SIEMENS

3VA Molded Case Circuit Breakers

Selectivity Guide

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Protective devices
Selectivity for 3VA molded case circuit breakers

Configuration Manual

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Introduction 1

There are growing demands in many sectors for more reliable, secure electricity supplies for installations, whether these are data centers, airports, industrial production facilities, power plants, etc. (Over-current) selectivity can make an important contribution to fulfilling these demands. It is capable of minimizing the effects of a fault in terms of its duration and the area it affects, thereby ensuring that plant sections that are not affected by the fault will remain in operation.

This "Selectivity" Configuration Manual introduces you to the subject of selectivity and describes the relevant implementation methods as well as the relationships between selectivity and infeed and/or selectivity and undervoltage.

The manual is aimed at engineers, planners and project managers.
Please note that the principles of selectivity described in this manual apply only to low-voltage switchboard and distribution systems.

Further information about implementing selectivity with 3VA molded case circuit breakers can be found in the following documents:

- 3VA Manual (order number 3ZW1012-0VA10-0AB1)
- 3VA Communications Manual (order number 3ZW1012-0VA20-0BB0)

Structure of the manual

The manual is divided into the following chapters:

- Selectivity - terms, definitions and methods (Page 9)

  This chapter explains important terms relating to selectivity and presents possible methods for implementing selectivity.

- Application examples (Page 13)

  The methods by which selectivity can be implemented using circuit breakers are explained in greater depth and demonstrated by specific examples.

- Selectivity implemented by combinations of protective devices (Page 47)

  Conditions are demonstrated under which different protective devices can be combined in order to afford selectivity.

- Selectivity with parallel incoming feeders (Page 57)

  The effects of parallel incoming feeders on selectivity are explained.

- Selectivity and undervoltage protection (Page 69)

  The boundary conditions for implementing selectivity using circuit breakers equipped with an undervoltage release are illustrated.

Navigation around the manual

The following guides to accessing information are provided:

- Table of contents
- Section "Structure of the manual"
- Index

Selectivity - terms and definitions 2

This chapter introduces you to the subject of "selectivity" on the basis of the key terms associated with the concept.

For additional information, especially in relation to selectivity methods, please refer to chapter "Methods of implementing selectivity using circuit breakers (Page 13)".

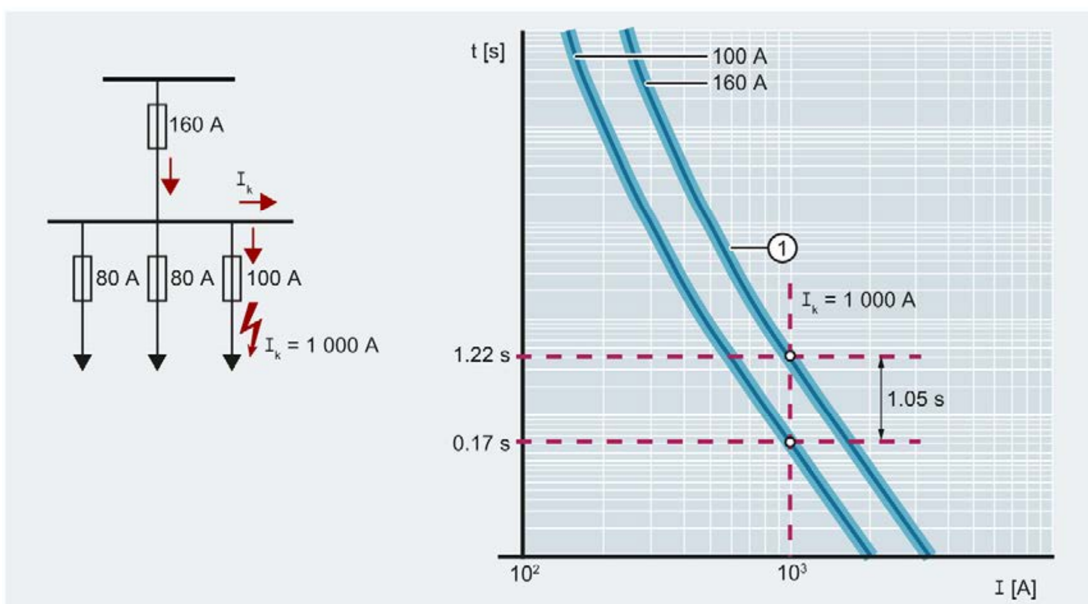
Selectivity

Selectivity exists in a low-voltage network if only the protective device connected directly upstream of the fault location (as viewed in the direction of current flow) trips in response to over-currents.

Selectivity is achieved by combining two or more protective devices with appropriately coordinated operating characteristics.

