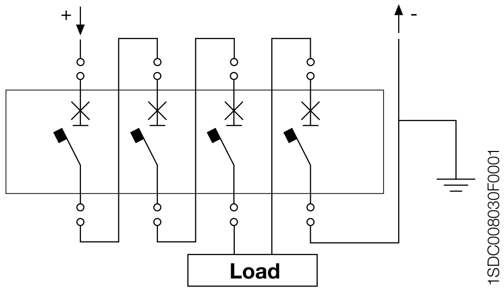
Four-pole breaker with two poles in parallel per polarity



5 Special applications

Diagram E

Four-pole breaker with three poles in series on the polarity not connected to earth, and one pole on the remaining polarity



Diagrams to be used without circuit isolation are as follows:

Diagram C

Three-pole breaker with three poles in series

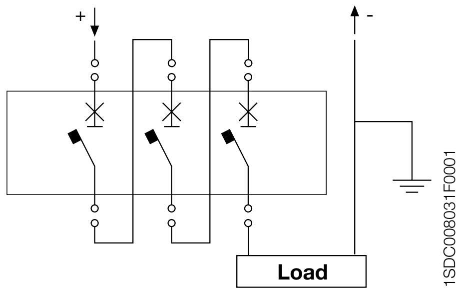
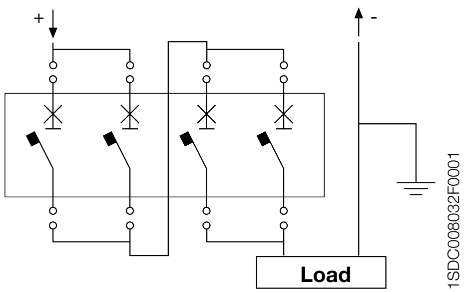


Diagram H

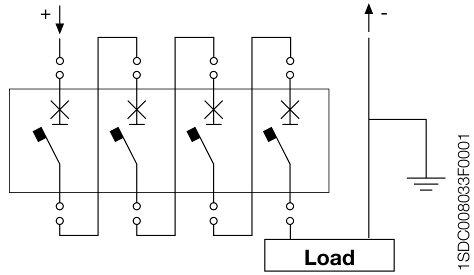
Four-pole breaker with series of two poles in parallel



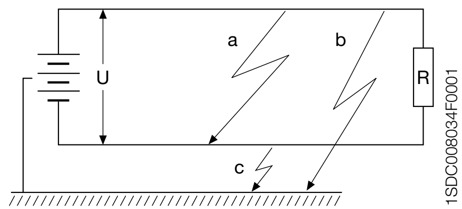
5 Special applications

Diagram D

Four-pole breaker with four poles in series on the polarity not connected to earth



Network with the median point connected to earth



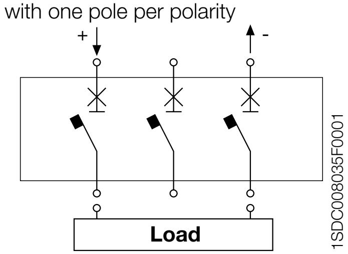
- Fault a: the fault between the two polarities sets up a short-circuit current to which both polarities contribute to the full voltage U, according to which the breaking capacity of the breaker is selected.
- Fault b: the fault between the polarity and earth sets up a short-circuit current less than that of a fault between the two polarities, as it is supplied by a voltage equal to 0.5 U.
- Fault c: the fault in this case is analogous to the previous case, but concerns the negative polarity.

With network with the median point connected to earth the breaker must be inserted on both polarities.

Diagrams to be used are as follows:

Diagram A

Three-pole breaker with one pole per polarity



5 Special applications

Diagram G

Four-pole breaker with two poles in parallel per polarity

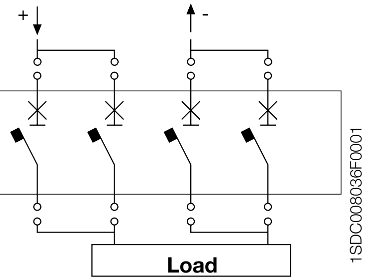
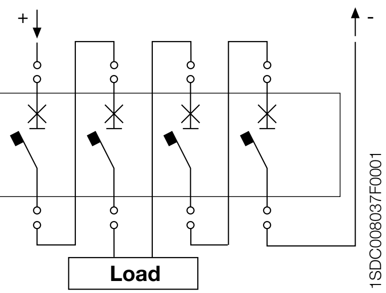


Diagram F

Four-pole breaker with two poles in series per polarity



Use of switching devices in direct current

Parallel connection of breaker poles

According to the number of poles connected in parallel, the coefficients detailed in the following table must be applied:

Table 1: Correction factor for poles connected in parallel

number of poles in parallel	2	3	4 (neutral 100%)
reduction factor of dc carrying capacity	0.9	0.8	0.7
breaker current carrying capacity	1.8xIn	2.4xIn	2.8xIn

The connections which are external from the breaker terminals must be carried out by the user in such a way as to ensure that the connection is perfectly balanced.

5 Special applications

Example:

Using a Tmax T6N800 In800 circuit-breaker with three poles in parallel, a coefficient equal to 0.8 must be applied, therefore the maximum carrying current will be 0.8·3·800 = 1920 A.

Behaviour of thermal releases

As the functioning of these releases is based on thermal phenomena arising from the flowing of current, they can therefore be used with direct current, their trip characteristics remaining unaltered.

Behaviour of magnetic releases

The values of the trip thresholds of ac magnetic releases, used for direct current, must be multiplied by the following coefficient (k_m), according to the breaker and the connection diagram:

Table 2: k_m coefficient

Circuit-breaker	diagram A	diagram B	diagram C	diagram D	diagram E	diagram F	diagram G	diagram H
T1	1.3	1	1	-	-	-	-	-
T2	1.3	1.15	1.15	-	-	-	-	-
T3	1.3	1.15	1.15	-	-	-	-	-
T4	1.3	1.15	1.15	1	1	1	-	-
T5	1.1	1	1	0.9	0.9	0.9	-	-
T6	1.1	1	1	0.9	0.9	0.9	1.1	1

Example

Data:
- Direct current network connected to earth;
- Rated voltage Ur = 250 V;
- Short-circuit current Ik = 32 kA
- Load current Ib = 230 A

Using Table 3, it is possible to select the Tmax T3N250 In = 250 A three pole breaker, using the connection shown in diagram B (two poles in series for the polarity not connected to earth and one poles in series for the polarity connected to earth).
From Table 2 corresponding to diagram B, and with breaker Tmax T3, it risults k_m=1.15; therefore the nominal magnetic trip will occur at 2875 A (taking into account the tolerance, the trip will occur between 2300 A and 3450 A).

5 Special applications

The following table summarizes the breaking capacity of the various circuit-breakers available for direct current. The number of poles to be connected in series to guarantee the breaking capacity is given in brackets.

Table 3: Breaking capacity in direct current according to the voltage

Circuit-breaker	Rated current [A]	Breaking capacity [kA] ≤ 125 [V][1]	250 [V]	500 [V]	750 [V]
T1B160	16 ÷ 160	16 (1P)	20 (3P) - 16 (2P)	16 (3P)	
T1C160	25 ÷ 160	25 (1P)	30 (3P) - 25 (2P)	25 (3P)	
T1N160	32 ÷ 160	36 (1P)	40 (3P) - 36 (2P)	36 (3P)	
T2N160	1.6 ÷ 160	36 (1P)	40 (3P) - 36 (2P)	36 (3P)	
T2S160	1.6 ÷ 160	50 (1P)	55 (3P) - 50 (2P)	50 (3P)	
T2H160	1.6 ÷ 160	70 (1P)	85 (3P) - 70 (2P)	70 (3P)	
T2L160	1.6 ÷ 160	85 (1P)	100 (3P) - 85 (2P)	85 (3P)	
T3N250	63 ÷ 250	36 (1P)	40 (3P) - 36 (2P)	36 (3P)	
T3S250	63 ÷ 250	50 (1P)	55 (3P) - 50 (2P)	50 (3P)	
T4N250/320	20 ÷ 250	36 (1P)	36 (2P)	25 (2P)	16 (3P)
T4S250/320	20 ÷ 250	50 (1P)	50 (2P)	36 (2P)	25 (3P)
T4H250/320	20 ÷ 250	70 (1P)	70 (2P)	50 (2P)	36 (3P)
T4L250/320	20 ÷ 250	100 (1P)	100 (2P)	70 (2P)	50 (3P)
T4V250/320	20 ÷ 250	100 (1P)	100 (2P)	100 (2P)	70 (3P)
T5N400/630	320 ÷ 500	36 (1P)	36 (2P)	25 (2P)	16 (3P)
T5S400/630	320 ÷ 500	50 (1P)	50 (2P)	36 (2P)	25 (3P)
T5H400/630	320 ÷ 500	70 (1P)	70 (2P)	50 (2P)	36 (3P)
T5L400/630	320 ÷ 500	100 (1P)	100 (2P)	70 (2P)	50 (3P)
T5V400/630	320 ÷ 500	100 (1P)	100 (2P)	100 (2P)	70 (3P)
T6N630/800	630-800	36 (1P)	36 (2P)	20 (2P)	16 (3P)
T6S630/800	630-800	50 (1P)	50 (2P)	35 (2P)	20 (3P)
T6H630/800	630-800	70 (1P)	70 (2P)	50 (2P)	36 (3P)
T6L630/800	630-800	100 (1P)	100 (2P)	65 (2P)	50 (3P)

[1] Minimum allowed voltage 24 Vdc.

5 Special applications

5.2 Networks at particular frequencies: 400 Hz and 16 2/3 Hz

Standard production breakers can be used with alternating currents with frequencies other than 50/60 Hz (the frequencies to which the rated performance of the device refer, with alternating current) as appropriate derating coefficients are applied.

5.2.1 400 Hz networks

At high frequencies, performance is reclassified to take into account phenomena such as:
- the increase in the skin effect and the increase in the inductive reactance directly proportional to the frequency causes overheating of the conductors or the copper components in the breaker which normally carry current;
- the lengthening of the hysteresis loop and the reduction of the magnetic saturation value with the consequent variation of the forces associated with the magnetic field at a given current value.

In general these phenomena have consequences on the behaviour of both thermo-magnetic releases and the current interrupting parts of the circuit-breaker.

The following tables refer to circuit-breakers with thermomagnetic releases, with a breaking capacity lower than 36 kA. This value is usually more than sufficient for the protection of installations where such a frequency is used, normally characterized by rather low short-circuit currents.
As can be seen from the data shown, the tripping threshold of the thermal element (I_n) decreases as the frequency increases because of the reduced conductivity of the materials and the increase of the associated thermal phenomena; in general, the derating of this performance is generally equal to 10%.
Vice versa, the magnetic threshold (I_3) increases with the increase in frequency.

5 Special applications

Table 1: Tmax performance T1 16-63 A TMD

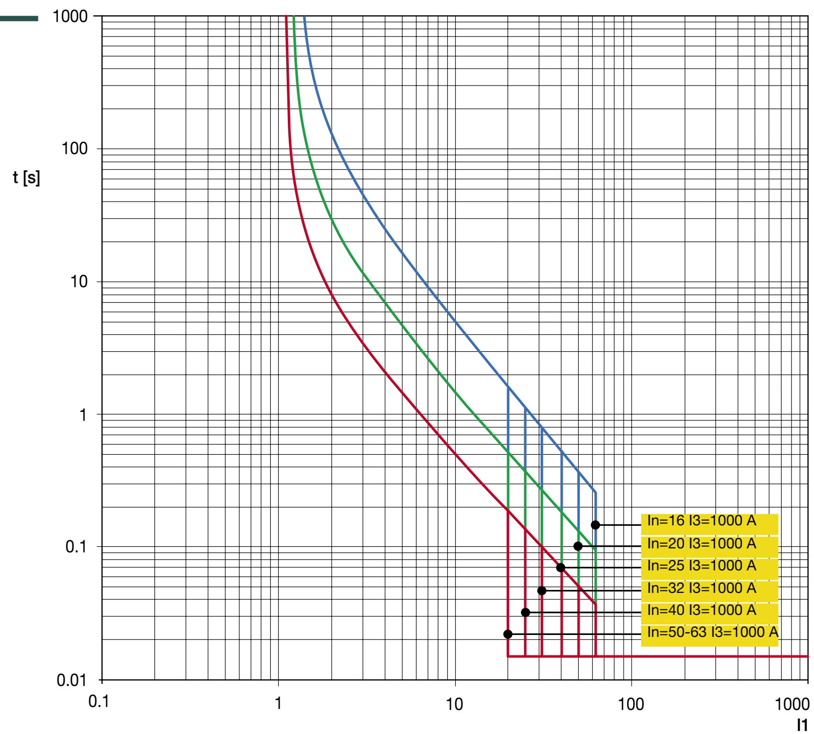
		I1 (400Hz)			I3		
		MIN	MED	MAX	I3 (50Hz)	K_m	I3 (400Hz)
T1B 160 T1C 160 T1N 160	In16	10	12	14	500	2	1000
	In20	12	15	18	500	2	1000
	In25	16	19	22	500	2	1000
	In32	20	24.5	29	500	2	1000
	In40	25	30.5	36	500	2	1000
	In50	31	38	45	500	2	1000
	In63	39	48	57	630	2	1260

K_m = Multiplier factor of I3 due to the induced magnetic fields

Trip curves
thermomagnetic release

T1 B/C/N 160

In 16 to 63 A
TMD



5 Special applications

Table 2: Tmax performance T1 80 A TMD

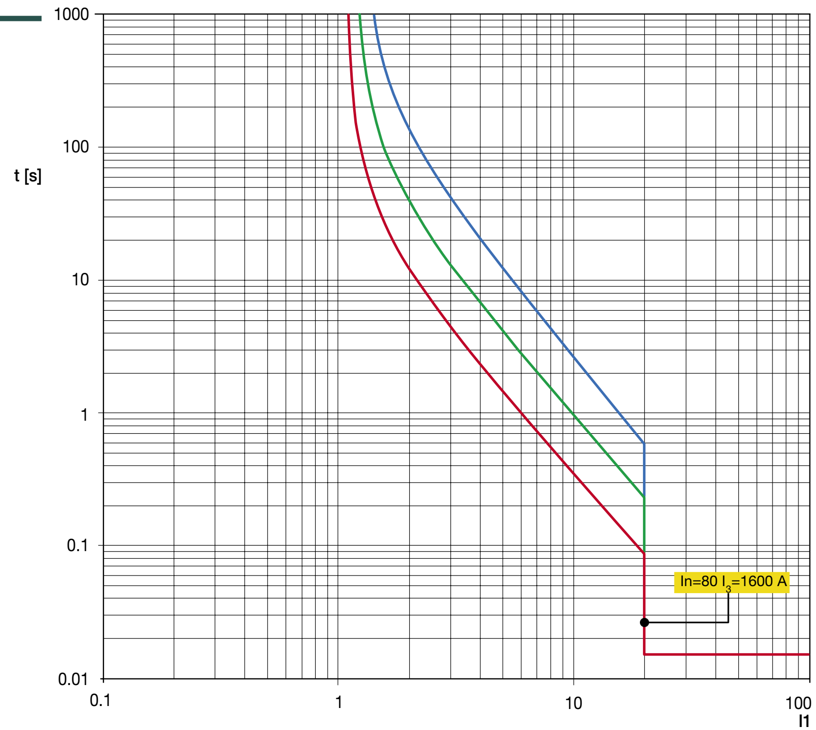
		I1 (400Hz)			I3		
		MIN	MED	MAX	I3 (50Hz)	K_m	I3 (400Hz)
T1B 160 T1C 160 T1N 160	In80	50	61	72	800	2	1600

K_m = Multiplier factor of I3 due to the induced magnetic fields

Trip curves
thermomagnetic release

T1 B/C/N 160

In 80 A
TMD



5 Special applications

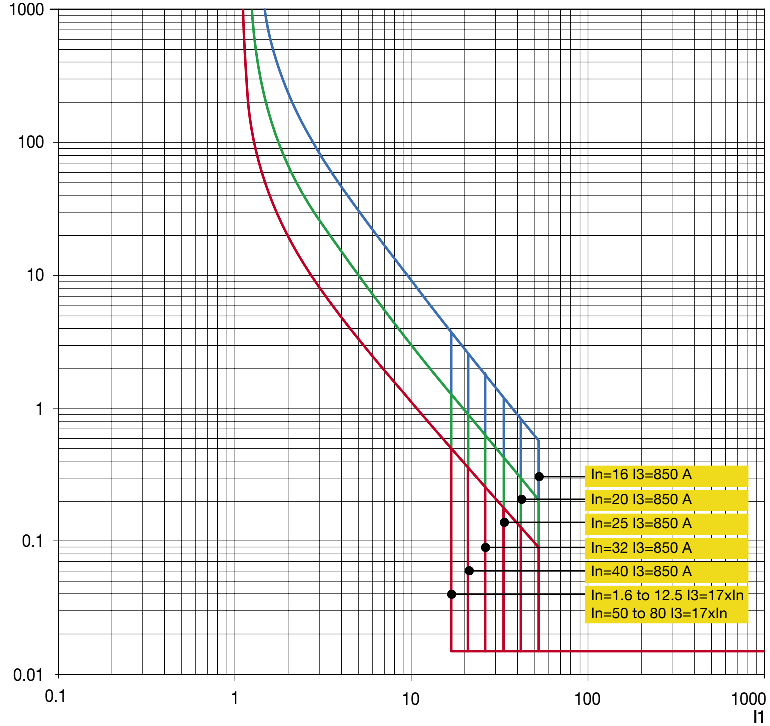
Table 3: Tmax performance T2 1.6-80 A TMD

T2N 160		I1 (400Hz)			I3		
		MIN	MED	MAX	I3 (50Hz)	K_m	I3 (400Hz)
	In1.6	1	1.2	1.4	16	1.7	27.2
	In2	1.2	1.5	1.8	20	1.7	34
	In2.5	1.5	1.9	2.2	25	1.7	42.5
	In3.2	2	2.5	2.9	32	1.7	54.4
	In4	2.5	3	3.6	40	1.7	68
	In5	3	3.8	4.5	50	1.7	85
	In6.3	4	4.8	5.7	63	1.7	107.1
	In8	5	6.1	7.2	80	1.7	136
	In10	6.3	7.6	9	100	1.7	170
	In12.5	7.8	9.5	11.2	125	1.7	212.5
	In16	10	12	14	500	1.7	850
	In20	12	15	18	500	1.7	850
	In25	16	19	22	500	1.7	850
	In32	20	24.5	29	500	1.7	850
	In40	25	30.5	36	500	1.7	850
	In50	31	38	45	500	1.7	850
	In63	39	48	57	630	1.7	1071
	In80	50	61	72	800	1.7	1360

K_m = Multiplier factor of I3 due to the induced magnetic fields

Trip curves
thermomagnetic release
T2N 160

In 1.6 to 80 A
TMD



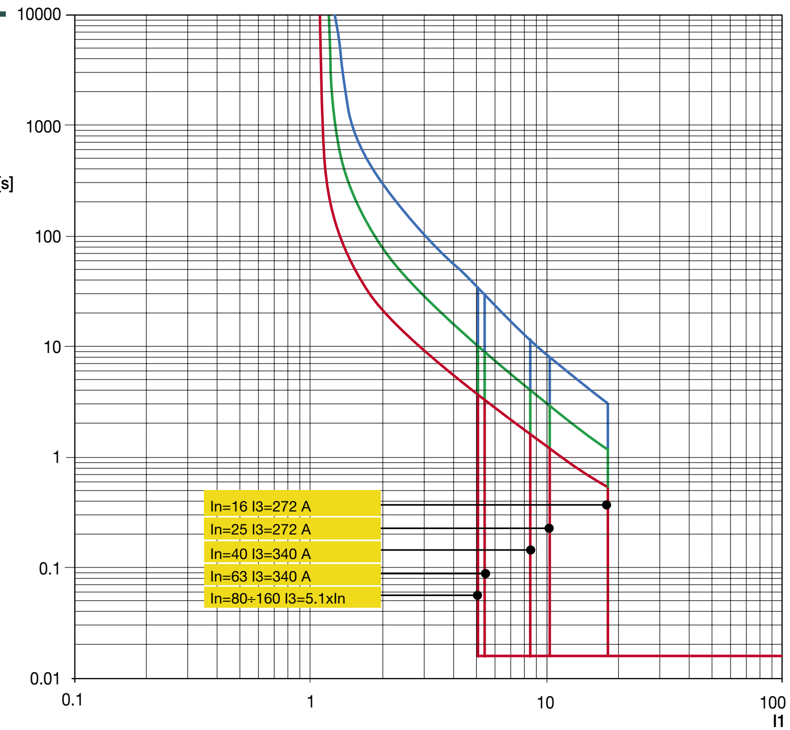
5 Special applications

Table 4: Tmax performance T2 16-160 A TMG

T2N 160		I1 (400Hz)			I3		
		MIN	MED	MAX	I3 (50Hz)	K_m	I3 (400Hz)
	In16	10	12	14	160	1,7	272
	In25	16	19	22	160	1,7	272
	In40	25	30,5	36	200	1,7	340
	In63	39	48	57	200	1,7	340
	In80	50	61	72	240	1,7	408
	In100	63	76,5	90	300	1,7	510
	In125	79	96	113	375	1,7	637,5
	In160	100	122	144	480	1,7	816

Trip curves
thermomagnetic release
T2N 160

In 16 to 160 A
TMG



5 Special applications

Table 5: Tmax performance T3 63-250 A TMG

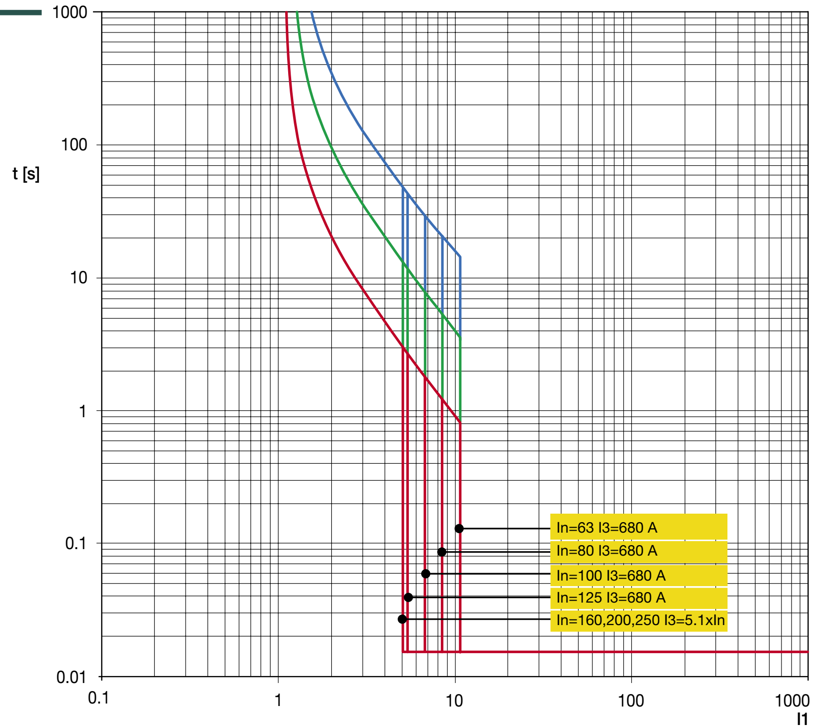
T3N 250	I1 (400Hz) MIN	I1 (400Hz) MED	I1 (400Hz) MAX	I3 (Low magnetic setting) I3 (50Hz)	K_m	I3 (400Hz)
In63	39	48	57	400	1.7	680
In80	50	61	72	400	1.7	680
In100	63	76.5	90	400	1.7	680
In125	79	96	113	400	1.7	680
In160	100	122	144	480	1.7	816
In200	126	153	180	600	1.7	1020
In250	157	191	225	750	1.7	1275

K_m = Multiplier factor of I3 due to the induced magnetic fields

Trip curves
thermomagnetic release

T3N 250

In 63 to 250 A
TMG



5 Special applications

Table 6: Tmax performance T3 63-125 A TMD

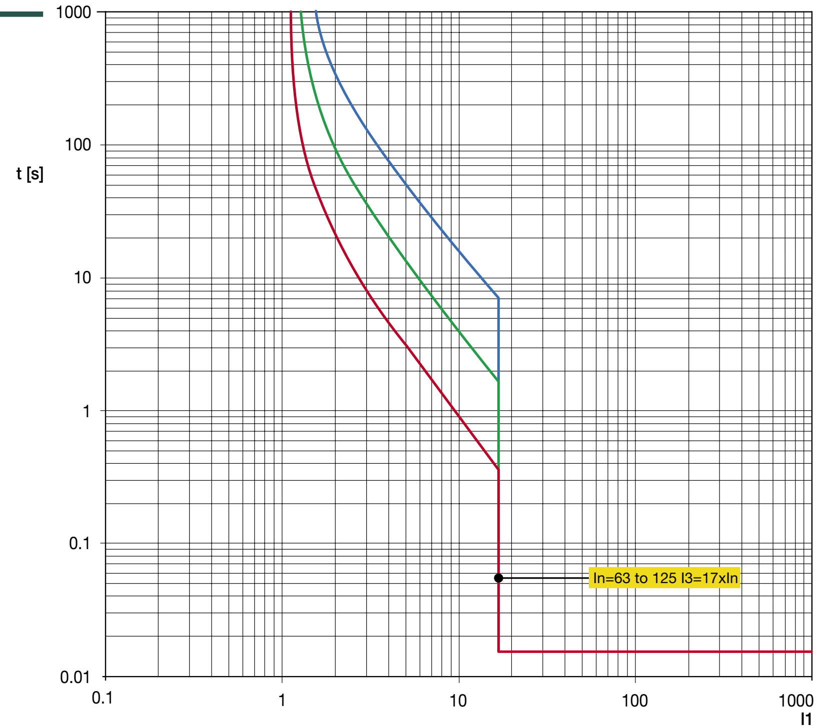
T3N 250	I1 (400Hz) MIN	I1 (400Hz) MED	I1 (400Hz) MAX	I3 I3 (50Hz)	K_m	I3 (400Hz)
In63	39	48	57	630	1.7	1071
In80	50	61	72	800	1.7	1360
In100	63	76.5	90	1000	1.7	1700
In125	79	96	113	1250	1.7	2125

K_m = Multiplier factor of I3 due to the induced magnetic fields

Trip curves
thermomagnetic release

T3N 250

In 63 to 125 A
TMD



5 Special applications

Table 7: Tmax performance T4 20-50 A TMD

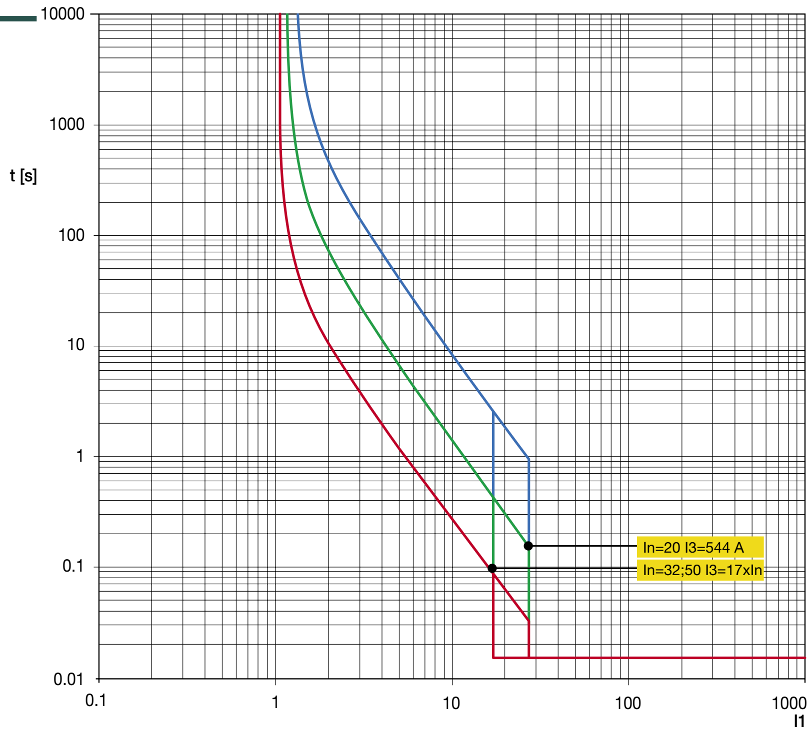
		I1 (400Hz)			I3		
T4N 250		MIN	MED	MAX	I3 (50Hz)	K_m	I3 (400Hz)
	In20	12	15	18	320	1.7	544
	In32	20	24.5	29	320	1.7	544
	In50	31	38	45	500	1.7	850

K_m = Multiplier factor of I3 due to the induced magnetic fields

Trip curves
thermomagnetic release

T4N 250

In 20 to 50 A
TMD



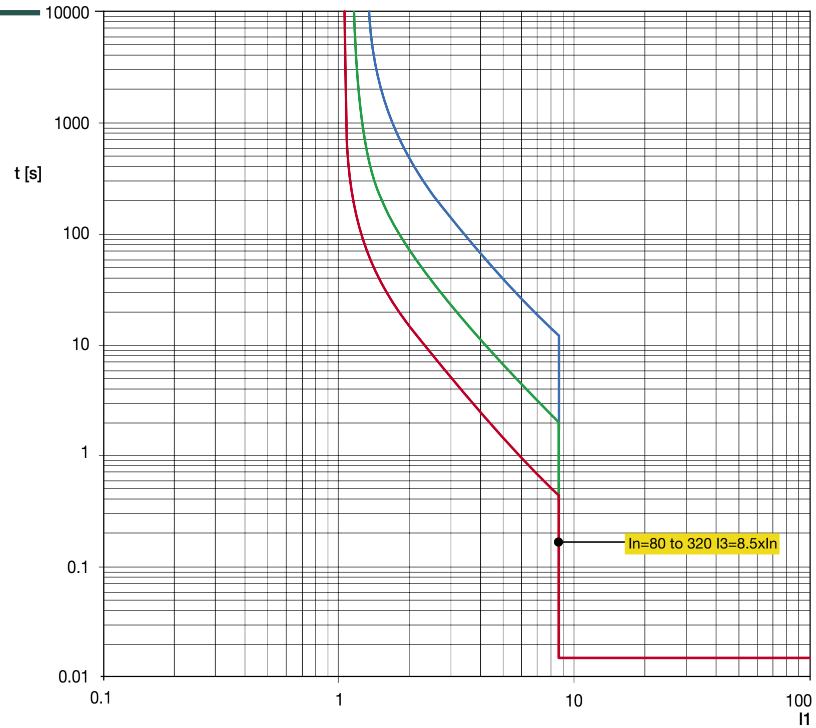
		I1 (400Hz)			I3 setting (MIN=5xIn)		
T4N 250/320		MIN	MED	MAX	I3 @ 5xIn (50Hz)	K_m	I3 @ 5xIn (400Hz)
	In80	50	61	72	400	1.7	680
	In100	63	76.5	90	500	1.7	850
	In125	79	96	113	625	1.7	1060
	In160	100	122	144	800	1.7	1360
	In200	126	153	180	1000	1.7	1700
	In250	157	191	225	1250	1.7	2125

K_m = Multiplier factor of I3 due to the induced magnetic fields

Trip curves
thermomagnetic release

T4N 250/320

In 80 to 250 A
TMA



5 Special applications

Table 9: Tmax performance T5N 320-500 A TMA

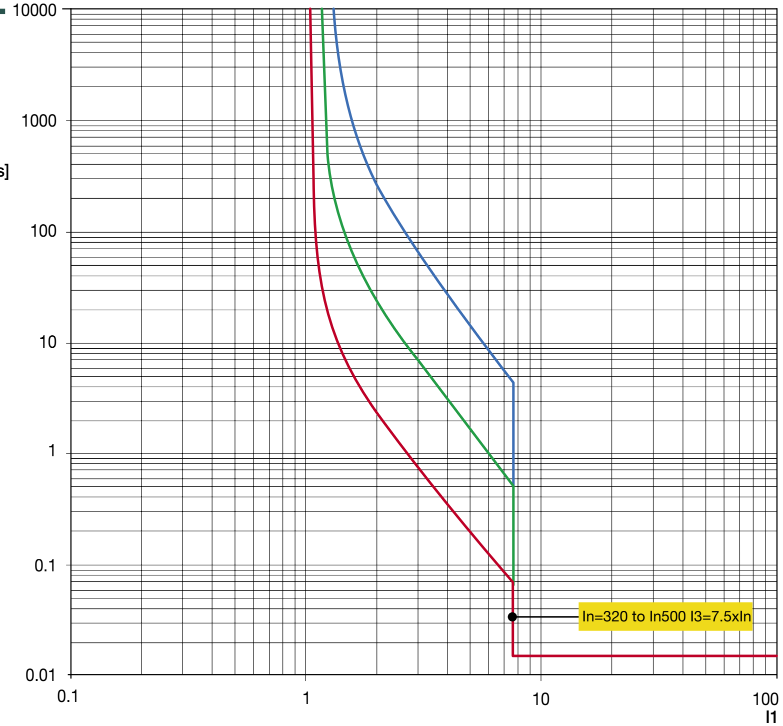
T5N400/630	I1 (400Hz)			I3 setting (MIN=5xIn)		
	MIN	MED	MAX	I3 @ 5xIn(50Hz)	K_m	I3 @ 5xIn (400)Hz
In320	201	244	288	1600	1.5	2400
In400	252	306	360	2000	1.5	3000
In500	315	382	450	2500	1.5	3750

K_m = Multiplier factor of I3 due to the induced magnetic fields

Trip curves
thermomagnetic release

T5 N 400/630

In 320 to 500 A
TMA



5 Special applications

Table 10: Tmax performance T5N 320-500 A TMG

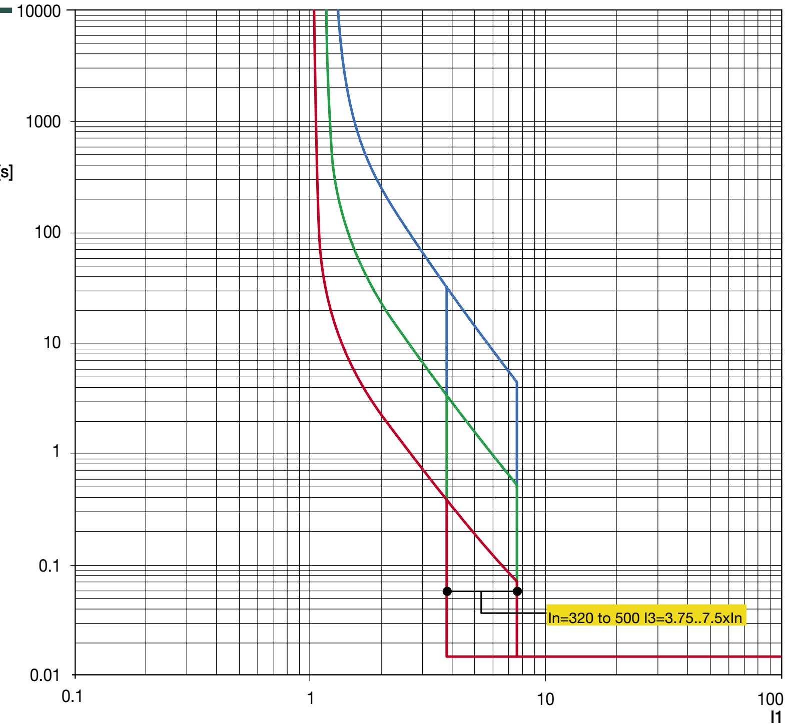
T5N400/630	I1 (400Hz)			I3 setting (2.5…5xIn)		
	MIN	MED	MAX	I3 @ 2.5..5xIn (50Hz)	K_m	I3 @ 2.5..5xIn (400Hz)
In320	201	244	288	800…1600	1.5	1200…2400
In400	252	306	360	1000…2000	1.5	1500…3000
In500	315	382	450	1250…2500	1.5	1875…3750

K_m = Multiplier factor of I3 due to the induced magnetic fields

Trip curves
thermomagnetic release

T5N 400/630

In 320 to 500 A
TMG



5 Special applications

Table 11: Tmax performance T6N 630 A TMA

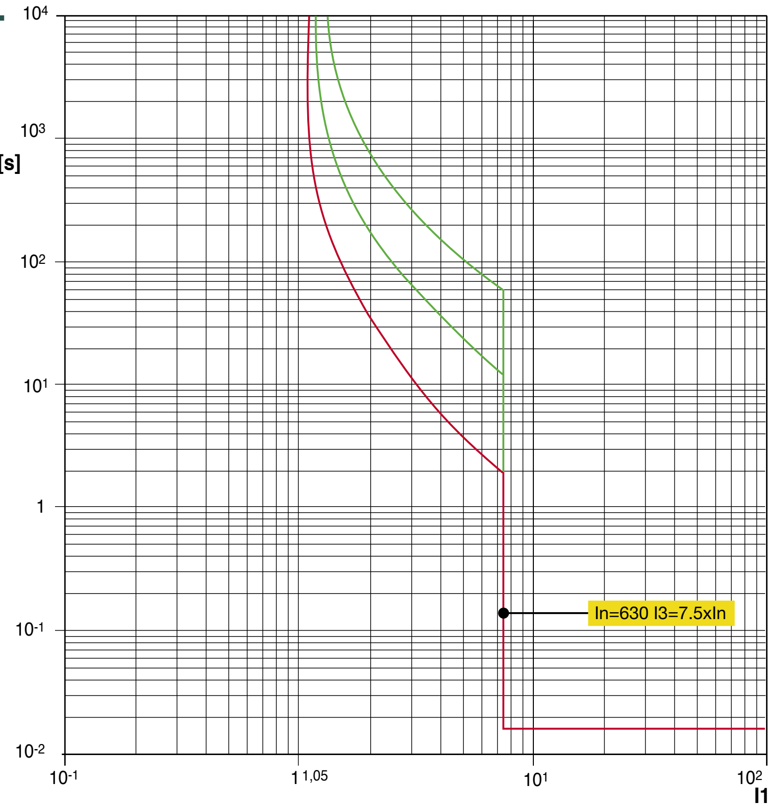
		I1 (400Hz)			I3 = 5÷10In (set I3=5In)		
		MIN	MED	MAX	I3 (50Hz)	K_m	I3 (400Hz)
T6N630	In630	397	482	567	3150	1.5	4725

K_m = Multiplier factor of I3 due to the induced magnetic fields

Trip curves
thermomagnetic release

T6N 630

In 630 A
TMA



5 Special applications

Table 12: Tmax performance T6N 800 A TMA

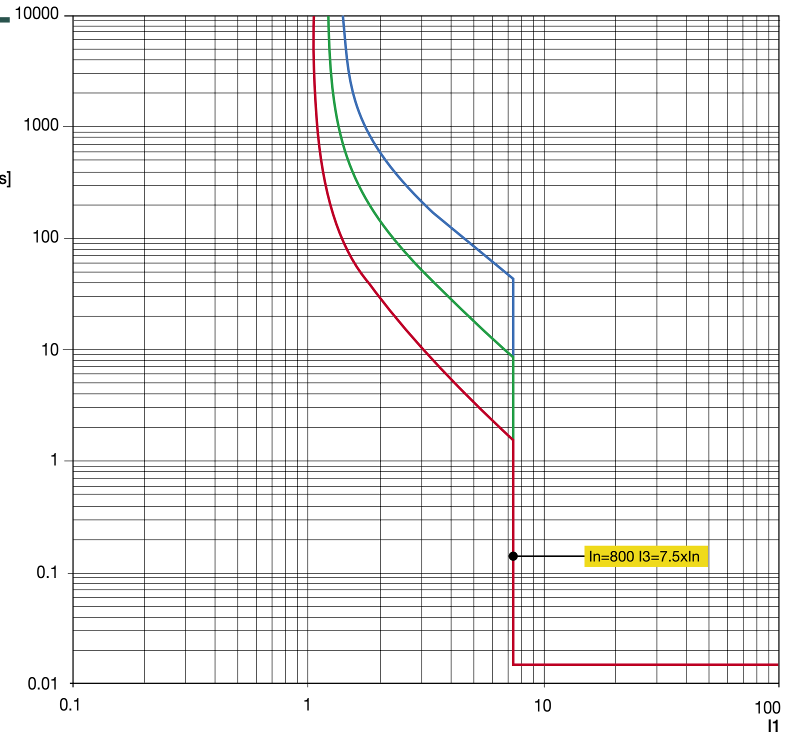
		I1 (400Hz)			I3 = 5-10In (set I3=5In)		
		MIN	MED	MAX	I3 (50Hz)	K_m	I3 (400Hz)
T6N 800	In800	504	602	720	4000	1.5	6000

K_m = Multiplier factor of I3 due to the induced magnetic fields

Trip curves
thermomagnetic release

T6N 800

In 800 A
TMA



5 Special applications

5.2.2 16 2/3 Hz networks

Single phase distribution with a frequency of 16 2/3 Hz was developed for electrical traction systems as an alternative to three phase 50 Hz systems, and to direct current systems.
At low frequencies the thermal tripping threshold is not subject to any derating, while the magnetic threshold requires a correction coefficient k_m, as detailed in table 2.
The Tmax series thermomagnetic moulded-case circuit-breakers are suitable for use with frequencies of 16 2/3 Hz; the electrical performance and the relevant connection diagrams are shown below.