Example

Selectivity implemented by series-connected LV HRC fuses of the same operating class



① Time-current characteristic with tolerance range

In the event of a 1000 A over-current, the 100 A fuse directly upstream of the fault location disconnects the fault location from the mains supply, while the 160 A fuse does not respond due to its longer pre-arcing time. Sections of the plant unaffected by the fault continue to be supplied with power.

This graph showing the time-current characteristic for determining selectivity applies only to tripping times in excess of 100 ms. For tripping times of less than 100 ms, the I_2t values defined according to DIN VDE 0636-2 are applied.

Over-current selectivity

Excerpt from EN 60947-1, 2.5.23:

Over-current selectivity (discrimination) is the "co-ordination 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 other(s) does (do) not".

See also DIN VDE 100-530: 2011-06 or IEC 60364-7-710 or DIN VDE 0100-710.

Partial selectivity

Partial selectivity exists in cases where the protective devices behave selectively only up to a specific current, i.e. in addition to the protective device directly at the fault location, other upstream protective devices also operate even though the maximum over-current at the fault location is not yet reached.

Total selectivity is not achieved, i.e. sections of plant that are not immediately affected by the over-current fault are also disconnected from the supply system.
If the actual short-circuit current is lower than the selectivity limit current, then total selectivity is also afforded (see EN 60947-2, 2.17.4).

Excerpt from EN 60947-2, 2.17.3:

Partial selectivity is "over-current selectivity where, in the presence of two over-current protective devices in series, the protective device on the load side effects the protection up to a given level of over-current without causing the other protective device to operate".

Total selectivity

Total selectivity exists if only the protective device situated immediately upstream of the fault location operates across the entire over-current zone (in the direction of current flow) that can occur at the fault location.

Excerpt from EN 60947-2, 2.17.2:

Total selectivity is "over-current selectivity where, in the presence of two over-current protective devices in series, the protective device on the load side effects the protection without causing the other protective device to operate".

Total selectivity

Total selectivity is afforded if only the protective device situated immediately upstream of the fault location operates across the entire over-current zone up to

- the rated ultimate short-circuit breaking capacity I_{cu} of the downstream circuit breaker according to IEC 60947-2, or
- the rated short-circuit breaking capacity I_{cn} of the downstream miniature circuit breaker according to IEC 60898, or
- up to the rated breaking capacity of the fuse according to IEC 60269-3.

Selectivity limit current I_S

The selectivity limit current corresponds exactly to the over-current value at which an upstream protective device operates in addition to the protective device situated immediately upstream of the fault source.

In other words, the operating characteristics of the protective devices touch or intersect at a specific current magnitude. The point of contact or intersection determines the selectivity limit current.

Only partial selectivity is afforded if the maximum potential over-current is higher than the selectivity limit current. Total selectivity is afforded if the maximum potential over-current is lower than the selectivity limit current.

Over-current

According to EN 60947-1, 2.1.4, over-current is a "[...] current that exceeds rated current [...]", in other words, it is a short-circuit or overload current.

Excerpt from EN 60947-2, 2.17.4:

The "selectivity limit current is the current co ordinate of the intersection between the total time-current characteristic of the protective device on the load side and the pre-arcing (for fuses), or tripping (for circuit breakers) time-current characteristic of the other protective device".