Table 1: Breaking capacity [kA]

	Rated current	Breaking capacity [kA]			
Circuit-breaker	[A]	250 V	500 V	750 V	1000 V (1)
T1B160	16 ÷160	16 (2P) 20 (3P)	16 (3P)	-	-
T1C160	25 ÷ 160	25 (2P) 30 (3P)	25 (3P)	-	-
T1N160	32 ÷ 160	36 (2P) 40 (3P)	36 (3P)	-	-
T2N160	1.6 ÷ 160	36 (2P) 40 (3P)	36 (3P)	-	-
T2S160	1.6 ÷ 160	50 (2P) 55 (3P)	50 (3P)	-	-
T2H160	1.6 ÷ 160	70 (2P) 85 (3P)	70 (3P)	-	-
T2L160	1.6 ÷ 160	85 (2P) 100 (3P)	85 (3P)	50 (4P) (2)	-
T3N250	63 ÷ 250	36 (2P) 40 (3P)	36 (3P)	-	-
T3S250	63 ÷ 250	50 (2P) 55 (3P)	50 (3P)	-	-
T4N250/320	20 ÷ 250	36 (2P)	25 (2P)	16 (3P)	-
T4S250/320	20 ÷ 250	50 (2P)	36 (2P)	25 (3P)	-
T4H250/320	20 ÷ 250	70 (2P)	50 (2P)	36 (3P)	-
T4L250/320	20 ÷ 250	100 (2P)	70 (2P)	50 (3P)	-
T4V250/320	20 ÷ 250	150 (2P)	100 (2P)	70 (3P)	-
T4V250	32 ÷ 250				40 (4P)
T5N400/630	320 ÷ 500	36 (2P)	25 (2P)	16 (3P)	-
T5S400/630	320 ÷ 500	50 (2P)	36 (2P)	25 (3P)	-
T5H400/630	320 ÷ 500	70 (2P)	50 (2P)	36 (3P)	-
T5L400/630	320 ÷ 500	100 (2P)	70 (2P)	50 (3P)	-
T5V400/630	320 ÷ 500	150 (2P)	100 (2P)	70 (3P)	-
T5V400/630	400 ÷ 500				40 (4P)
T6N630/800	630 ÷ 800	36 (2P)	20 (2P)	16 (3P)	-
T6S630/800	630 ÷ 800	50 (2P)	35 (2P)	20 (3P)	-
T6H630/800	630 ÷ 800	70 (2P)	50 (2P)	36 (3P)	-
T6L630/800	630 ÷ 800	100 (2P)	70 (2P)	50 (3P)	40 (4P)

(1) 1000V version circuit-breakers in dc, with neutral at 100%.
(2) Circuit-breakers with neutral at 100%.

5 Special applications

Table 2: k_m factor

	Diagram A	Diagram B-C	Diagram D-E-F
T1	1	1	-
T2	0.9	0.9	0.9
T3	0.9	0.9	-
T4	0.9	0.9	0.9
T5	0.9	0.9	0.9
T6	0.9	0.9	0.9

Table 3: Possible connections according to the voltage, the type of distribution and the type of fault

	Neutral not grounded	Neutral grounded*	
		L-N fault	L-E fault
250 V 2 poles in series	A1	A2	B2
250 V 3 poles in series**	B1	B2, C	B3
500 V 2 poles in series	A1	A2, B2	B2, C
500 V 3 poles in series**	B1	B2, C	C
750 V 3 poles in series	B1	B2, C	C
750 V 4 poles in series***	E-F	E1, D	E1
1000 V 4 poles in series	E-F	E1, C3	E1

* In the case of the only possible faults being L-N or L-E (E=Earth) with non-significant impedance, use the diagrams shown. If both faults are possible, use the diagrams valid for L-E fault.
** T1, T2, T3 only,
*** T2 only

Connection diagrams

Diagram A1

Configuration with two poles in series (without neutral connected to earth)
• Interruption for phase to neutral fault: 2 poles in series
• Interruption for phase to earth fault: not considered
(The installation method must be such as to make the probability of a second earth fault negligible)

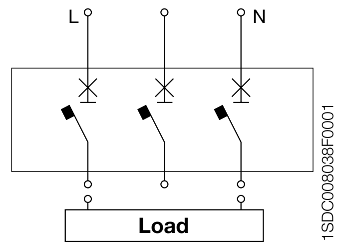
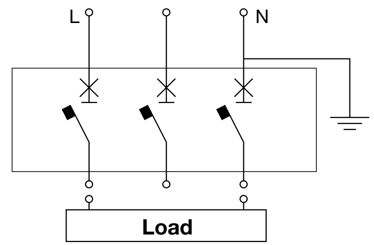


Diagram A2

Configuration with two poles in series (with neutral connected to earth)
• Interruption for phase to neutral fault: 2 poles in series
• Interruption for phase to earth fault: single pole (same capacity as two poles in series, but limited to 125V)



5 Special applications

Diagram B1

Configuration with three poles in series (without neutral connected to earth)
• Interruption for phase to neutral fault: 3 poles in series
• Interruption for phase to earth fault: not considered
(The installation method must be such as to make the probability of a second earth fault negligible)

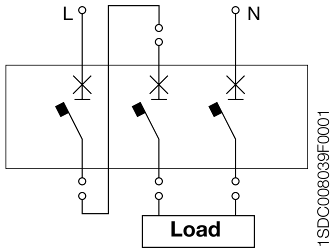


Diagram B2

Configuration with three poles in series (with neutral connected to earth and interrupted)
• Interruption for phase to neutral fault: 3 poles in series
• Interruption for phase to earth fault: 2 poles in series

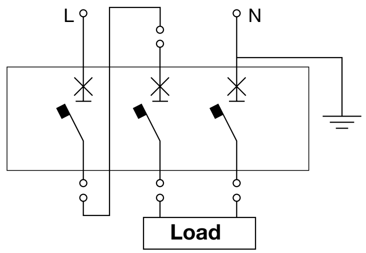
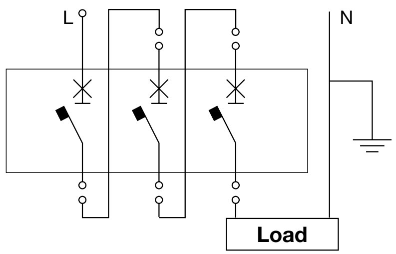


Diagram C

Configuration with three poles in series (with neutral connected to earth but not interrupted)
• Interruption for phase to neutral fault: 3 poles in series
• Interruption for phase to earth fault: 3 poles in series



5 Special applications

Diagram E-F

Configuration with four poles in series (without neutral connected to earth)
• Interruption for phase to neutral fault: 4 poles in series
• Interruption for phase to earth fault: not considered
(The installation method must be such as to make the probability of a second earth fault negligible)

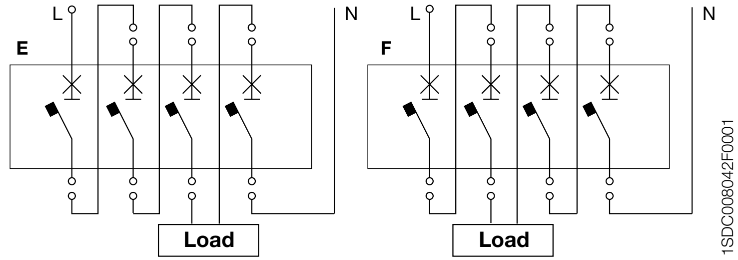


Diagram D

Configuration with four poles in series, on one polarity (with neutral connected to earth and not interrupted)
• Interruption for phase to neutral fault: 4 poles in series
• Interruption for phase to earth fault: 4 poles in series

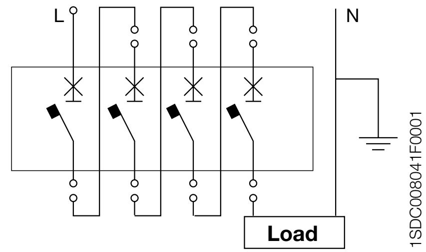
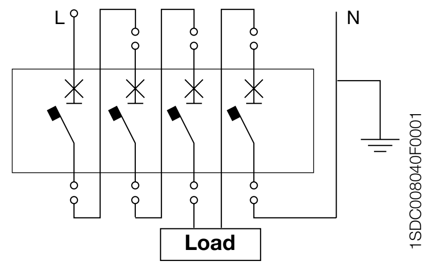


Diagram E1

Interruption with four poles in series (with neutral connected to earth and interrupted)
• Interruption for phase to neutral fault: 4 poles in series
• Interruption for phase to earth fault: 3 poles in series



5 Special applications

Example:

Network data:
Rated voltage 250 V
Rated frequency 16 2/3 Hz
Load current 120 A
Phase to neutral short-circuit current 45 kA
Neutral connected to earth

Assuming that the probability of a phase to earth fault is negligible, Table 3 shows that connections A2, B2 or B3 may be used.
Therefore it is possible to choose a Tmax T2S160 In125 circuit-breaker, which with the connection according to diagram A2 (two poles in series) has a breaking capacity of 50 kA, while according to diagrams B2 or B3 (three poles in series) the breaking capacity is 55 kA (Table 1). To determine the magnetic trip, see factor k_m in Table 2. The magnetic threshold will be:
$I_3 = 1250 \cdot 0.9 = 1125$ A
whichever diagram is used.
If it is possible to have an earth fault with non significant impedance, the diagrams to be considered (Table 3) are only B2 or B3. In particular, in diagram B2 it can be seen that only 2 poles are working in series, the breaking capacity will be 50 kA (Table 1), while with diagram B3, with 3 poles working in series, the breaking capacity is 55 kA.

5.3 1000 Vdc and 1000 Vac networks

The Tmax and Emax /E 1000 V and 1150 V circuit-breakers are particularly suitable for use in installations in mines, petrochemical plants and services connected to electrical traction (tunnel lighting).

5.3.1 1000 V dc networks

1000 Vdc Moulded case circuit-breakers

General characteristics

The range of Tmax moulded-case circuit-breakers for use in installations with rated voltage up to 1000 Vdc comply with international standard IEC 60947-2.
The range is fitted with adjustable thermo-magnetic releases and is suitable for all installation requirements and has a range of available settings from 32 A to 800 A. The four-pole version circuit-breakers allow high performance levels to be reached thanks to the series connection of the poles.
The circuit breakers in the Tmax 1000 V range maintain the same dimensions and fixing points as standard circuit breakers.
These circuit-breakers can also be fitted with the relevant range of standard accessories, with the exception of residual current releases for Tmax.
In particular it is possible to use conversion kits for removable and withdrawable moving parts and various terminal kits.

5 Special applications

1000 V dc Moulded-case circuit-breakers		**T4**	**T5**	**T6**
Rated uninterrupted current, **Iu**	[A]	**250**	**400/630**	**630/800**
Poles	Nr.	4	4	4
Rated operational voltage, **Ue**	[V –]	1000	1000	1000
Rated impulse withstand voltage, **Uimp**	[kV]	8	8	8
Rated insulation voltage, **Ui**	[V]	1000	1000	1000
Test voltage at industrial frequency for 1 min.	[V]	3500	3500	3500
Rated ultimate short-circuit breaking capacity, **Icu**		**V**	**V**	**L**
(4 poles in series)	[kA]	40	40	40
Rated services short-circuit breaking capacity, **Ics**				
(4 poles in series)	[kA]	20	20	
Rated short-time withstand current for 1 s, Icw	[kA]	–	5 (400A)	7.6 (630A) - 10 (800A)
Utilisation category (EN 60947-2)		A	B (400A)-A (630A)	B
Isolation behaviour		■	■	■
IEC 60947-2, EN 60947-2		■	■	■
Thermomagnetic releases	TMD	■	–	–
Thermomagnetic releases	TMA	■	up to 500 A	■
Versions		F	F	F
Terminals	Fixed	FC Cu	FC Cu	F - FC CuAl - R
Mechanical life [No. operations / operations per hours]		20000/240	20000/120	20000/120
Basic dimensions, fixed	L [mm]	140	184	280
	D [mm]	103.5	103.5	103.5
	H [mm]	205	205	268

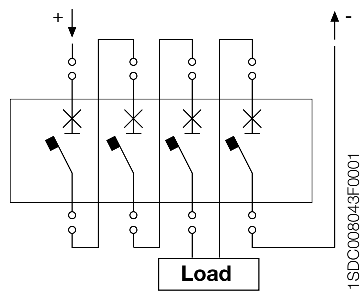
TERMINAL CAPTION
F = Front
EF = Front extended
ES = Front extended spread
FC Cu =Front for copper cables
FC CuAl = Front for CuAl cables
R = Rear orientated
HR = Rear in horizontal flat bar
VR = Rear in vertical flat bar
MC = Multicable

Connection diagrams

Possible connection diagrams with reference to the type of distribution system in which they can be used follow.

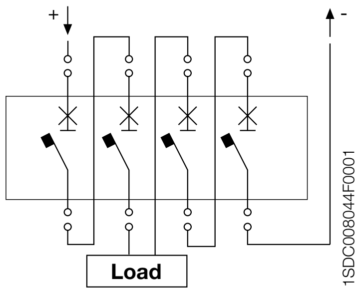
Networks insulated from earth

The following diagrams can be used (the polarity may be inverted).



A) 3+1 poles in series (1000 Vdc)

5 Special applications

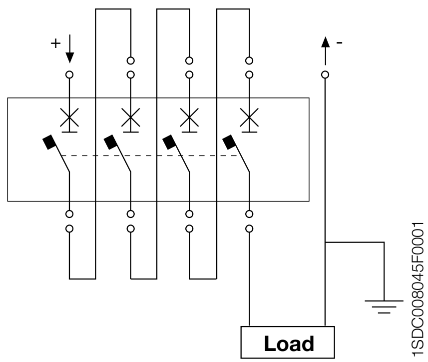


B) 2+2 poles in series (1000 Vdc)

It is assumed that the risk of a double earth fault in which the first fault is downstream of the breaker on one polarity and the second is upstream of the same switching device on the opposite polarity is null.
In this condition the fault current, which can reach high values, effects only some of the 4 poles necessary to ensure the breaking capacity.
It is possible to prevent the possibility of a double earth fault by installing a device which signals the loss of insulation and identifies the position of the first earth fault, allowing it to be eliminated quickly.

Networks with one polarity connected to earth

As the polarity connected to earth does not have to be interrupted (in the example it is assumed that the polarity connected to earth is negative, although the following is also valid with the polarity inverted), the diagram which shows the connection of 4 poles in series on the polarity not connected to earth may be used.

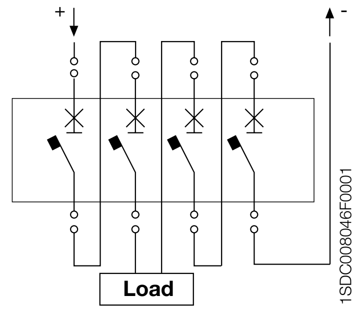


C) 4 poles in series (1000 Vdc)

5 Special applications

Networks with median point of the supply source connected to earth

In the presence of an earth fault of positive or negative polarity, the poles involved in the fault work at U/2 (500 V); the following diagram must be used:



D) 2+2 poles in series (1000 Vdc)

Correction factors for tripping thresholds

With regard to overload protection, no correction factors need to be applied. However, for the magnetic threshold values in use with 1000 Vdc with the previously described applicable diagrams, refer to the corresponding values for alternating current, multiplied by the correction factors given in the following table:

Circuit-breaker	k_m
T4V	1
T5V	0.9
T6L	0.9

Circuit-breakers with thermomagnetic release for direct current

In [A]	32 (1)	50 (1)	80 (2)	100 (2)	125 (2)	160 (2)	200 (2)	250 (2)	320 (2)	400 (2)	500 (2)	630 (2)	800 (2)
T4V 250	■	■	■	■	■	■	■	■	–	–	–	–	–
T5V 400	–	–	–	–	–	–	–	–	■	■	–	–	–
T5V 630	–	–	–	–	–	–	–	–	–	–	■	–	–
T6L 630	–	–	–	–	–	–	–	–	–	–	–	■	–
T6L 800	–	–	–	–	–	–	–	–	–	–	–	–	■
I3 = (10xI_n) [A]	320	500	–	–	–	–	–	–	–	–	–	–	–
I3 = (5 -10xI_n) [A]	–	–	400÷800	500÷1000	625÷1250	800÷1600	1000÷2000	1250÷2500	1600÷3200	2000÷4000	2500÷5000	3150÷6300	4000÷8000

(1) Thermal threshold adjustable from 0.7 and 1 x In; fixed magnetic threshold
(2) Thermal threshold adjustable from 0.7 and 1 x In; magnetic threshold adjustable between 5 and 10 x In.

5 Special applications

Example

To ensure the protection of a user supplied with a network having the following characteristics:
Rated voltage U_r = 1000 Vdc
Short-circuit current I_k = 18 kA
Load current I_b = 420 A
Network with both polarities insulated from earth.

From the table of available settings, the circuit-breaker to be used is:
T5V 630 I_n=500 four-pole I_{cu}@1000 Vdc = 40 kA
Thermal trip threshold adjustable from (0.7-1) x I_n therefore from 350 A to 500 A to be set at 0.84.
Magnetic trip threshold adjustable from (5-10) x I_n which with correction factor k_m = 0.9 gives the following adjustment range: 2250 A to 4500 A. The magnetic threshold will be adjusted according to any conductors to be protected.
The connection of the poles must be as described in diagrams A or B.
A device which signals any first earth fault must be present.
With the same system data, if the network is carried out with a polarity connected to earth, the circuit-breaker must be connected as described in diagram C.

5 Special applications

1000 Vdc air switch disconnectors

The air switch disconnectors derived from the Emax air breakers are identified by the standard range code together with the code "/E MS".
These comply with the international Standard IEC 60947-3 and are especially suitable for use as bus-ties or principle isolators in direct current installations, for example in electrical traction applications.
The overall dimensions and the fixing points remain unaltered from those of standard breakers, and they can be fitted with various terminal kits and all the accessories for the Emax range; they are available in both withdrawable and fixed versions, and in three-pole version (up to 750 Vdc) and four-pole (up to 1000 Vdc).
The withdrawable breakers are assembled with special version fixed parts for applications of 750/1000 Vdc.
The range covers all installation requirements up to 1000 Vdc / 6300 A or up to 750 Vdc / 6300 A.
A breaking capacity equal to the rated short-time withstand current is attributed to these breakers when they are associated with a suitable external relay.

The following table shows the available versions and their relative electrical performance:

			E1B/E MS		E2N/E MS		E3H/E MS		E4H/E MS		E6H/E MS	
Rated current (at 40 °C) Iu		[A]	**800**		**1250**		**1250**		**3200**		**5000**	
		[A]	**1250**		**1600**		**1600**		**4000**		**6300**	
		[A]			**2000**		**2000**					
		[A]					**2500**					
		[A]					**3200**					
Poles			3	4	3	4	3	4	3	4	3	4
Rated service voltage **Ue**		[V]	750	1000	750	1000	750	1000	750	1000	750	1000
Rated insulation voltage **Ui**		[V]	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Rated impulse withstand voltage **Uimp**		[kV]	12	12	12	12	12	12	12	12	12	12
Rated short-time withstand current **Icw** (1s)		[kA]	20	20 (1)	25	25(1)	40	40 (1)	65	65	65	65
Rated making capacity **Icm**	750V DC	[kA]	42	42	52.5	52.5	105	105	143	143	143	143
	1000V DC		-	42	-	52.5	-	105	-	143	-	143

Note: The breaking capacity Icu, by means of external protection relay, with 500 ms maximum timing, is equal to the value of Icw (1s).
(1) The performances at 750 V are:
for E1B/E MS Icw = 25 kA,
for E2N/E MS Icw = 40 kA and
for E3H/E MS Icw = 50 kA.

5 Special applications

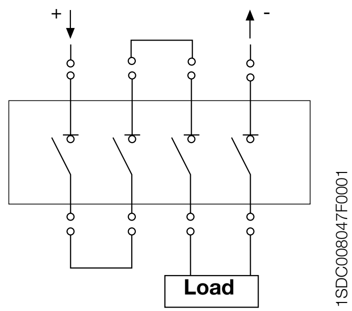
Connection diagrams

Connection diagrams to be used according to the type of distribution system follow.

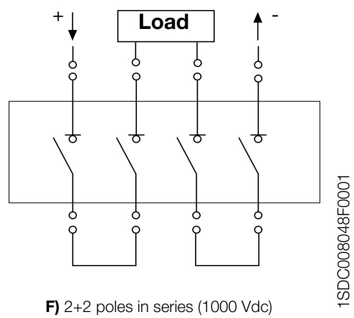
The risk of a double earth fault on different poles is assumed to be zero, that is, the fault current involves only one part of the breaker poles.

Networks insulated from earth

The following diagrams may be used (the polarity may be inverted).

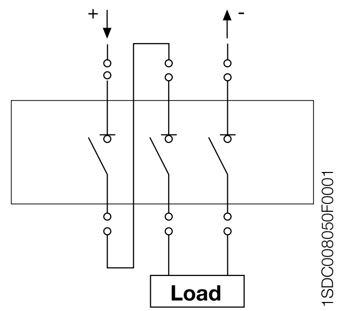


E) 3+1 poles in series (1000 Vdc)



F) 2+2 poles in series (1000 Vdc)

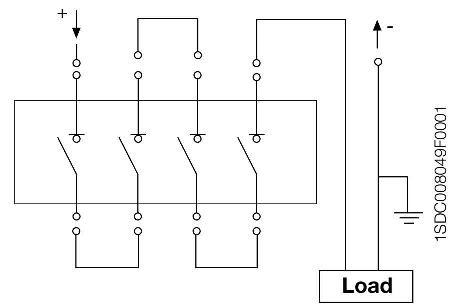
5 Special applications



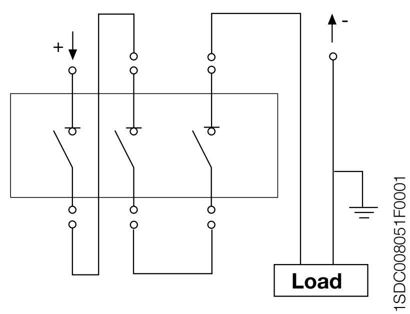
G) 2+1 poles in series (750 Vdc)

Networks with one polarity connected to earth

The polarity connected to earth does not have to be interrupted (in the examples it is assumed that the polarity connected to earth is negative):



H) 4 poles in series (1000 Vdc)



I) 3 poles in series (750 Vdc)

Networks with median point of the supply source connected to earth

Only four-pole breakers may be used as in the configuration shown in diagram F).

5 Special applications

5.3.2 1000 Vac networks

Moulded-case circuit-breakers up to 1150 Vac

General characteristics

The circuit-breakers in the Tmax range up to 1150 V comply with the international standard IEC 60947-2.
These circuit breakers can be fitted with thermo-magnetic releases (for the smaller sizes) and with electronic releases. All installation requirements can be met with a range of available settings from 32 A to 800 A and with breaking capacity up to 20 kA at 1150 Vac.

Moulded-case circuit-breakers up to 1150 Vac

			T4		T5		T6
Rated uninterrupted current, **Iu**		[A]	**250**		**400/630**		**630/800**
Poles		Nr.	3, 4		3, 4		3, 4
Rated service voltage, **Ue** (ac) 50-60Hz		[V]	1000	1150	1000	1150	1000
Rated impulse withstand voltage, **Uimp**		[kV]	8		8		8
Rated insulation voltage, **Ui**		[V]	1000	1150	1000	1150	1000
Test voltage at industrial frequency for 1 min.		[V]	3500		3500		3500
Rated ultimate short-circuit breaking capacity, **Icu**			**L**	**V**	**L**	**V** (1)	**L** (1)
	(ac) 50-60 Hz 1000 V	[kA]	12	20	12	20	12
	(ac) 50-60 Hz 1150 V	[kA]		12		12	
Rated service short-circuit breaking capacity, **Ics**							
	(ac) 50-60 Hz 1000 V	[kA]	12	12	10	10	6
	(ac) 50-60 Hz 1150 V	[kA]		6		6	
Rated short-circuit making capacity **Icm**							
	(ac) 50-60 Hz 1000 V	[kA]	24	40	24	40	24
	(ac) 50-60 Hz 1150 V	[kA]		24		24	
Utilisation category (EN 60947-2)			A		B (400 A) (2)/A (630 A)		B (3)
Isolation behaviour			■		■		■
Reference Standard			IEC 60947-2		IEC 60947-2		IEC 60947-2
Thermomagnetic releases		TMD	-	■	-	-	-
		TMA	-	■	-	■	■
Electronic releases		PR221DS/LS	■	■	■	■	■
		PR221DS/I	■	■	■	■	■
		PR222DS/P-LSI	■	■	■	■	■
		PR222DS/P-LSIG	■	■	■	■	■
		PR222DS/PD-LSI	■	■	■	■	■
		PR222DS/PD-LSIG	■	■	■	■	■
		PR222MP	■	-	■	-	-
Terminals			FC Cu		FC Cu		F-FC CuAl-R
Version			F, P, W	F	F, P, W (4)	F	F
Mechanical life		[No. operations]	20000		20000		20000
		[No. operations per hours]	240		120		120
Basic dimension-fixed version (5)		3 poles W [mm]	105		140		210
		4 poles W [mm]	140		184		280
		D [mm]	103.5		103.5		103.5
		H [mm]	205		205		268
Weigth	fixed	3/4 poles [kg]	2.35/3.05	2.35/3.05	3.25/4.15	3.25/4.15	9.5/12
	plug-in	3/4 poles [kg]	3.6/4.65		5.15/6.65		
	withdrawable	3/4 poles [kg]	3.85/4.9		5.4/6.9		

(1) Power supply only from above
(2) Icw=5kA
(3) Icw=7.6kA (630A) - 10kA (800A)
(4) Tmax T5630 is only available in the fixed version
(5) Circuit-breaker without high terminal covers

5 Special applications

The circuit-breakers in the range up to 1150 V maintain the same dimension as standard circuit breakers.
These circuit-breakers can also be fitted with the relevant range of standard accessories, with the exception of residual current releases.

The following tables show the electrical characteristics of the range:

TERMINAL CAPTION
F=Front
FC Cu= Front for copper cables
FC CuAl=Front for CuAl cables
R= Rear orientated

5 Special applications

The following tables show the available releases.

Circuit-breakers with electronic release for alternating currents

	In100	In250	In320	In400	In630	In800
T4 250	■	■	–	–	–	–
T5 400	–	–	■	■	–	–
T5 630	–	–	–	–	■	–
T6L 630	–	–	–	–	■	–
T6L 800	–	–	–	–	–	■
I_3 (1÷10x In) [A] (1)	100÷1000	250÷2500	320÷3200	400÷4000	630÷6300	800÷8000
I_3 (1.5÷12 x In) [A] (2)	150÷1200	375÷3000	480÷3840	600÷4800	945÷7560	1200÷9600

(1) PR221
(2) PR222

Circuit-breakers with thermomagnetic release for alternating currents

In [A]	32 (1)	50 (1)	80 (2)	100 (2)	125 (2)	160 (2)	200 (2)	250 (2)	320 (2)	400 (2)	500 (2)	630 (2)	800 (2)
T4V 250	■	■	■	■	■	■	■	■	–	–	–	–	–
T5V 400	–	–	–	–	–	–	–	–	■	■	–	–	–
T5V 630	–	–	–	–	–	–	–	–	–	–	■	–	–
T6L 630	–	–	–	–	–	–	–	–	–	–	–	■	–
T6L 800	–	–	–	–	–	–	–	–	–	–	–	–	■
$I_3 = (10xI_n)$ [A]	320	500	–	–	–	–	–	–	–	–	–	–	–
$I_3 = (5 - 10xI_n)$ [A]	–	–	400÷800	500÷1000	625÷1250	800÷1600	1000÷2000	1250÷2500	1600÷3200	2000÷4000	2500÷5000	31500÷6300	4000÷8000

(1) Thermal threshold adjustable from 0.7 and 1 x In; fixed magnetic threshold
(2) Thermal threshold adjustable from 0.7 and 1 x In; magnetic threshold adjustable between 5 and 10 x In.

Air circuit-breakers and switch disconnectors up to1150 Vac

For 1150 V alternating current applications, the following devices are available:

- **Circuit-breakers** in compliance with Standard IEC 60947-2
  The special version breakers up to 1150 Vac are identified by the standard range code together with the suffix "/E", and are derived from the correspondent Emax standard breakers and retain the same versions, accessories and overall dimensions.
  The Emax range of breakers is available in both withdrawable and fixed versions with three and four poles, and can be fitted with accessories and equipped with the full range of electronic releases and microprocessors (PR332/P-PR333/P-PR121-PR122-PR123).
- **Switch disconnectors** in compliance with Standard IEC 60947-3
  These breakers are identified by the code of the standard range, from which they are derived, together with the suffix "/E MS". Three-pole and four-pole versions are available in both withdrawable and fixed versions with the same dimensions, accessory characteristics and installation as the standard switch disconnectors.

5 Special applications

The following tables show the electrical characteristics of the devices:

Air circuit-breakers (up to 1150 Vac)

		XIB/E	E2B/E		E2N/E			E3H/E					E4H/E		E6H/E		
Rated uninterrupted current (at 40 °C) Iu	[A]	**630/800 1000/1250 1600**	**1600**	**2000**	**1250**	**1600**	**2000**	**1250**	**1600**	**2000**	**2500**	**3200**	**3200**	**4000**	**4000**	**5000**	**6300**
Rated service voltage **Ue**	[V~]	1000	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150
Rated insulation voltage **Ui**	[V~]	1000	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250
Rated ultimate breaking capacity under short-circuit **Icu**																	
1000 V	[kA]	20	20	20	30	30	30	50	50	50	50	50	65	65	65	65	65
1150 V	[kA]		20	20	30	30	30	30	30	30	30	30	65	65	65	65	65
Rated service breaking capacity under short-circuit **Ics**																	
1000 V	[kA]	20	20	20	30	30	30	50	50	50	50	50	65	65	65	65	65
1150 V	[kA]		20	20	30	30	30	30	30	30	30	30	65	65	65	65	65
Rated short-time withstand current **Icw** (1s)	[kA]	20	20	20	30	30	30	50(*)	50(*)	50(*)	50(*)	50(*)	65	65	65	65	65
Rated making capacity under short-circuit (peak value) **Icm**																	
1000 V	[kA]	40	40	40	63	63	63	105	105	105	105	105	143	143	143	143	143
1150 V	[kA]		40	40	63	63	63	63	63	63	63	63	143	143	143	143	143

(*) 30 kA @ 1150 V

Air switch disconnectors (up to 1150 Vac)

		XIB/E MS	E2B/E MS	E2N/E MS	E3H/E MS	E4H/E MS	E6H/E MS
Rated current (at 40 °C) Iu	[A]	**1000**	**1600**	**1250**	**1250**	**3200**	**4000**
	[A]	**1250**	**2000**	**1600**	**1600**	**4000**	**5000**
	[A]	**1600**		**2000**	**2000**		**6300**
	[A]				**2500**		
	[A]				**3200**		
Poles		3/4	3/4	3/4	3/4	3/4	3/4
Rated service voltage **Ue**	[V]	1000	1150	1150	1150	1150	1150
Rated insulation voltage **Ui**	[V]	1000	1250	1250	1250	1250	1250
Rated impulse withstand voltage **Uimp**	[kV]	12	12	12	12	12	12
Rated short-time withstand voltage **Icw** (1s)	[kA]	20	20	30	30(1)	63	65
Rated making capacity under short-circuit (peak value) **Icm**	[kA]	40	40	63	63(2)	143	143

Note: The breaking capacity Icu, by means of external protection relay, with 500 ms maximum timing, is equal to the value of Icw (1s).
(1) The performance at 1000V is 50 kA
(2) The performance at 1000V is 105 kA

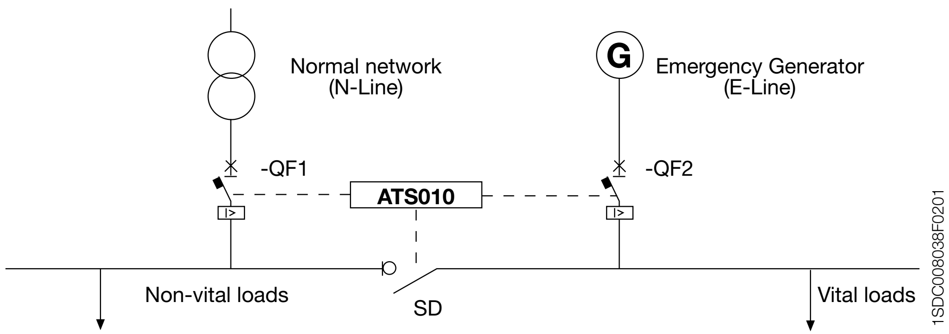
5 Special applications

5.4 Automatic Transfer Switches

In the electrical plants, where a high reliability is required from the power supply source because the operation cycle cannot be interrupted and the risk of a lack of power supply is unacceptable, an emergency line supply is indispensable to avoid the loss of large quantities of data, damages to working processes, plant stops etc.
For these reasons, transfer switch devices are used mainly for:
• power supply of hotels and airports;
• surgical rooms and primary services in hospitals;
• power supply of UPS groups;
• databanks, telecommunication systems, PC rooms;
• power supply of industrial lines for continuous processes.
ATS010 is the solution offered by ABB: it is an automatic transfer switch system with micro-processor based technology which allows switching of the supply from the normal line (N-Line) to the emergency line (E-Line) in case any of the following anomalies occurs on the main network:
• overvoltages and voltage dips;
• lack of one of the phases;
• asymmetries in the phase cycle;
• frequency values out of the setting range.
Then, when the network standard parameters are recovered, the system switches again the power supply to the main network (N-Line).

ATS010 is used in systems with two distinct supply lines connected to the same busbar system and functioning independently ("island condition"): the first one is used as normal supply line, the second is used for emergency power supply from a generator system. It is also possible to provide the system with a device to disconnect the non-priority loads when the network is supplied from the E-Line.

The following scheme shows a plant having a safety auxiliary power supply:



5 Special applications

ATS010 device is interfaced by means of appropriate terminals:
- with the protection circuit-breakers of the N-Line and of the E-Line, motorized and mechanically interlocked, to detect their status and send opening and closing commands according to the set time delays;
- with the control card of the Gen set to control its status and send start and stop commands;
- with any further signals coming from the plant in order to block the switching logic;
- with the N-Line to detect any possible anomaly and with the E-Line to verify the voltage presence;
- with an additional device to disconnect non-priority loads;
- with an auxiliary power supply at 24 Vdc ± 20% (or 48 Vdc ± 10%). This supply source shall be present also in case of lack of voltage on both lines (N-Line and E-Line).

6 Switchboards

6.1 Electrical switchboards

The switchboard is a combination of one or more low voltage switching, protection and other devices assembled in one or more enclosure so as to satisfy the requirements regarding safety and to allow the functions for which it was designed to be carried out.
A switchboard consists of a container, termed enclosure by the relevant Standards (which has the function of support and mechanical protection of the components contained within), and the electrical equipment, which consists of devices, internal connections and input and output terminals for connection with the system.

The reference Standard is IEC 60439-1 published in 2004, titled "Low-voltage switchgear and controlgear assemblies - Part 1: Type-tested and partially type-tested assemblies", approved by CENELEC code number EN 60439-1.

Supplementary calculation guides are:

IEC 60890 "A method of temperature-rise assessment by extrapolation for partially type-tested assemblies (PTTA) of low-voltage switchgear and controlgear".

IEC 61117 "A method for assessing the short-circuit withstand strength of partially type-tested assemblies (PTTA)".

IEC 60865-1 "Short-circuit currents - Calculation of effects - Part 1: Definitions and calculation methods".

Standard IEC 60439-1 sets out the requirements relating to the construction, safety and maintainability of electrical switchboards, and identifies the nominal characteristics, the operational environmental conditions, the mechanical and electrical requirements and the performance regulations.
The type-tests and individual tests are defined, as well as the method of their execution and the criteria necessary for the evaluation of the results.

Standard IEC 60439-1 distinguishes between the two types of switchboard: TTA (type-tested assemblies) and PTTA (partially type-tested assemblies).
By "type-tested assemblies" (TTA), it is meant a low voltage switchgear and controlgear assemblies conforming to an established type or system without deviations likely to significantly influence the performance from the typical assembly verified to be in accordance with the Standard prescriptions.
TTA switchboards are assemblies derived directly from a prototype designed in all details and subjected to type-tests; as the type-tests are very complex, switchboards designed by a manufacturer with a sound technical and financial basis are referred to. Nevertheless, TTA assemblies can be mounted by a panel builder or installer who follows the manufacturer's instructions; deviations from the prototype are only allowed if they do not significantly change the performance compared with the type-tested equipment.

6 Switchboards

By "partially type-tested assemblies" (PTTA), it is meant a low voltage and controlgear assembly, tested only with a part of the type-tests; some tests may be substituted by extrapolation which are calculations based on experimental results obtained from assemblies which have passed the type-tests. Verifications through simplified measurements or calculations, allowed as an alternative to type tests, concern heating, short circuit withstand and insulation.

Standard IEC 60439-1 states that some steps of assembly may take place outside the factory of the manufacturer, provided the assembly is performed in accordance with the manufacturer's instructions.
The installer may use commercial assembly kits to realize a suitable switchboard configuration.
The same Standard specifies a division of responsibility between the manufacturer and the assembler in Table 7: "List of verifications and tests to be performed on TTA and PTTA" in which the type-tests and individual tests to be carried out on the assembly are detailed.
The type-tests verify the compliance of the prototype with the requirements of the Standard, and are generally under the responsibility of the manufacturer, who must also supply instructions for the production and assembly of the switchboard. The assembler has responsibility for the selection and assembly of components in accordance with the instructions supplied and must confirm compliance with the Standards through the previously stated checks in the case of switchboards that deviate from a tested prototype. Routine tests must also be carried out on every example produced.

The distinction between TTA and PTTA switchgear and controlgear assemblies has no relevance to the declaration of conformity with Standard IEC 60439-1, in so far as the switchboard must comply with this Standard.

6 Switchboards

List of verifications and tests to be performed on TTA and PTTA

No.	Characteristics to be checked	Sub-clauses	TTA	PTTA
1	Temperature-rise limits	8.2.1	Verification of temperature-rise limits by test (type test)	Verification of temperature-rise limits by test or extrapolation
2	Dielectric properties	8.2.2	Verification of dielectric properties by test (type test)	Verification of dielectric properties by test according to 8.2.2 or 8.3.2, or verification of insulation resistance according to 8.3.4 (see No. 9 and 11)
3	Short-circuit withstand strength	8.2.3	Verification of the short-circuit withstand strength by test (type test)	Verification of the short-circuit withstand strength by test or by extrapolation from similar type-tested arrangements
4	Effectiveness of the protective circuit	8.2.4		
	Effective connection between the exposed conductive parts of the ASSEMBLY and the protective circuit	8.2.4.1	Verification of the effective connection between the exposed conductive parts of the ASSEMBLY and the protective circuit by inspection or by resistance measurement (type test)	Verification of the effective connection between the exposed conductive parts of the ASSEMBLY and the protective circuit by inspection or by resistance measurement
	Short-circuit withstand strength of the protective circuit	8.2.4.2	Verification of the short-circuit withstand strength of the protective circuit by test (type test)	Verification of the short-circuit withstand strength of the protective circuit by test or appropriate design and arrangement of the protective conductor (see 7.4.3.1.1, last paragraph)
5	Clearances and creepage distances	8.2.5	Verification of the clearances and creepage distances (type test)	Verification of clearances and creepage distances
6	Mechanical operation	8.2.6	Verification of mechanical operation (type test)	Verification of mechanical operation
7	Degree of protection	8.2.7	Verification of the degree of protection (type test)	Verification of the degree of protection
8	Wiring, electrical operation	8.3.1	Inspection of the ASSEMBLY including inspection of wiring and, if necessary, electrical operation test (routine test)	Inspection of the ASSEMBLY including inspection of wiring and, if necessary, electrical operation test
9	Insulation	8.3.2	Dielectric test (routine test)	Dielectric test or verification of insulation resistance according to 8.3.4 (see No. 2 and 11)
10	Protective measures	8.3.3	Checking of protective measures and of the electrical continuity of the protective circuits (routine test)	Checking of protective measures
11	Insulation resistance	8.3.4		Verification of insulation resistance unless test according to 8.2.2 or 8.3.2 has been made (see No. 2 and 9)

6 Switchboards

Degrees of protection

The degree of protection IP indicates a level of protection provided by the assembly against access to or contact with live parts, against ingress of solid foreign bodies and against the ingress of liquid. The IP code is the system used for the identification of the degree of protection, in compliance with the requirements of Standard IEC 60529. Unless otherwise specified by the manufacturer, the degree of protection applies to the complete switchboard, assembled and installed for normal use (with door closed).
The manufacturer shall also state the degree of protection applicable to particular configurations which may arise in service, such as the degree of protection with the door open or with devices removed or withdrawn.