3 Methods of implementing selectivity using circuit breakers

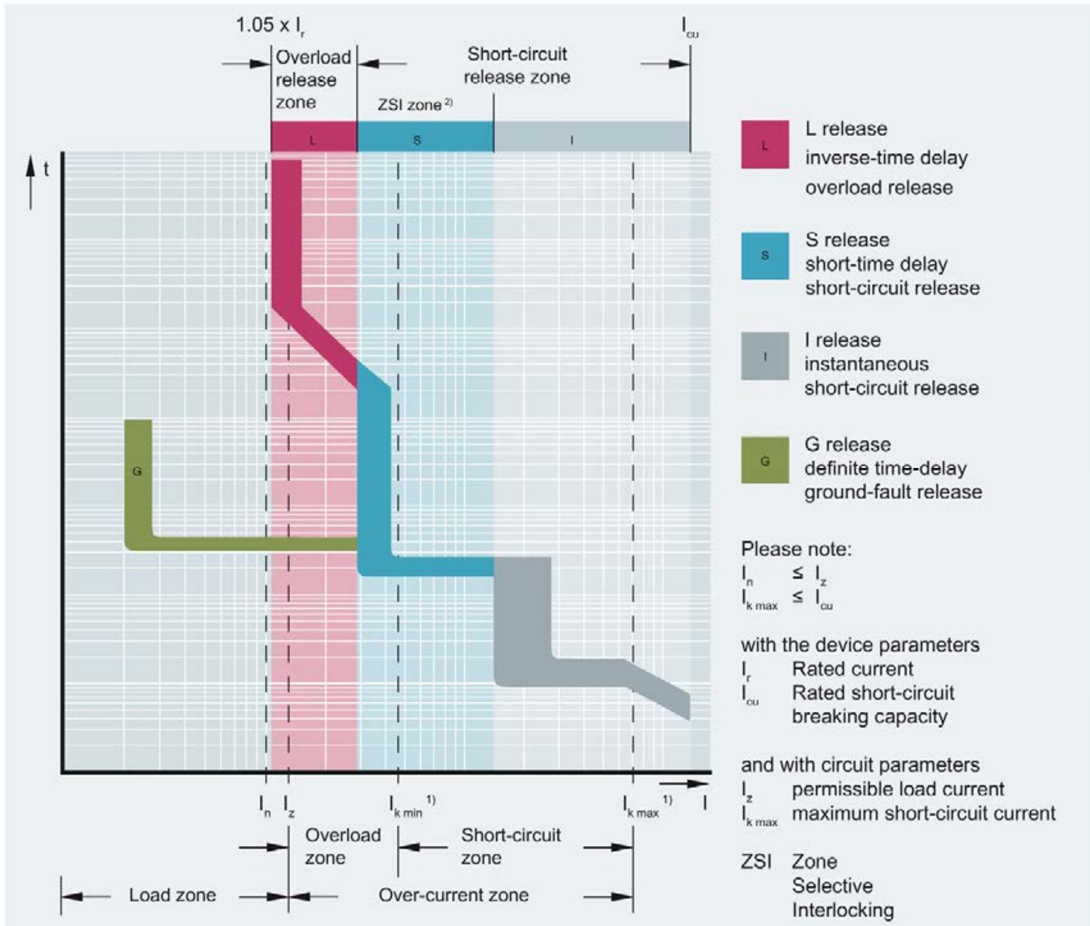
Using the example of a fault scenario in a power distribution system, this chapter explores the potential methods for implementing selectivity. The description in this chapter focuses on the implementation of selectivity between circuit breakers. The subject of implementing a selectivity concept using combinations of different protective devices is discussed in chapter "Selectivity implemented by combinations of protective devices (Page 47)".

Definition of selectivity

The following different methods can be used to implement selectivity with low-voltage circuit breakers:

- Selectivity in the overload zone
- Selectivity in the short-circuit zone
  - Current selectivity
  - Time selectivity
  - Dynamic selectivity (energy selectivity)
  - Zone selective interlocking (ZSI, zone selectivity, logical selectivity)

Overload zone and short-circuit zone for a circuit breaker

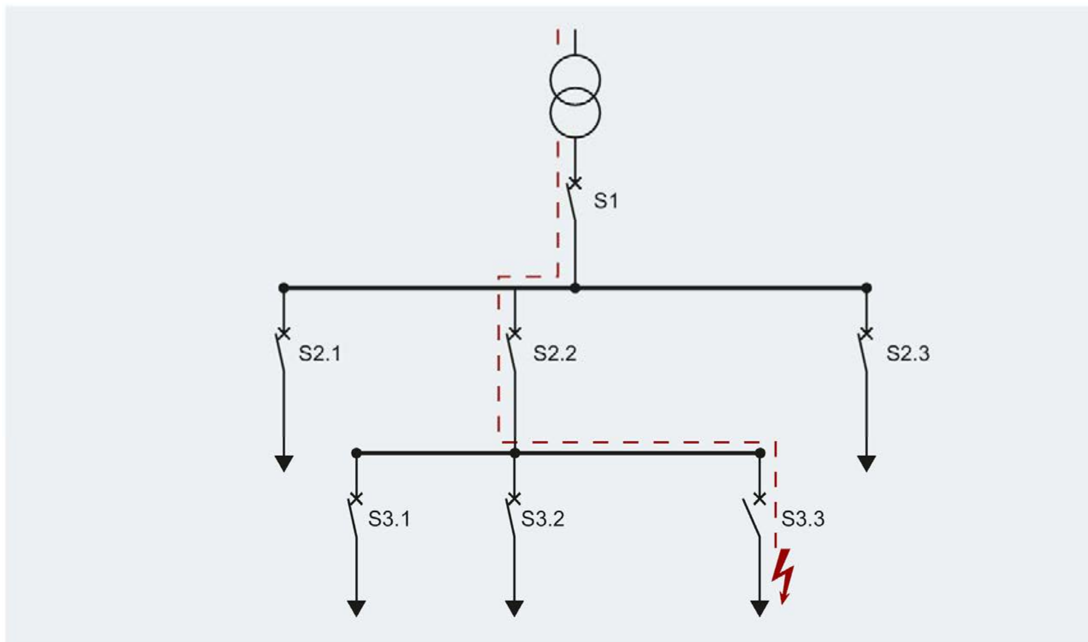


1) The boundary between the overload and short-circuit zones (definition I_{kmin} and I_{kmax}) is described in chapter "Setting of circuit breakers (Page 36)".