Elements of the IP Code and their meanings

Element	Numerials or letters	Meaning for the protection of equipment	Meaning for the protection of persons	Ref.
Code letters	**IP**			
First characteristic numeral		Against ingress of the solid foreign objects	Against access to hazardous parts with	Cl.5
	0	(non-protected)	(non-protected)	
	1	≥ 50 mm diameter	back of hand	
	2	≥ 12.5 mm diameter	finger	
	3	≥ 2.5 mm diameter	tool	
	4	≥ 1.0 mm diameter	wire	
	5	dust-protected	wire	
	6	dust-tight	wire	
Second characteristic numeral		Against ingress of water with harmful effects		Cl.6
	0	(non-protected)		
	1	vertically dripping		
	2	dripping (15° tilted)		
	3	spraying		
	4	splashing		
	5	jetting		
	6	powerful jetting		
	7	temporary immersion		
	8	continuous immersion		
Additional letter (optional)			Against access to hazardous parts with	Cl.7
	A		back of hand	
	B		finger	
	C		tool	
	D		wire	
Supplementary letter (optional)		Supplemetary information specific to:		Cl.8
	H	Hight voltage apparatus		
	M	Motion during water test		
	S	Stationary during water test		
	W	Weather conditions		

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Form of separation and classification of switchboards

Forms of internal separation

By form of separation it is meant the type of subdivision provided within the switchboard. Separation by means of barriers or partitions (metallic or insulating) may have the function to:

- provide protection against direct contact (at least IPXXB) in the case of access to a part of the switchboard which is not live, with respect to the rest of the switchboard which remains live;
- reduce the risk of starting or propagating an internal arc;
- impede the passage of solid bodies between different parts of the switchboard (degree of protection of at least IP2X).

A partition is a separation element between two parts, while a barrier protects the operator from direct contact and from arcing effects from any interruption devices in the normal access direction.
The following table from Standard IEC 60439-1 highlights typical forms of separation which can be obtained using barriers or partitions:

Main criteria	Subcriteria	Form
No separation		Form 1
Separation of busbars from the functional units	Terminals for external conductors not separated from busbars	Form 2a
	Terminals for external conductors separated from busbars	Form 2b
Separation of busbars from the functional units and separation of all functional units from one another. Separation of the terminals for external conductors from the functional units, but not from each other	Terminals for external conductors not separated from busbars	Form 3a
	Terminals for external conductors separated from busbars	Form 3b
Separation of busbars from the functional units and separation of all functional units from one another, including the terminals for external conductors which are an integral part of the functional unit	Terminals for external conductors in the same compartment as the associated functional unit	Form 4a
	Terminals for external conductors not in the same compartment as the associated functional unit, but in individual, separate, enclosed protected spaces or compartments	Form 4b

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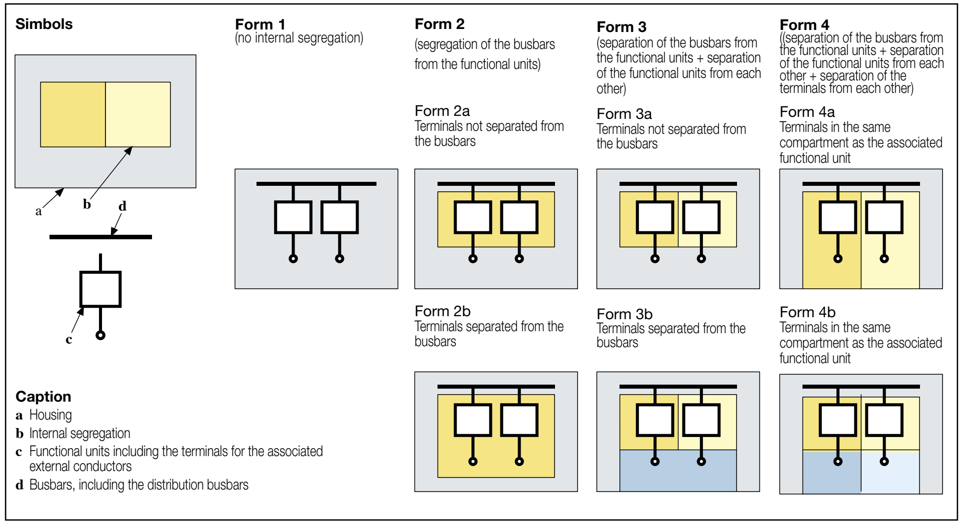

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Classification

Different classifications of electrical switchboard exist, depending on a range of factors.

Based on construction type, Standard IEC 60439-1 firstly distinguishes between open and enclosed assemblies.
A switchboard is enclosed when it comprises protective panels on all sides, providing a degree of protection against direct contact of at least IPXXB. Switchboards used in normal environments must be enclosed.

Open switchboards, with or without front covering, which have the live parts accessible. These switchboards may only be used in electrical plants.

With regard to external design, switchboards are divided into the following categories:

- **Cubicle-type assembly**
  Used for large scale control and distribution equipment; multi-cubicle-type assembly can be obtained by placing cubicles side by side.

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- Desk-type assembly
Used for the control of machinery or complex systems in the mechanical, iron and steel, and chemical industries.

- Box-type assembly
Characterized by wall mounting, either mounted on a wall or flush-fitting; these switchboards are generally used for distribution at department or zone level in industrial environments and in the tertiary sector.

- Multi-box-type assembly
Each box, generally protected and flanged, contains a functional unit which may be an automatic circuit-breaker, a starter, a socket complete with locking switch or circuit-breaker.

With regard to the intended function, switchboards may be divided into the following types:

- Main distribution boards
Main distribution boards are generally installed immediately downstream of MV/LV transformers, or of generators; they are also termed power centres. Main distribution boards comprise one or more incoming units, busbar connectors, and a relatively smaller number of output units.

- Secondary distribution boards
Secondary distribution boards include a wide range of switchboards for the distribution of power, and are equipped with a single input unit and numerous output units.

- Motor operation boards
Motor control boards are designed for the control and centralised protection of motors: therefore they comprise the relative coordinated devices for operation and protection, and auxiliary control and signalling devices.

- Control, measurement and protection boards
Control, measurement and protection boards generally consist of desks containing mainly equipment for the control, monitoring and measurement of industrial processes and systems.

- Machine-side boards
Machine-side boards are functionally similar to the above; their role is to provide an interface between the machine with the power supply and the operator.

- Assemblies for construction sites (ASC)
Assemblies for construction sites may be of different sizes, from a simple plug and socket assembly to true distribution boards with enclosures of metal or insulating material. They are generally mobile or, in any case, transportable.

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Method of temperature rise assessment by extrapolation for partially tested assemblies (PTTA)

For PTTA assemblies, the temperature rise can be determined by laboratory tests or calculations, which can be carried out in accordance with Standard IEC 60890. The formulae and coefficients given in this Standard are deduced from measurements taken from numerous switchboards, and the validity of the method has been checked by comparison with the test results.
This method does not cover the whole range of low voltage switchgear and controlgear assemblies since it has been developed under precise hypotheses which limit the applications; this can however be correct, suited and integrated with other calculation procedures which can be demonstrated to have a technical basis.
Standard IEC 60890 serves to determine the temperature rise of the air inside the switchboard caused by the energy dissipated by the devices and conductors installed within the switchboard.
To calculate the temperature rise of the air inside an enclosure, once the requirements of the Standard have been met, the following must be considered:

- Dimensions of the enclosure
- Type of installation:
  - enclosure open to air on all sides;
  - wall-mounted enclosure;
  - enclosure designed for mounting in extremities;
  - enclosure in an internal position in a multi-compartment switchboard;
- Any ventilation openings, and their dimensions
- Number of horizontal internal separators
- Power losses from the effective current flowing through any device and conductor installed within the switchboard or compartment.

The Standard allows the calculation of temperature rise of the air at mid-height and at the highest point of the switchboard. Once the values are calculated, it must be evaluated if the switchboard can comply with the requirements relating to the set limits at certain points within the same switchboard.
The Annex B explains the calculation method described in the Standard.
ABB supplies the client with calculation software which allows the temperature rise inside the switchboard to be calculated quickly.

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6.2 MNS switchboards

MNS systems are suitable for applications in all fields concerning the generation, distribution and use of electrical energy; e. g., they can be used as:
- main and sub-distribution boards;
- motor power supply of MCCs (Motor Control Centres);
- automation switchboards.

The MNS system is a framework construction with maintenance-free bolted connections which can be equipped as required with standardized components and can be adapted to any application. The consistent application of the modular principle both in electrical and mechanical design permits optional selection of the structural design, interior arrangement and degree of protection according to the operating and environmental conditions.

The design and material used for the MNS system largely prevent the occurrence of electric arcs, or provide for arc extinguishing within a short time. The MNS System complies with the requirements laid down in VDE0660 Part 500 as well as IEC 61641 and has furthermore been subjected to extensive accidental arc tests by an independent institute.

The MNS system offers the user many alternative solutions and notable advantages in comparison with conventional-type installations:
- compact, space-saving design;
- back-to-back arrangement;
- optimized energy distribution in the cubicles;
- easy project and detail engineering through standardized components;
- comprehensive range of standardized modules;
- various design levels depending on operating and environmental conditions;
- easy combination of the different equipment systems, such as fixed and withdrawable modules in a single cubicle;
- possibility of arc-proof design (standard design with fixed module design);
- possibility of earthquake-, vibration- and shock-proof design;
- easy assembly without special tools;
- easy conversion and retrofit;
- largely maintenance-free;
- high operational reliability;
- high safety for human beings.

The basic elements of the frame are C-sections with holes at 25 mm intervals in compliance with Standard DIN 43660. All frame parts are secured maintenance-free with tapping screws or ESLOK screws. Based on the basic grid size of 25 mm, frames can be constructed for the various cubicle types without any special tools. Single or multi-cubicle switchgear assemblies for front or front and rear operations are possible.
Different designs are available, depending on the enclosure required:
- single equipment compartment door;
- double equipment compartment door;
- equipment and cable compartment door;
- module doors and/or withdrawable module covers and cable compartment door.

The bottom side of the cubicle can be provided with floor plates. With the aid of flanged plates, cable ducts can be provided to suit all requirements. Doors and cladding can be provided with one or more ventilation opening, roof plates can be provided with metallic grid (IP 30 – IP40) or with ventilation chimney (IP 40, 41, 42).

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Depending on the requirements, a frame structure can be subdivided into the following compartments (functional areas):
- equipment compartment;
- busbar compartment;
- cable compartment.

The equipment compartment holds the equipment modules, the busbar compartment contains the busbars and distribution bars, the cable compartment houses the incoming and outgoing cables (optionally from above and from below) with the wiring required for connecting the modules as well as the supporting devices (cable mounting rails, cable connection parts, parallel connections, wiring ducts, etc.). The functional compartments of a cubicle as well as the cubicles themselves can be separated by partitions. Horizontal partitions with or without ventilation openings can also be inserted between the compartments.
All incoming/outgoing feeder and bus coupler cubicles include one switching device. These devices can be fixed-mounted switch disconnectors, fixed-mounted or withdrawable air or moulded-case circuit-breakers.
This type of cubicles is subdivided into equipment and busbar compartments; their size (H x W) is 2200 mm x 400 mm / 1200 mm x 600 mm, and the depth depends on the dimensions of the switchgear used.
Cubicles with air circuit-breakers up to 2000 A can be built in the reduced dimensioned version (W = 400 mm).
It is possible to interconnect cubicles to form optimal delivery units with a maximum width of 3000 mm.

6.3 ArTu distribution switchboards

The range of ABB SACE ArTu distribution switchboards provides a complete and integrated offer of switchboards and kit systems for constructing primary and secondary low voltage distribution switchboards.
With a single range of accessories and starting from simple assembly kits, the ArTu switchboards make it possible to assembly a wide range of configurations mounting modular, moulded-case and air circuit-breakers, with any internal separation up to Form 4.
ABB SACE offers a series of standardized kits, consisting of pre-drilled plates and panels for the installation of the whole range of circuit-breakers type System pro *M* compact, Tmax and Emax X1, E1, E2, E3, E4 without the need of additional drilling operations or adaptations.
Special consideration has been given to cabling requirements, providing special seats to fix the plastic cabling duct horizontally and vertically.
Standardization of the components is extended to internal separation of the switchboard: in ArTu switchboards, separation is easily carried out and it does not require either construction of “made-to-measure” switchboards or any additional sheet cutting, bending or drilling work.

ArTu switchboards are characterized by the following features:
- integrated range of modular metalwork structures up to 4000 A with common accessories;
- possibility of fulfilling all application requirements in terms of installation (wall-mounting, floor-mounting, monoblock and cabinet kits) and degree of protection (IP31, IP41, IP43, IP65);
- structure made of hot-galvanized sheet;

6 Switchboards

- maximum integration with modular devices and ABB SACE moulded-case and air circuit-breakers;
- minimum switchboard assembly times thanks to the simplicity of the kits, the standardization of the small assembly items, the self-supporting elements and the presence of clear reference points for assembly of the plates and panels;
- separations in kits up to Form 4.

The range of ArTu switchboards includes four versions, which can be equipped with the same accessories.

ArTu L series

ArTu L series consists of a range of modular switchboard kits, with a capacity of 24/36 modules per row and degree of protection IP31 (without door) or IP43 (basic version with door). These switchboards can be wall- or floor-mounted:
- wall-mounted ArTu L series, with heights of 600, 800, 1000 and 1200 mm, depth 204 mm, width 690 mm. Both System pro M modular devices and moulded-case circuit-breakers Tmax T1-T2-T3 are housed inside this switchboard series;
- floor-mounted ArTu L series, with heights of 1400, 1600, 1800 and 2000 mm, depth 240 mm, width 690/890 mm. System pro M modular devices, moulded- case circuit-breakers type Tmax T1-T2-T3-T4-T5-T6 (fixed version with front terminals) are housed inside this switchboard series.

ArTu M series

ArTu M series consists of a modular range of monoblock switchboards for wall-mounted (with depths of 150 and 200 mm with IP65 degree of protection) or floor-mounted (with depth of 250 mm and IP31 or IP65 degrees of protection) installations, in which it is possible to mount System pro M modular devices and Tmax T1-T2-T3 moulded-case circuit-breakers on a DIN rail ArTu M series of floor-mounted switchboards can be equipped with Tmax series.

ArTu K series

ArTu K series consists of a range of modular switchboard kits for floor-mounted installation with four different depths (150, 225, 300, 500, 700 and 800 mm) and with degree of protection IP31 (without front door), IP41 (with front door and ventilated side panels) or IP65 (with front door and blind side panels), in which it is possible to mount System pro M modular devices, the whole range of moulded-case circuit–breakers Tmax, and Emax circuit-breakers X1, E1, E2, E3 and E4.
ArTu switchboards have three functional widths:
- 400 mm, for the installation of moulded-case circuit-breakers up to 630 A (T5);
- 600 mm, which is the basic dimension for the installation of all the apparatus;
- 800 mm, for the creation of the side cable container within the structure of the floor-mounted switchboard or for the use of panels with the same width.

The available internal space varies in height from 600 mm (wall-mounted L series) to 2000 mm (floor-mounted M series and K series), thus offering a possible solution for the most varied application requirements.

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ArTu PB Series (Panelboard and Pan Assembly)

The ArTu line is now upgraded with the new ArTu PB Panelboard solution.
The ArTu PB Panelboard is suitable for distribution applications with an incomer up to 800A and outgoing feeders up to 250A.
The ArTu PB Panelboard is extremely sturdy thanks to its new designed framework and it is available both in the wall-mounted version as well as in the floor-mounted one.
ArTu PB Panelboard customisation is extremely flexible due to the smart design based on configurations of 6, 12 and 18 outgoing ways and to the new ABB plug-in system that allows easy and fast connections for all T1 and T3 versions.
Upon request, extension boxes are available on all sides of the structure, for metering purposes too.
The vertical trunking system is running behind the MCCB's layer allowing easy access to every accessory wiring (SR's, UV's, AUX contacts).
The ArTu PB Panelboard, supplied as a standard with a blind door, is available with a glazed one as well.

Annex A: Protection against short-circuit effects inside low-voltage switchboards

The Std. IEC 60439-1 specifies that ASSEMBLIES (referred to hereafter as switchboards) shall be constructed so as to be capable of withstanding the thermal and dynamic stresses resulting from short-circuit currents up to the rated values.
Furthermore, switchboards shall be protected against short-circuit currents by means of circuit-breakers, fuses or a combination of both, which may either be incorporated in the switchboard or arranged upstream.
When ordering a switchboard, the user shall specify the short-circuit conditions at the point of installation.

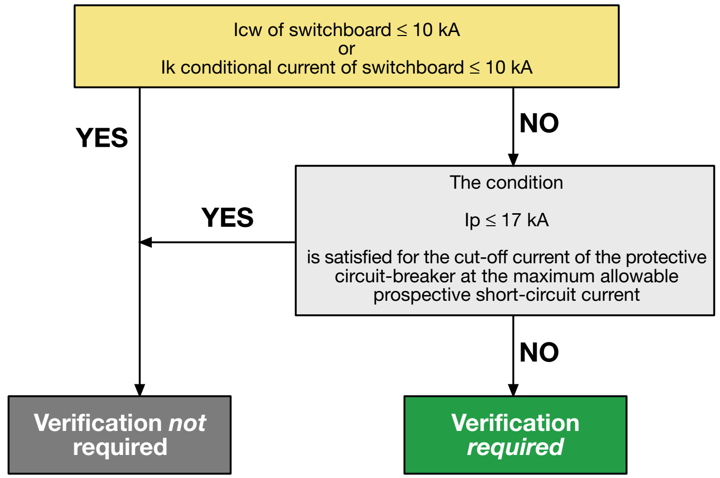
This chapter takes into consideration the following aspects:
- **The need, or not, to carry out a verification of the short-circuit withstand strength of the switchboard.**
- **The suitability of a switchboard for a plant as a function of the prospective short-circuit current of the plant and of the short-circuit parameters of the switchboard.**
- **The suitability of a busbar system as a function of the short-circuit current and of the protective devices.**

Annex A: Protection against short-circuit effects inside low-voltage switchboards

Verification of short-circuit withstand strength

The verification of the short-circuit withstand strength is dealt with in the Standard IEC 60439-1, where, in particular, the cases requiring this verification and the different types of verification are specified.
The verification of the short-circuit withstand strength is not required if the following conditions are fulfilled:
- For switchboards having a rated short-time current (Icw) or rated conditional current (Ik) not exceeding 10 kA.
- For switchboards protected by current limiting devices having a cut-off current not exceeding 17 kA at the maximum allowable prospective short-circuit current at the terminals of the incoming circuit of the switchboard.
- For auxiliary circuits of switchboards intended to be connected to transformers whose rated power does not exceed 10 kVA for a rated secondary voltage of not less than 110 V, or 1.6 kVA for a rated secondary voltage less than 110 V, and whose short-circuit impedance is not less than 4%.
- For all the parts of switchboards (busbars, busbar supports, connections to busbars, incoming and outgoing units, switching and protective devices, etc.) which have already been subjected to type tests valid for conditions in the switchboard.

Therefore, from an engineering point of view, the need to verify the short-circuit withstand strength may be viewed as follows:



As regards the details of the test performance, reference shall be made directly to the Standard IEC 60439-1.

Annex A: Protection against short-circuit effects inside low-voltage switchboards

Short-circuit current and suitability of the switchboard for the plant

The verification of the short-circuit withstand strength is based on two values stated by the manufacturer in alternative to each other:
- the rated short-time current Icw
- the rated conditional short-circuit current Ik

Based on one of these two values, it is possible to determine whether the switchboard is suitable to be installed in a particular point of the system.

It shall be necessary to verify that the breaking capacities of the apparatus inside the switchboard are compatible with the short-circuit values of the system.

The rated short-time withstand current Icw is a predefined r.m.s. value of test current, to which a determined peak value applied to the test circuit of the switchboard for a specified time (usually 1s) corresponds. The switchboard shall be able to withstand the thermal and electro-dynamical stresses without damages or deformations which could compromise the operation of the system. From this test (if passed) it is possible to obtain the specific let-through energy (I^2t) which can be carried by the switchboard:

$$I^2t = Icw^2t$$

The test shall be carried out at a power factor value specified below in the Table 4 of the Std. IEC 60439-1. A factor "n" corresponding at this cosφ value allows to determine the peak value of the short-circuit current withstood by the switchboard through the following formula:

$$Ip = Icw \cdot n$$

Table 4

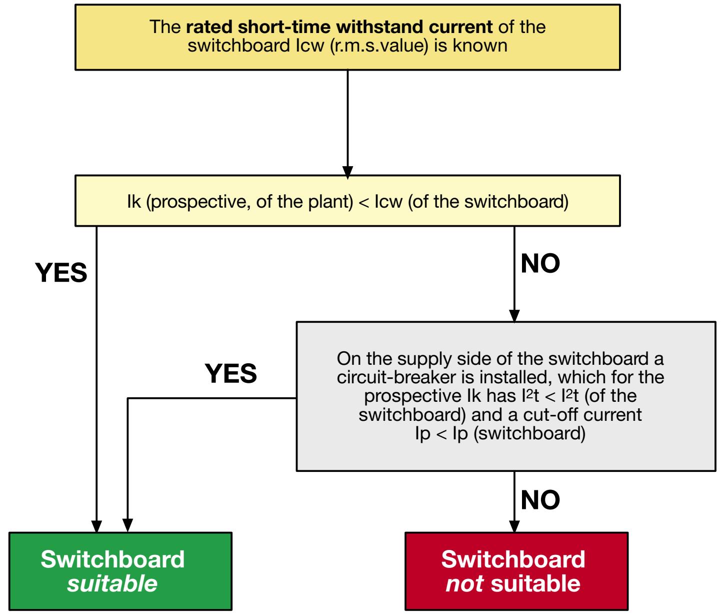
r.m.s. value of short-circuit current	power factor cosφ	n
I ≤ 5 kA	0.7	1.5
5<I ≤ 10 kA	0.5	1.7
10<I ≤ 20 kA	0.3	2
20<I ≤ 50 kA	0.25	2.1
50<I	0.2	2.2

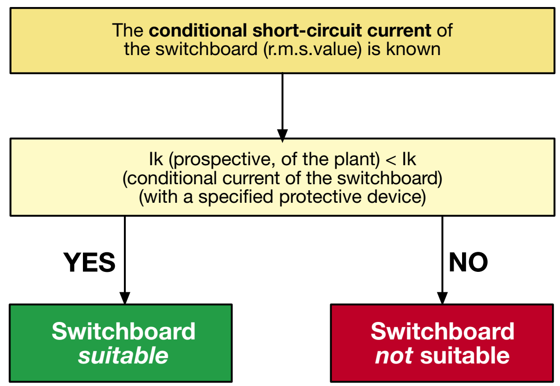
The values of this table represent the majority of applications. In special locations, for example in the vicinity of transformers or generators, lower values of power factor may be found, whereby the maximum prospective peak current may become the limiting value instead of the r.m.s. value of the short-circuit current.

The conditional short-circuit current is a predetermined r.m.s. value of test current to which a defined peak value corresponds and which can be withstand by the switchboard during the operating time of a specified protective device. This devices is usually the main circuit-breaker of the switchboard.

By comparing the two values Icw and Ip with the prospective short-circuit current of the plant, it is possible to establish whether the switchboard is suitable to be installed at a specified point of the system.
The following diagrams show the method to determine the compatibility of the switchboard with the plant.

Annex A: Protection against short-circuit effects inside low-voltage switchboards





The breaking capacities of the apparatus inside the switchboard shall be verified to be compatible with the short-circuit values of the plant.

Annex A: Protection against short-circuit effects inside low-voltage switchboards

Example

Plant data: Rated voltage Ur=400 V
Rated frequency fr=50Hz
Short-circuit current Ik=35kA

Assume that in an existing system there is a switchboard with Icw equal to 35kA and that, at the installation point of the switchboard, the prospective short-circuit current is equal to 35kA.

Now assume that an increase in the power supply of a plant is decided and that the short-circuit value rises to 60 kA.
Plant data after the increase: Rated voltage Ur=400 V
Rated frequency fr=50Hz
Short-circuit current Ik=60kA

Since the Icw of the switchboard is lower than the short-circuit current of the system, in order to verify that the actual switchboard is still compatible, it is necessary to:
- determine the I^2t and Ip values let-through by the circuit-breaker on the supply side of the switchboard
- verify that the protective devices installed inside the switchboard have a sufficient breaking capacity (separately or in back-up)

Icw = 35kA from which:
$I^2t_{switchboard} = 35^2 x1 = 1225\ MA^2s$
$Ip_{switchboard} = 73.5$ kA (according to Table 4)

Assuming that on the supply side of the switchboard a circuit-breaker type Tmax T5H **(Icu=70kA@415V)** is installed
$I^2t_{CB} < 4MA^2s$
$Ip_{CB} < 40kA$

since
$I^2t_{switchboard} > I^2t_{CB}$
$Ip_{switchboard} > Ip_{CB}$

it results that the switchboard (structure and busbar system) is suitable.

Assume that the circuit-breakers installed inside the switchboard are circuit-breakers type T1, T2 and T3 version N with **Icu=36kA@415V**. From the back-up tables (see Chapter 4.3), it results that the circuit-breakers inside the switchboard are suitable for the plant, since their breaking capacity is increased to 65 kA thanks to the circuit-breaker type T5H on the supply side.

Annex A: Protection against short-circuit effects inside low-voltage switchboards

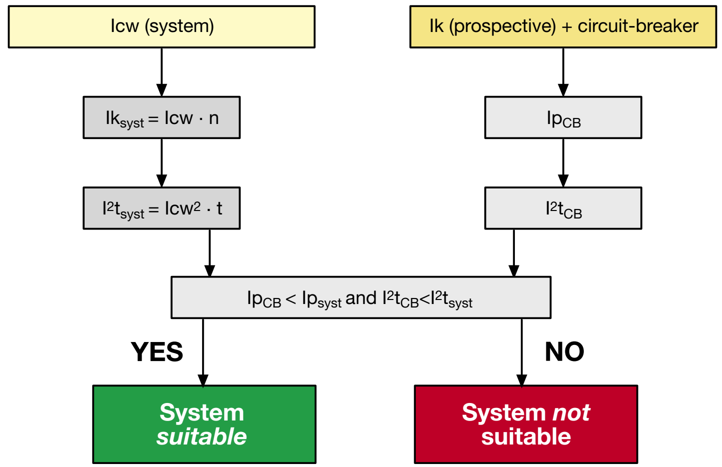
Selection of the distribution system in relation to short-circuit withstand strength

The dimensioning of the distribution system of the switchboard is obtained by taking into consideration the rated current flowing through it and the prospective short-circuit current of the plant.
The manufacturer usually provides tables which allow the choice of the busbar cross-section as a function of the rated current and give the mounting distances of the busbar supports to ensure the short-circuit withstand strength.

To select a distribution system compatible with the short-circuit data of the plant, one of these procedures shall be followed:

- **If the protective device on the supply side of the distribution system is known**
  From the Icw value of the distribution system it results:
  $Ik_{syst} = Icw \cdot n$ where n is the factor deduced from the Table 4
  $I^2t_{syst} = Icw^2 \cdot t$ where t is equal to 1 s

  In correspondence with the prospective short-circuit current value of the plant the following values can be determined:
  the cut-off current of the circuit-breaker Ip_{CB}
  the specific let-through energy of the circuit-breaker I^2t_{CB}
  If $Ip_{CB} < Ip_{syst}$ and $I^2t_{CB} < I^2t_{syst}$, then the distribution system is suitable.



- **If the protective device on the supply side of the distribution system is not known**

  The following condition must be fulfilled:

  Ik (prospective) < Icw (system)

Annex A: Protection against short-circuit effects inside low-voltage switchboards

Example

Plant data: Rated voltage Ur=400 V
Rated frequency fr=50Hz
Short-circuit current Ik=65kA

By considering the need of using a system of 400 A busbars with shaped form, in the ABB SACE catalogue "ArTu distribution switchboards" the following choice is possible:
BA0400 In=400 A (IP65) Icw=35kA.

By assuming to have on the supply side of the busbar system a moulded-case circuit-breaker type

ABB SACE Tmax T5400 In400

from the Icw of the busbar system, it derives:

$Ip_{syst} = Icw \cdot n = 35 \cdot 2.1 = 73.5$ [kA]
$I^2t_{syst} = Icw^2 \cdot t = 35^2 \cdot 1 = 1225$ $[(kA)^2 s]$

From the curves
- Ik 65kA corresponds at about Ip_{CB}=35 kA
- Ik 65kA corresponds at about $I^2t_{CB}=4\ [(kA)^2s]= 4\ [MA^2sec]$

Thus, since
$Ip_{CB} < Ip_{syst}$
and
$I^2t_{CB} < I^2t_{syst}$
it results that the busbar system is compatible with the switchboard.

Annex A: Protection against short-circuit effects inside low-voltage switchboards

Selection of conductors on the supply side of the protective devices

The Standard IEC 60439-1 prescribes that in a switchboard, the active conductors (distribution busbars included) positioned between the main busbars and the supply side of the single functional units, as well as the constructional components of these units, can be dimensioned according to the reduced short-circuit stresses which occur on the load side of the short-circuit protective device of the unit.

This may be possible if the conductors are installed in such a way throughout the switchboard that, under normal operating conditions, an internal short-circuit between phases and/or between phase and earth is only a remote possibility. It is advisable that such conductors are of solid rigid manufacture.
As an example, this Standard gives conductor types and installation requirements which allow to consider a short-circuit between phases and/or between phase and earth only a remote possibility.

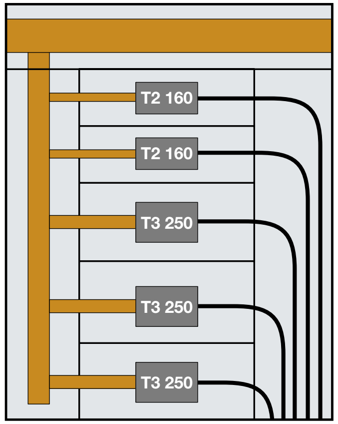
Type of conductor	Requirements
Bare conductors or single-core conductors with basic insulation, for example cables according to IEC 60227-3.	Mutual contact or contact with conductive parts shall be avoided, for example by use of spacers.
Single-core conductors with basic insulation and a maximum permissible conductor-operating temperature above 90°C, for example cables according to IEC 60245-3, or heat-resistant PVC insulated cables according to IEC 60227-3.	Mutual contact or contact with conductive parts is permitted where there is no applied external pressure. Contact with sharp edges must be avoided. There must be no risk of mechanical damage. These conductors may only be loaded such that an operating temperature of 70°C is not exceeded.
Conductors with basic insulation, for example cables according to IEC 60227-3, having additional secondary insulation, for example individually covered cables with shrink sleeving or individually run cables in plastic conduits.	No additional requirements if there is no risk of mechanical damage.
Conductors insulated with a very high mechanical strength material, for example FTFE insulation, or double-insulated conductors with an enhanced outer sheath rated for use up to 3 kV, for example cables according to IEC 60502.	
Single or multi-core sheathed cables, for example cables according to IEC 60245-4 or 60227-4.	

Under these conditions or if anyway the integral short-circuit may be considered a remote possibility, the above described procedure shall be used to verify the suitability of the distribution system to the short-circuit conditions, when these are determined as a function of the characteristics of the circuit-breakers on the load side of the busbars.

Annex A: Protection against short-circuit effects inside low-voltage switchboards

Example

Plant data:
Rated voltage Ur=400 V
Rated frequency fr=50Hz
Short-circuit current Ik=45kA



In the switchboard shown in the figure, the vertical distribution busbars are derived from the main busbars.
These are 800 A busbars with shaped section and with the following characteristics:
In (IP65) = 800 A,
Icw max = 35 kA
Since it is a "rigid" system with spacers, according to the Std. IEC 60439-1 a short-circuit between busbars is a remote possibility.
Anyway, a verification that the stresses reduced by the circuit-breakers on the load side of the system are compatible with the system is required.
Assuming that in the cubicles there are the following circuit-breakers:

ABB SACE T3S250
ABB SACE T2S160

it is necessary to verify that, in the case of a short-circuit on any outgoing conductor, the limitations created by the circuit-breaker are compatible with the busbar system; to comply with this requirement, at the maximum allowable prospective short-circuit current, the circuit-breaker with higher cut-off current and let-through energy must have an adequate current limiting capability for the busbar system.

In this case the circuit-breaker is type ABB SACE T3S250 In250.
The verification shall be carried out as in the previous paragraph:

From the Icw of the busbar system, it derives:

$Ip_{syst} = Icw \cdot n = 35 \cdot 2.1 = 73.5$ [kA]
$I^2t_{syst} = Icw^2 \cdot t = 35^2 \cdot 1 = 1225$ $[(kA)^2 s]$

From the limitation and let-through energy curves
- Ik = 45kA corresponds at about Ip_{CB}=30 kA
- Ik = 45kA corresponds at about I^2t_{CB}=2 $[(kA)^2s]$

Thus, since
$Ip_{CB} < Ip_{syst}$
and
$I^2t_{CB} < I^2t_{syst}$

it results that the busbar system is compatible with the switchboard.

Annex B: Temperature rise evaluation according to IEC 60890

The calculation method suggested in the Standard IEC 60890 makes it possible to evaluate the temperature rise inside an assembly (PTTA); this method is applicable only if the following conditions are met:
- there is an approximately even distribution of power losses inside the enclosure;
- the installed equipment is arranged in a way that air circulation is only slightly impeded;
- the equipment installed is designed for direct current or alternating current up to and including 60 Hz with the total of supply currents not exceeding 3150 A;
- conductors carrying high currents and structural parts are arranged in a way that eddy-current losses are negligible;
- for enclosures with ventilating openings, the cross-section of the air outlet openings is at least 1.1 times the cross-section of the air inlet openings;
- there are no more than three horizontal partitions in the PTTA or a section of it;
- where enclosures with external ventilation openings have compartments, the surface of the ventilation openings in each horizontal partition shall be at least 50% of the horizontal cross section of the compartment.

The data necessary for the calculation are:
- dimensions of the enclosure: height, width, depth;
- the type of installation of the enclosure (see Table 8);
- presence of ventilation openings;
- number of internal horizontal partitions;
- the power loss of the equipment installed in the enclosure (see Tables 13 and 14);
- the power loss of the conductors inside the enclosure, equal to the sum of the power loss of every conductor, according to Tables 1, 2 and 3.

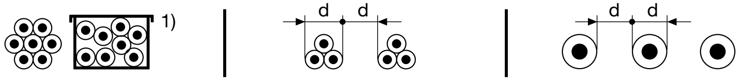
For equipment and conductors not fully loaded, it is possible to evaluate the power loss as:

$$P = P_n \left(\frac{I_b}{I_n}\right)^2 \quad (1)$$

where:
P is the actual power loss;
P_n is the rated power loss (at I_r);
I_b is the actual current;
I_n is the rated current.

Annex B: Temperature rise evaluation according to IEC 60890

Table 1: Operating current and power losses of insulated conductors



Cross-section (Cu)	Maximum permissible conductor temperature 70 °C – Air temperature inside the enclosure around the conductors											
	35 °C		55 °C		35 °C		55 °C		35 °C		55 °C	
	operating current	power losses 2)	operating current	power losses 2)	operating current	power losses 2)	operating current	power losses 2)	operating current	power losses 2)	operating current	power losses 2)
mm²	A	W/m	A	W/m	A	W/m	A	W/m	A	W/m	A	W/m
1.5	12	2.1	8	0.9	12	2.1	8	0.9	12	2.1	8	0.9
2.5	17	2.5	11	1.1	20	3.5	12	1.3	20	3.5	12	1.3
4	22	2.6	14	1.1	25	3.4	18	1.8	25	3.4	20	2.2
6	28	2.8	18	1.2	32	3.7	23	1.9	32	3.7	25	2.3
10	38	3.0	25	1.3	48	4.8	31	2.0	50	5.2	32	2.1
16	52	3.7	34	1.6	64	5.6	42	2.4	65	5.8	50	3.4
25					85	6.3	55	2.6	85	6.3	65	3.7
35					104	7.5	67	3.1	115	7.9	85	5.0
50					130	7.9	85	3.4	150	10.5	115	6.2
70					161	8.4	105	3.6	175	9.9	149	7.2
95					192	8.7	125	3.7	225	11.9	175	7.2
120					226	9.6	147	4.1	250	11.7	210	8.3
150					275	11.7	167	4.3	275	11.7	239	8.8
185					295	10.9	191	4.6	350	15.4	273	9.4
240					347	12.0	225	5.0	400	15.9	322	10.3
300					400	13.2	260	5.6	460	17.5	371	11.4

Conductors for auxiliary circuits

					Diam.
0.12	2.6	1.2	1.7	0.5	0.4
0.14	2.9	1.3	1.9	0.6	-
0.20	3.2	1.1	2.1	0.5	-
0.22	3.6	1.3	2.3	0.5	0.5
0.30	4.4	1.4	2.9	0.6	0.6
0.34	4.7	1.4	3.1	0.6	0.6
0.50	6.4	1.8	4.2	0.8	0.8
0.56		1.6		0.7	-
0.75	8.2	1.9	5.4	0.8	1.0
1.00	9.3	1.8	6.1	0.8	-

1) Any arrangement desired with the values specified referring to six cores in a multi-core bundle with a simultaneous load 100%

2) single length

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Annex B: Temperature rise evaluation according to IEC 60890

Table 2: Operating current and power losses of bare conductors, in vertical arrangement without direct connections to apparatus

Width x Thickness	Cross-section (Cu)	Maximum permissible conductor temperature 85 °C															
		Air temperature inside the enclosure around the conductors 35 °C								Air temperature inside the enclosure around the conductors 55 °C							
		50 Hz to 60 Hz ac				dc and ac to 16 2/3 Hz				50 Hz to 60 Hz ac				dc and ac to 16 2/3 Hz			
		operating current	power losses 1)	operating current	power losses 1)	operating current	power losses 1)	operating current	power losses 1)	operating current	power losses 1)	operating current	power losses 1)	operating current	power losses 1)	operating current	power losses 1)
mm x mm	mm²	A*	W/m	A**	W/m	A*	W/m	A**	W/m	A*	W/m	A**	W/m	A*	W/m	A**	W/m
12 x 2	23.5	144	19.5	242	27.5	144	19.5	242	27.5	105	10.4	177	14.7	105	10.4	177	14.7
15 x 2	29.5	170	21.7	282	29.9	170	21.7	282	29.9	124	11.6	206	16.0	124	11.6	206	16.0
15 x 3	44.5	215	23.1	375	35.2	215	23.1	375	35.2	157	12.3	274	18.8	157	12.3	274	18.8
20 x 2	39.5	215	26.1	351	34.8	215	26.1	354	35.4	157	13.9	256	18.5	157	12.3	258	18.8
20 x 3	59.5	271	27.6	463	40.2	271	27.6	463	40.2	198	14.7	338	21.4	198	14.7	338	21.4
20 x 5	99.1	364	29.9	665	49.8	364	29.9	668	50.3	266	16.0	485	26.5	266	16.0	487	26.7
20 x 10	199	568	36.9	1097	69.2	569	36.7	1107	69.6	414	19.6	800	36.8	415	19.5	807	37.0
25 x 5	124	435	34.1	779	55.4	435	34.1	78	55.6	317	18.1	568	29.5	317	18.1	572	29.5
30 x 5	149	504	38.4	894	60.6	505	38.2	899	60.7	368	20.5	652	32.3	369	20.4	656	32.3
30 x 10	299	762	44.4	1410	77.9	770	44.8	1436	77.8	556	27.7	1028	41.4	562	23.9	1048	41.5
40 x 5	199	641	47.0	1112	72.5	644	47.0	1128	72.3	468	25.0	811	38.5	469	24.9	586	38.5
40 x 10	399	951	52.7	1716	88.9	968	52.6	1796	90.5	694	28.1	1251	47.3	706	28.0	1310	48.1
50 x 5	249	775	55.7	1322	82.9	782	55.4	1357	83.4	566	29.7	964	44.1	570	29.4	989	44.3
50 x 10	499	1133	60.9	2008	102.9	1164	61.4	2141	103.8	826	32.3	1465	54.8	849	32.7	1562	55.3
60 x 5	299	915	64.1	1530	94.2	926	64.7	1583	94.6	667	34.1	1116	50.1	675	34.4	1154	50.3
60 x 10	599	1310	68.5	2288	116.2	1357	69.5	2487	117.8	955	36.4	1668	62.0	989	36.9	1814	62.7
80 x 5	399	1170	80.7	1929	116.4	1200	80.8	2035	116.1	858	42.9	1407	61.9	875	42.9	1484	61.8
80 x 10	799	1649	85.0	2806	138.7	1742	85.1	3165	140.4	1203	45.3	2047	73.8	1271	45.3	1756	74.8
100 x 5	499	1436	100.1	2301	137.0	1476	98.7	2407	121.2	1048	53.3	1678	72.9	1077	52.5	1756	69.8
100 x 10	999	1982	101.7	3298	164.2	2128	102.6	3844	169.9	1445	54.0	2406	84.4	1552	54.6	2803	90.4
120 x 10	1200	2314	115.5	3804	187.3	2514	115.9	4509	189.9	1688	61.5	2774	99.6	1833	61.6	3288	101.0

*) one conductor per phase **) two conductors per phase 1) single length

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Annex B: Temperature rise evaluation according to IEC 60890

Table 3: Operating current and power losses of bare conductors used as connections between apparatus and busbars

Width x Thickness	Cross-section (Cu)	Maximum permissible conductor temperature 65 °C							
		Air temperature inside the enclosure around the conductors 35 °C				Air temperature inside the enclosure around the conductors 55 °C			
		50 Hz to 60 Hz ac and dc				50 Hz to 60 Hz ac and dc			
		operating current	power losses 1)	operating current	power losses 1)	operating current	power losses 1)	operating current	power losses 1)
mm x mm	mm ^{2}	A*	W/m	A**	W/m	A*	W/m	A**	W/m
12 x 2	23.5	82	5.9	130	7.4	69	4.2	105	4.9
15 x 2	29.5	96	6.4	150	7.8	88	5.4	124	5.4
15 x 3	44.5	124	7.1	202	9.5	102	4.8	162	6.1
20 x 2	39.5	115	6.9	184	8.9	93	4.5	172	7.7
20 x 3	59.5	152	8.0	249	10.8	125	5.4	198	6.8
20 x 5	99.1	218	9.9	348	12.7	174	6.3	284	8.4
20 x 10	199	348	12.8	648	22.3	284	8.6	532	15.0
25 x 5	124	253	10.7	413	14.2	204	7.0	338	9.5
30 x 5	149	288	11.6	492	16.9	233	7.6	402	11.3
30 x 10	299	482	17.2	960	32.7	402	11.5	780	21.6
40 x 5	199	348	12.8	648	22.3	284	8.6	532	15.0
40 x 10	399	648	22.7	1245	41.9	532	15.3	1032	28.8
50 x 5	249	413	14.7	805	27.9	338	9.8	655	18,5
50 x 10	499	805	28.5	1560	53.5	660	19.2	1280	36.0
60 x 5	299	492	17.2	960	32.7	402	11.5	780	21.6
60 x 10	599	960	34.1	1848	63.2	780	22.5	1524	43.0
80 x 5	399	648	22.7	1256	42.6	532	15.3	1032	28.8
80 x 10	799	1256	45.8	2432	85.8	1032	30.9	1920	53.5
100 x 5	499	805	29.2	1560	54.8	660	19.6	1280	36.9
100 x 10	999	1560	58.4	2680	86.2	1280	39.3	2180	57.0
120 x 10	1200	1848	68.3	2928	85.7	1524	46.5	2400	57.6

*) one conductor per phase **) two conductors per phase 1) single length

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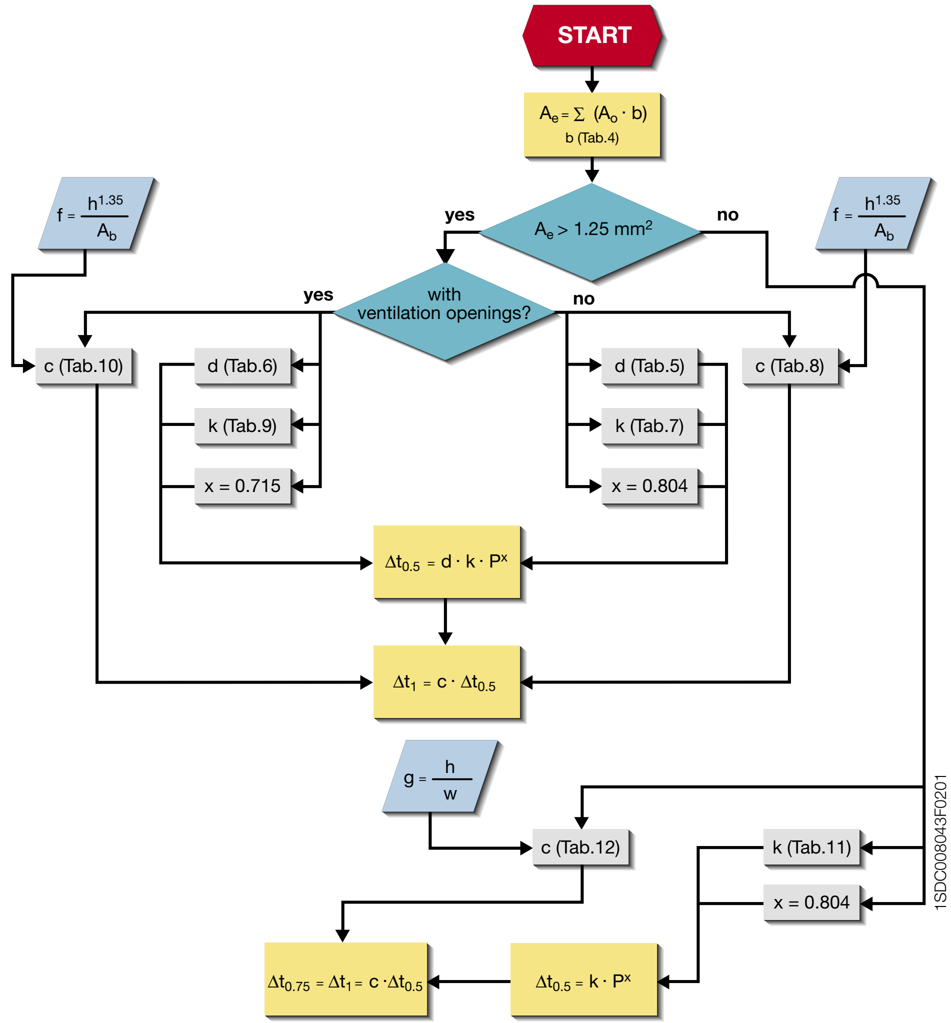
Annex B: Temperature rise evaluation according to IEC 60890

Where enclosures without vertical partitions or individual sections have an effective cooling surface greater than about 11.5 m or a width grater than about 1.5 m, they should be divided for the calculation into fictitious sections, whose dimensions approximate to the foregoing values.

The following diagram shows the procedure to evaluate the temperature rise.



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Annex B: Temperature rise evaluation according to IEC 60890

Table 4: Surface factor *b* according to the type of installation

Type of installation	Surface factor *b*
Exposed top surface	1.4
Covered top surface, e.g. of built-in enclosures	0.7
Exposed side faces, e.g. front, rear and side walls	0.9
Covered side faces, e.g. rear side of wall-mounted enclosures	0.5
Side faces of central enclosures	0.5
Floor surface	Not taken into account

Fictitious side faces of sections which have been introduced only for calculation purposes are not taken into account

Table 5: Factor *d* for enclosures without ventilation openings and with an effective cooling surface $A_e > 1.25\ m^2$

Number of horizontal partitions *n*	Factor *d*
0	1
1	1.05
2	1.15
3	1.3

Table 6: Factor *d* for enclosures with ventilation openings and with an effective cooling surface $A_e > 1.25\ m^2$

Number of horizontal partitions *n*	Factor *d*
0	1
1	1.05
2	1.1
3	1.15

Table 7: Enclosure constant *k* for enclosures without ventilation openings, with an effective cooling surface $A_e > 1.25\ m^2$

A_e [m²]	k	A_e [m²]	k
1.25	0.524	6.5	0.135
1.5	0.45	7	0.13
2	0.35	7.5	0.125
2.5	0.275	8	0.12
3	0.225	8.5	0.115
3.5	0.2	9	0.11
4	0.185	9.5	0.105
4.5	0.17	10	0.1
5	0.16	10.5	0.095
5.5	0.15	11	0.09
6	0.14	11.5	0.085

Annex B: temperature rise evaluation

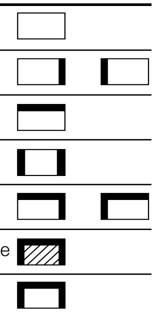
Annex B: Temperature rise evaluation according to IEC 60890

Table 8: Temperature distribution factor *c* for enclosures without ventilation openings, with an effective cooling surface $A_e > 1.25\ m^2$

$f = \frac{h^{1.35}}{A_b}$	Type of installation				
	1	2	3	4	5
0.6	1.225	1.21	1.19	1.17	1.113
1	1.24	1.225	1.21	1.185	1.14
1.5	1.265	1.245	1.23	1.21	1.17
2	1.285	1.27	1.25	1.23	1.19
2.5	1.31	1.29	1.275	1.25	1.21
3	1.325	1.31	1.295	1.27	1.23
3.5	1.35	1.33	1.315	1.29	1.255
4	1.37	1.355	1.34	1.32	1.275
4.5	1.395	1.375	1.36	1.34	1.295
5	1.415	1.395	1.38	1.36	1.32
5.5	1.435	1.415	1.4	1.38	1.34
6	1.45	1.435	1.42	1.395	1.355
6.5	1.47	1.45	1.435	1.41	1.37
7	1.48	1.47	1.45	1.43	1.39
7.5	1.495	1.48	1.465	1.44	1.4
8	1.51	1.49	1.475	1.455	1.415
8.5	1.52	1.505	1.49	1.47	1.43
9	1.535	1.52	1.5	1.48	1.44
9.5	1.55	1.53	1.515	1.49	1.455
10	1.56	1.54	1.52	1.5	1.47
10.5	1.57	1.55	1.535	1.51	1.475
11	1.575	1.565	1.549	1.52	1.485
11.5	1.585	1.57	1.55	1.525	1.49
12	1.59	1.58	1.56	1.535	1.5
12.5	1.6	1.585	1.57	1.54	1.51

where h is the height of the enclosure, and A_b is the area of the base.
For "Type of installation":

Type of installation n°	
1	Separate enclosure, detached on all sides
2	First or last enclosure, detached type
3	Separate enclosure for wall-mounting
	Central enclosure, detached type
4	First or last enclosure, wall-mounting type
	Central enclosure for wall-mounting and with covered top surface
5	Central enclosure, wall-mounting type



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Annex B: Temperature rise evaluation according to IEC 60890

Table 9: Enclosure constant *k* for enclosures with ventilation openings and an effective cooling surface $A_e > 1.25\ m^2$

Ventilation opening in cm^2	$A_e\ [m^2]$												
	1	1.5	2	2.5	3	4	5	6	7	8	10	12	14
50	0.36	0.33	0.3	0.28	0.26	0.24	0.22	0.208	0.194	0.18	0.165	0.145	0.135
100	0.293	0.27	0.25	0.233	0.22	0.203	0.187	0.175	0.165	0.153	0.14	0.128	0.119
150	0.247	0.227	0.21	0.198	0.187	0.173	0.16	0.15	0.143	0.135	0.123	0.114	0.107
200	0.213	0.196	0.184	0.174	0.164	0.152	0.143	0.135	0.127	0.12	0.11	0.103	0.097
250	0.19	0.175	0.165	0.155	0.147	0.138	0.13	0.121	0.116	0.11	0.1	0.095	0.09
300	0.17	0.157	0.148	0.14	0.133	0.125	0.118	0.115	0.106	0.1	0.093	0.088	0.084
350	0.152	0.141	0.135	0.128	0.121	0.115	0.109	0.103	0.098	0.093	0.087	0.082	0.079
400	0.138	0.129	0.121	0.117	0.11	0.106	0.1	0.096	0.091	0.088	0.081	0.078	0.075
450	0.126	0.119	0.111	0.108	0.103	0.099	0.094	0.09	0.086	0.083	0.078	0.074	0.07
500	0.116	0.11	0.104	0.1	0.096	0.092	0.088	0.085	0.082	0.078	0.073	0.07	0.067
550	0.107	0.102	0.097	0.093	0.09	0.087	0.083	0.08	0.078	0.075	0.07	0.068	0.065
600	0.1	0.095	0.09	0.088	0.085	0.082	0.079	0.076	0.073	0.07	0.067	0.065	0.063
650	0.094	0.09	0.086	0.083	0.08	0.077	0.075	0.072	0.07	0.068	0.065	0.063	0.061
700	0.089	0.085	0.08	0.078	0.076	0.074	0.072	0.07	0.068	0.066	0.064	0.062	0.06

Table 10: Temperature distribution factor *c* for enclosures with ventilation openings and an effective cooling surface $A_e > 1.25\ m^2$

$$f = \frac{h^{1.35}}{A_b}$$

Ventilation opening in cm^2	1.5	2	3	4	5	6	7	8	9	10
50	1.3	1.35	1.43	1.5	1.57	1.63	1.68	1.74	1.78	1.83
100	1.41	1.46	1.55	1.62	1.68	1.74	1.79	1.84	1.88	1.92
150	1.5	1.55	1.63	1.69	1.75	1.8	1.85	1.9	1.94	1.97
200	1.56	1.61	1.67	1.75	1.8	1.85	1.9	1.94	1.97	2.01
250	1.61	1.65	1.73	1.78	1.84	1.88	1.93	1.97	2.01	2.04
300	1.65	1.69	1.75	1.82	1.86	1.92	1.96	2	2.03	2.06
350	1.68	1.72	1.78	1.85	1.9	1.94	1.97	2.02	2.05	2.08
400	1.71	1.75	1.81	1.87	1.92	1.96	2	2.04	2.07	2.1
450	1.74	1.77	1.83	1.88	1.94	1.97	2.02	2.05	2.08	2.12
500	1.76	1.79	1.85	1.9	1.95	1.99	2.04	2.06	2.1	2.13
550	1.77	1.82	1.88	1.93	1.97	2.01	2.05	2.08	2.11	2.14
600	1.8	1.83	1.88	1.94	1.98	2.02	2.06	2.09	2.12	2.15
650	1.81	1.85	1.9	1.95	1.99	2.04	2.07	2.1	2.14	2.17
700	1.83	1.87	1.92	1.96	2	2.05	2.08	2.12	2.15	2.18

Annex B: Temperature rise evaluation according to IEC 60890

Table 11: Enclosure constant *k* for enclosures without ventilation openings and with an effective cooling surface $A_e \leq 1.25\ m^2$

$A_e\ [m^2]$	k	$A_e\ [m^2]$	k
0.08	3.973	0.65	0.848
0.09	3.643	0.7	0.803
0.1	3.371	0.75	0.764
0.15	2.5	0.8	0.728
0.2	2.022	0.85	0.696
0.25	1.716	0.9	0.668
0.3	1.5	0.95	0.641
0.35	1.339	1	0.618
0.4	1.213	1.05	0.596
0.45	1.113	1.1	0.576
0.5	1.029	1.15	0.557
0.55	0.960	1.2	0.540
0.6	0.9	1.25	0.524

Table 12: Temperature distribution factor *c* for enclosures without ventilation openings and with an effective cooling surface $A_e \leq 1.25\ m^2$

g	c	g	c
0	1	1.5	1.231
0.1	1.02	1.6	1.237
0.2	1.04	1.7	1.24
0.3	1.06	1.8	1.244
0.4	1.078	1.9	1.246
0.5	1.097	2	1.249
0.6	1.118	2.1	1.251
0.7	1.137	2.2	1.253
0.8	1.156	2.3	1.254
0.9	1.174	2.4	1.255
1	1.188	2.5	1.256
1.1	1.2	2.6	1.257
1.2	1.21	2.7	1.258
1.3	1.22	2.8	1.259
1.4	1.226		

where g is the ratio of the height and the width of the enclosure.

Annex B: Temperature rise evaluation according to IEC 60890

Table 13: MCCB power losses

Total (3/4 poles) power loss in W

Releases	In[A]	T11P F	T1 F	T2 F	T2 P	T3 F	T3 P	T4 F	T4 P/W	T5 F	T5 P/W	T6 F	T6 W	T7 S,H,L F	T7 S,H,L W	T7 V F	T7 V W
	1			4.5	5.1												
	1.6			6.3	7.5												
	2			7.5	8.7												
	2.5			7.8	9												
	3.2			8.7	10.2												
	4			7.8	9												
	5			8.7	10.5												
	6.3			10.5	12.3												
	8			8.1	9.6												
	10			9.3	10.8												
	12.5			3.3	3.9												
	16	1.5	4.5	4.2	4.8												
TMF	20	1.8	5.4	5.1	6			10.8	10.8								
TMD	25	2	6	6.9	8.4												
TMA	32	2.1	6.3	8.1	9.6			11.1	11.1								
MF	40	2.6	7.8	11.7	13.8												
MA	50	3.7	11.1	12.9	15			11.7	12.3								
	63	4.3	12.9	15.3	18	12.9	15.3										
	80	4.8	14.4	18.3	21.6	14.4	17.4	13.8	15								
	100	7	21	25.5	30	16.8	20.4	15.6	17.4								
	125	10.7	32.1	36	44.1	19.8	23.7	18.6	21.6								
	160	15	45	51	60	23.7	28.5	22.2	27								
	200					39.6	47.4	29.7	37.2								
	250					53.4	64.2	41.1	52.8								
	320									40.8	62.7						
	400									58.5	93						
	500									86.4	110.1						
	630											91.8	90				
	800											93	118.8				
	10			1.5	1.8												
	25			3	3.6												
	63			10.5	12												
	100			24	27.6			5.1	6.9								
	160			51	60			13.2	18								
PR21...	250							32.1	43.8								
PR22...	320							52.8	72	31.8	53.7						
PR33...	400									49.5	84			15	27	24	36
	630									123	160.8	90	115	36	66	60	90
	800											96	124.8	57.9	105.9	96	144
	1000											150		90	165	150	225
	1250													141	258	234.9	351.9
	1600													231	423		

The values indicated in the table refer to balanced loads, with a current flow equal to the In, and are valid for both circuit-breakers and switch-disconnectors, three-pole and four-pole versions.
For the latter, the current of the neutral is nil by definition.

Annex B: Temperature rise evaluation according to IEC 60890

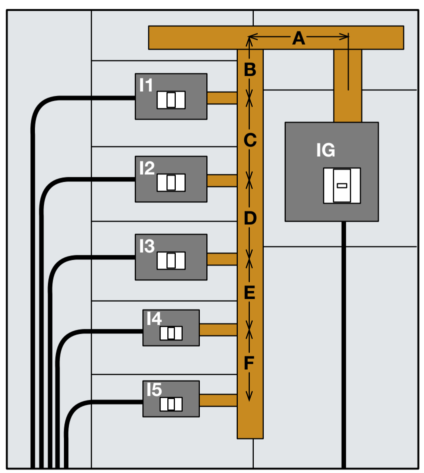
Table 14: Emax power losses

Total (3/4 poles) power loss in W	X1-BN F	X1-BN W	X1-L F	X1-L W	E1B-N F	E1B-N W	E2B-N-S F	E2B-N-S W	E2L F	E2L W	E3N-S-H-V F	E3N-S-H-V W	E3L F	E3L W	E4S-H-V F	E4S-H-V W	E6H-V F	E6H-V W
In=630	31	60	61	90														
In=800	51	104	99	145	65	95	29	53			22	36						
In=1000	79	162	155	227	96	147	45	83			38	58						
In=1250	124	293	242	354	150	230	70	130	105	165	60	90						
In=1600	209	415			253	378	115	215	170	265	85	150						
In=2000							180	330			130	225	215	330				
In=2500											205	350	335	515				
In=3200											330	570			235	425	170	290
In=4000															360	660	265	445
In=5000																	415	700
In=6300																	650	1100

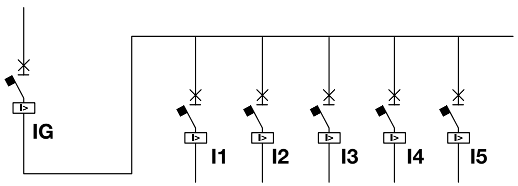
Example

Hereunder an example of temperature rise evaluation for a switchboard with the following characteristics:
- enclosure without ventilation openings
- no internal segregation
- separate enclosure for wall-mounting
- one main circuit-breaker
- 5 circuit-breakers for load supply
- busbars and cable systems

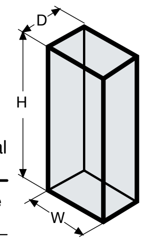
Enclosure



Circuit diagram



Dimensions [mm] Height	Width	Depth	Number of horizontal partitions = 0
2000	1440	840	Separate enclosure for wall-mounting



Annex B: Temperature rise evaluation according to IEC 60890

The power losses from each component of the above switchboard are evaluated hereunder.
For the circuit-breakers, the power losses are calculated as $P = Pn \left(\frac{Ib}{In}\right)^2$ with In and Pn given in the Tables 14 and 15.
The table below shows the values relevant to each circuit-breaker of the switchboard in question:

Circuit-breakers		In CB [A]	Ib [A]	Power losses [W]
IG	E2 1600 EL	1600	1340	80.7
I1	T5 400 EL	400	330	33.7
I2	T5 400 EL	400	330	33.7
I3	T5 400 EL	400	330	33.7
I4	T3 250 TMD	250	175	26.2
I5	T3 250 TMD	250	175	26.2
Total power loss of circuit-breakers [W]				**234**

For the busbars, the power losses are calculated as $P = Pn \left(\frac{Ib}{In}\right)^2 \cdot (3 \cdot Length)$ with In and Pn given in the Table 2.
The table below shows the power losses of busbars:

Busbars	Cross-section nx[mm]x[mm]	Length [m]	Ib [A]	Power losses [W]
A	2x60x10	0.393	1340	47.2
B	80x10	0.332	1340	56
C	80x10	0.300	1010	28.7
D	80x10	0.300	680	13
E	80x10	0.300	350	3.5
F	80x10	0.300	175	0.9
Total power loss of busbars [W]				**149**

For the bare conductors connecting the busbars to the circuit-breakers, the power losses are calculated as $P = Pn \left(\frac{Ib}{In}\right)^2 \cdot (3 \cdot Lenght)$, with In and Pn given in the Table 2. Here below the values for each section:

Connection bare conductors	Cross-section nx[mm]x[mm]	Length [m]	Ib [A]	Power losses [W]
Ig	2x60x10	0.450	1340	54
I1	30x10	0.150	330	3.8
I2	30x10	0.150	330	3.8
I3	30x10	0.150	330	3.8
I4	20x10	0.150	175	1.6
I5	20x10	0.150	175	1.6
Total power loss of bare conductors [W]				**68**

Annex B: Temperature rise evaluation according to IEC 60890

For the cables connecting the circuit-breakers to the supply and the loads, the power losses are calculated as $P = Pn \left(\frac{Ib}{In}\right)^2 \cdot (3 \cdot Length)$, with In and Pn given in the Table 4.

Here below the power losses for each connection:

Cables	Cross-section [n]xmm^2	Length [m]	Ib [A]	Power losses [W]
IG	4x240	1.0	1340	133.8
I1	240	2.0	330	64.9
I2	240	1.7	330	55.2
I3	240	1.4	330	45.4
I4	120	1.1	175	19
I5	120	0.8	175	13.8
Total power loss of cables [W]				**332**

Thus, the total power loss inside the enclosure is: **P = 784 [W]**

From the geometrical dimensions of the switchboard, the effective cooling surface Ae is determined below:

	Dimensions[m]x[m]	$A_0[m^2]$	b factor	A_0
Top	0.840x1.44	1.21	1.4	1.69
Front	2x1.44	1.64	0.9	2.59
Rear	2x1.44	1.64	0.5	1.44
Left-hand side	2x0.840	1.68	0.9	1.51
Right-hand side	2x0.840	1.68	0.9	1.51
			$Ae=\Sigma(A_0 \cdot b)$	8.75

Making reference to the procedure described in the diagram at page 207, it is possible to evaluate the temperature rise inside the switchboard.

Annex B: Temperature rise evaluation according to IEC 60890

From Table 7, k results 0.112 (value interpolated)

Since x = 0.804, the temperature rise at half the height of the enclosure is:

$\Delta t_{0.5} = d \cdot k \cdot P^x = 1 \cdot 0.112 \cdot 784^{0.804} = 23.8$ k

For the evaluation of the temperature rise at the top of the enclosure, it is necessary to determine the *c* factor by using the *f* factor:

$f = \frac{h^{1.35}}{A_b} = \frac{2^{1.35}}{1.44 \cdot 0.84} = 2.107$ (A_b is the base area of the switchboard)

From Table 8, column 3 (separate enclosure for wall-mounting), c results to be equal to1.255 (value interpolated).

$\Delta t_1 = c \cdot \Delta t_{0.5} = 1.255 \cdot 23.8 = 29.8$ k

Considering 35°C ambient temperature, as prescribed by the Standard, the following temperatures shall be reached inside the enclosure:

$t_{0.5} = 35 + 23.8 \approx 59°C$
$t_1 = 35 + 29.8 \approx 65°C$

Assuming that the temperature derating of the circuit-breakers inside the switchboard can be compared to the derating at an ambient temperature different from 40°C, through the tables of Chapter 3.5, it is possible to verify if the selected circuit-breakers can carry the required currents:

E2 1600	at 65°C	In=1538[A]	>	Ig = 1340 [A]
T5 400	at 65°C	In=384 [A]	>	I1 = I2 = I3 = 330 [A]
T3 250	at 60° C	In=216 [A]	>	I4 = I5 = 175 [A]

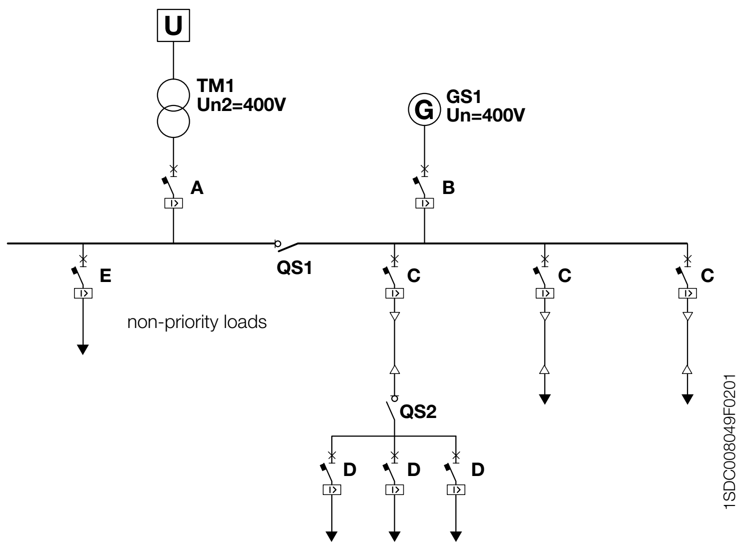
Annex C: Application examples Advanced protection functions with PR123/P and PR333/P releases

Dual Setting

Thanks to the new PR123 and PR333 releases, it is possible to program two different sets of parameters and, through an external command, to switch from one set to the other.
This function is useful when there is an emergency source (generator) in the system, only supplying voltage in the case of a power loss on the network side.

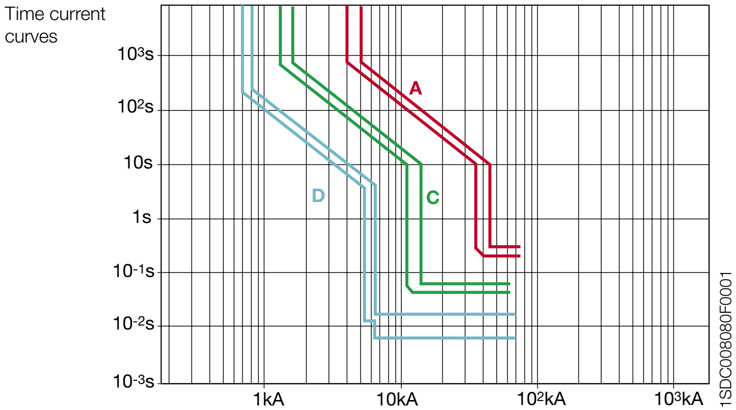
Example:

In the system described below, in the case of a loss of the normal supply on the network side, by means of ABB SACE ATS010 automatic transfer switch, it is possible to switch the supply from the network to the emergency power unit and to disconnect the non-primary loads by opening the QS1 switch-disconnector.
Under normal service conditions of the installation, the circuit-breakers C are set in order to be selective with both circuit-breaker A, on the supply side, as well as with circuit-breakers D on the load side.
By switching from the network to the emergency power unit, circuit-breaker B becomes the reference circuit-breaker on the supply side of circuit-breakers C. This circuit-breaker, being the protection of a generator, must be set to trip times shorter than A and therefore the setting values of the circuit-breakers on the load side might not guarantee the selectivity with B.
By means of the "dual setting" function of the PR123 and PR 333 releases, it is possible to switch circuit-breakers C from a parameter set which guarantees selectivity with A, to another set which make them selective with B.
However, these new settings could make the combination between circuit-breakers C and the circuit-breakers on the load side non-selective.

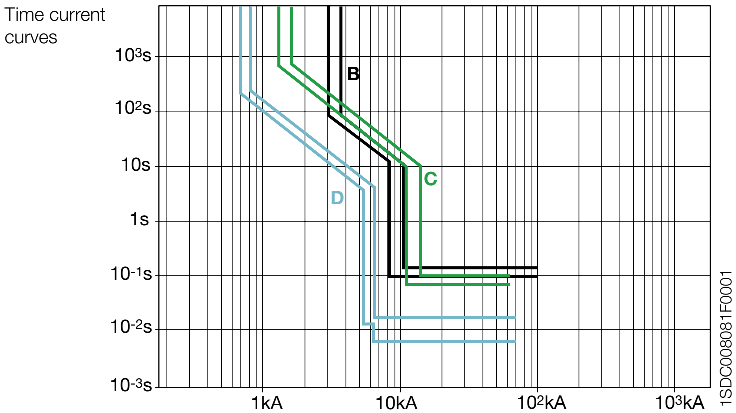


Annex C: Application examples
Advanced protection functions with PR123/P and PR333/P releases

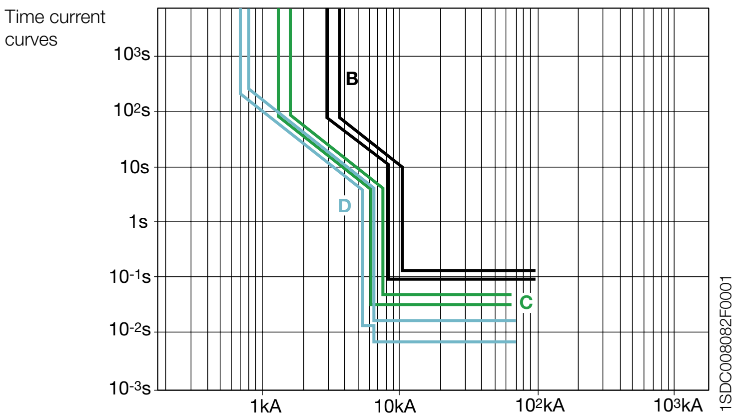
The figure at the side shows the time-current curves of the installation under normal service conditions.
The values set allow no intersection of the curves.



The figure at the side shows the situation in which, after switching, the power is supplied by the power unit through circuit-breaker B. If the settings of circuit-breakers C are not modified, there will be no selectivity with the main circuit-breaker B.



This last figure shows how it is possible to switch to a set of parameters which guarantees selectivity of circuit-breakers C with B by means of the "dual setting" function.



Annex C: Application examples
Advanced protection functions with PR123/P and PR333/P releases

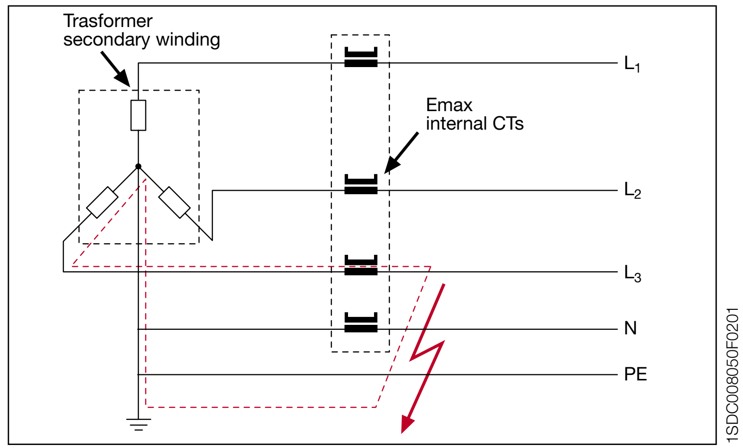
Double G

The Emax type circuit-breakers, equipped with the PR123 and PR333 electronic releases, allow two independent curves for protection G:
-one for the internal protection (function G without external toroid);
-one for the external protection (function G with external toroid)

A typical application of function double G consists in simultaneous protection both against earth fault of the secondary of the transformer and of its connection cables to the circuit-breaker terminals (restricted earth fault protection), as well as against earth faults on the load side of the circuit-breaker (outside the restricted earth fault protection).

Example:
Figure 1 shows a fault on the load side of an Emax circuit-breaker: the fault current flows through one phase only and, if the vectorial sum of the currents detected by the four current transformers (CTs) results to be higher than the set threshold, the electronic release activates function G (and the circuit-breaker trips).

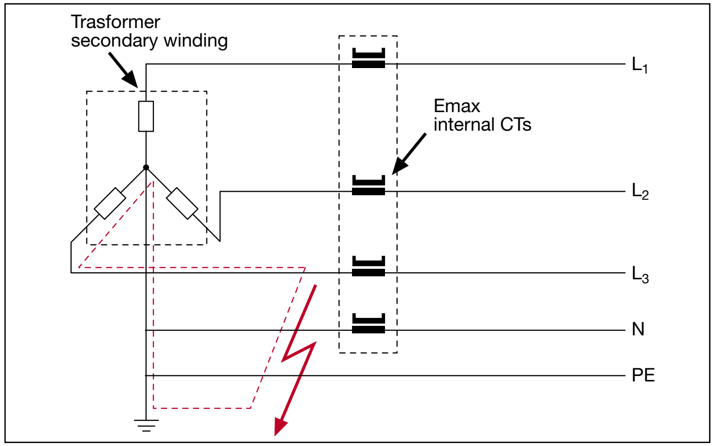
Figure 1



Annex C: Application examples
Advanced protection functions with PR123/P and PR333/P releases

With the same configuration, a fault on the supply side of the circuit-breaker (Figure 2) does not cause intervention of function G since the fault current does not affect either the CT of the phase or that of the neutral.

Figure 2



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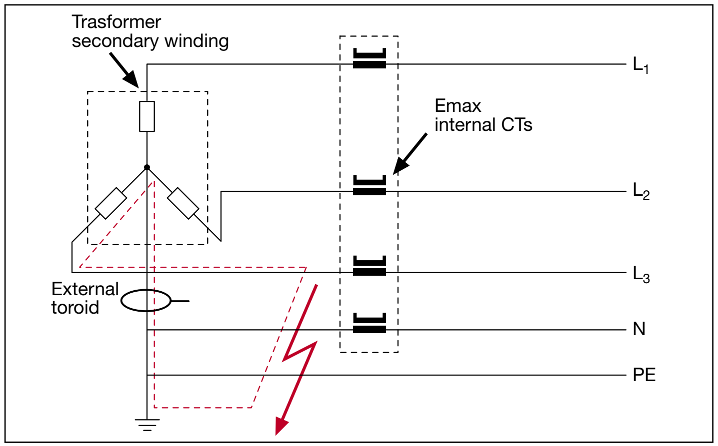
The use of function "double G" allows installation of an external toroid, as shown in Figure 3, so that earth faults on the supply side of Emax CB can be detected
as well. In this case, the alarm contact of the second G is exploited in order to trip the circuit-breaker installed on the primary and to ensure fault disconnection.

Figure 3



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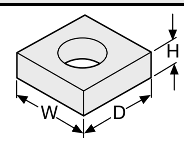
Annex C: Application examples
Advanced protection functions with PR123/P and PR333/P releases

If, with the same configuration as Figure 3, the fault occurs on the load side of the Emax circuit-breaker, the fault current would affect both the toroid as well as the current transformers on the phases. To define which circuit-breaker is to trip (MV or LV circuit-breaker), suitable coordination of the trip times is required: in particular, it is necessary to set the times so that LV circuit-breaker opening due to internal function G is faster than realization of the alarm signal coming from the external toroid. Therefore, thanks to the time-current discrimination between the two G protection functions, before the MV circuit-breaker on the primary of the transformer receives the trip command, the circuit-breaker on the LV side is able to eliminate the earth fault.
Obviously, if the fault occurred on the supply side of the LV circuit-breaker, only the circuit-breaker on the MV side would trip.

The table shows the main characteristics of the range of toroids (available only in the closed version).

Characteristics of the toroid ranges

Rated current	**100 A, 250 A, 400 A, 800 A**
Outer dimensions of the tooid	
	W = 165 mm
	D = 160 mm
	H = 112 mm
Internal diameter of the toroid	Ø = 112 mm

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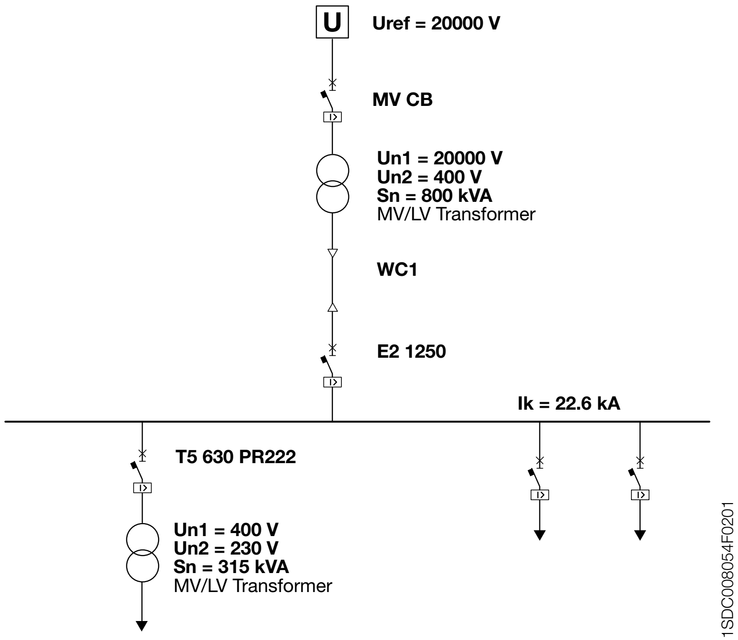
Annex C: Application examples
Advanced protection functions with PR123/P and PR333/P releases

Double S

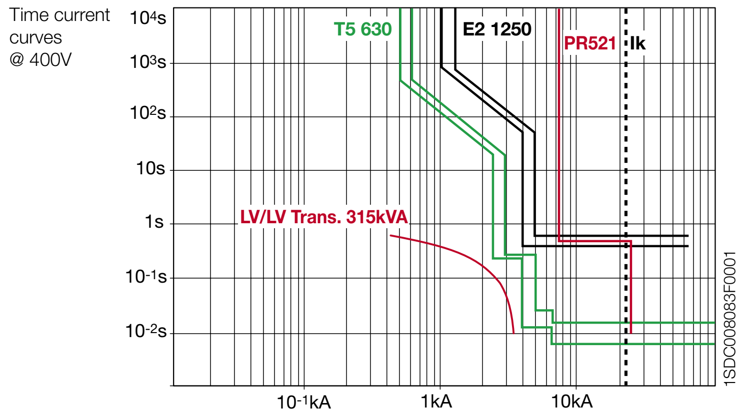
Thanks to the new PR123 and PR333 releases, which allows two thresholds of protection function S to be set independently and be activated simultaneously, selectivity can also be achieved under highly critical conditions.
Here is an example of how, by using the new release, it is possible to obtain a better selectivity level compared with the use of a release without "double S".
This is the wiring diagram of the system under examination; in particular, attention must be focussed on:

- the presence, on the supply side, of a MV circuit-breaker, which, for selectivity reasons, imposes low setting values for the Emax circuit-breaker on the LV side
- the presence of a LV/LV transformer which, due to the inrush currents, imposes high setting values for the circuit-breakers on its primary side



Annex C: Application examples
Advanced protection functions with PR123/P and PR333/P releases

Solution with a release without "double S"



MV CB (PR521)

50	(I>): 50A	t=0.5s
51	(I>>): 500A	t=0s

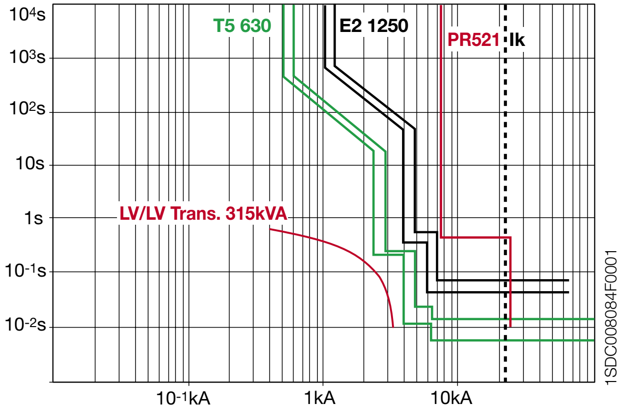
			E2N 1250 PR122 LSIG R1250	**T5V 630 PR222DS/P LSIG R630**
L		Setting	0.8	0.74
		Curve	108s	12s
S	t=constant	Setting	3.5	4.2
		Curve	0.5s	0.25s
I		Setting	OFF	7

In the case of a short-circuit, the Emax E2 circuit-breaker and the MV circuit-breaker will open simultaneously with this solution. Attention must be paid to the fact that, owing to the value Ik, function I of the E2 circuit-breaker has to be disabled (I3=OFF) so that selectivity with the T5 on the load side is guaranteed.

Annex C: Application examples
Advanced protection functions with PR123/P and PR333/P releases

Solution with the PR123 release with “double S”

Time current curves @ 400V



MV CB (PR521)

50	(I>):	50A	t=0.5s
51	(I>>):	500A	t=0s

		E2N 1250 PR123 LSIG R1250	T5V 630 PR222DS/P LSIG R630
L	Setting	0.8	0.74
	Curve	108s	12s
S t=constant	Setting	3.5	4.2
	Curve	0.5s	0.25s
S2 t=constant		Setting	5 -
	Curve	0.05s	-
I	Setting	OFF	7

As evident, by means of the “double S” function, selectivity can be achieved both with the T5 circuit-breaker on the load side as well as with the MV circuit-breaker on the supply side.
A further advantage obtained by using the “double S” function is the reduction in the time of permanence of high current values under short-circuit conditions, which results in lower thermal and dynamic stresses on the busbars and on the other installation components.

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Due to possible developments of standards as well as of materials, the characteristics and dimensions specified in this document may only be considered binding after confirmation by ABB SACE.

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Volume 1
5th edition

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Electrical devices

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