2) For further information, please see chapter "Zone selective interlocking (Page 30)".

3.1 Starting point

The starting point is a fault scenario in a low-voltage power distribution system that is protected by circuit breakers.



S1	Incoming feeder circuit breaker
S2.1 - S2.3	Main distribution board circuit breaker
S3.1 - S3.3	Subdistribution board circuit breaker

Figure 3-1 Fault scenario in a low-voltage power distribution system

The fault occurs downstream of circuit breaker S3.3. The three circuit breakers in the energy line marked in red are all affected by the over-current.

If all of the circuit breakers are operating selectively, only circuit breaker S3.3 situated directly at the fault source is permitted to trip. Circuit breakers S1 and S2.2 that are further upstream must not trip even though they might detect the over-current.

3.2 Selectivity in the overload zone

Selectivity in the overload zone is implemented by using a suitable combination of protective devices. It is determined by plotting the tripping characteristics in a graph.

Circuit breakers suitable for this application

Devices suitable for implementing selectivity in the overload zone include, for example, molded case circuit breakers with an electronic and a thermal-magnetic trip unit and air circuit breakers.

A fictitious example will be assessed below; this comprises a combination of a downstream 100 A molded case circuit breaker and an upstream 250 A molded case circuit breaker, both of which are equipped with an electronic trip unit with adjustable LI/LSI protective function. To make the examples shown below in chapters 3.2 - 3.4 easier to understand, the tolerances of the tripping characteristics are not shown.

3.2.1 Example

The rated operational currents are as follows in the starting situation described in chapter 3.1:

- S1 Rated operational current I_{rated} = 630 A
- S2.2 Rated operational current I_{rated} = 250 A
- S3.3 Rated operational current I_{rated} = 100 A

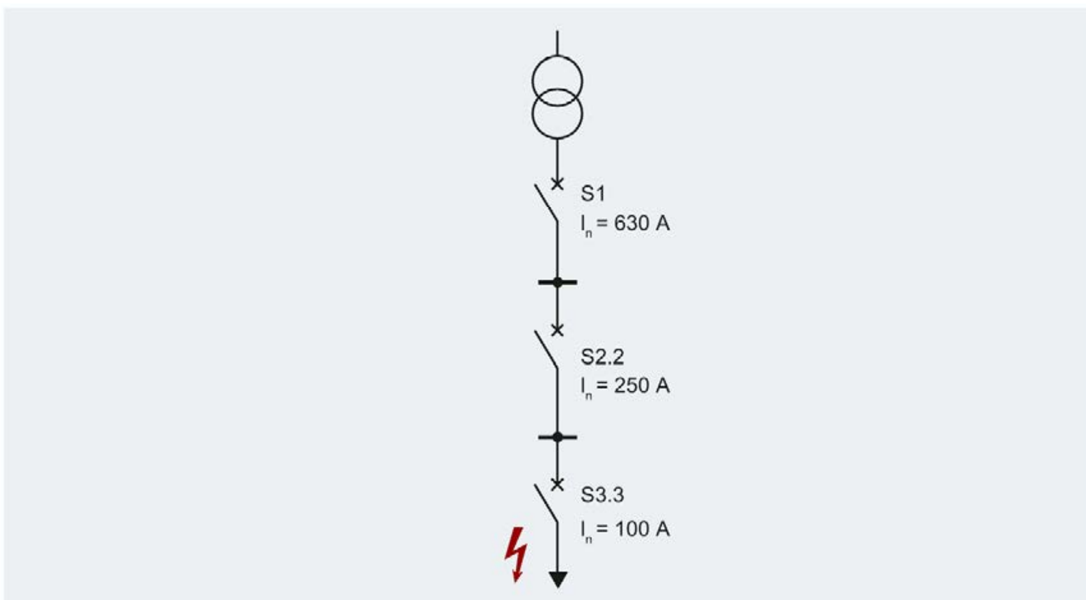


Figure 3-2 Fault scenario with overload zone selectivity

The analysis below will focus solely on the selectivity between circuit breaker S2.2 and circuit breaker S3.3.

3.2.2 Circuit breaker parameters

In order to ensure selectivity, the protection parameters of the LI protective function must be set appropriately for the given situation.

The following parameters are important for the overload zone:

- Settings of the inverse-time delay L release (I_r)
- Delay time of the inverse-time delay L release (t_r)

Parameter			S3.3 100 A circuit breaker	S2.2 250 A circuit breaker
Rated current	I_{rated}	[A]	100	250
Settings at L release	I_r	[factor x I_{rated}]	1	1
Delay time of L release	t_r	[s]	3	10
Settings at S release	I_{sd}	[factor x I_r]	-	-
Delay time of S release	t_{sd}	[s]	-	-
Settings at I release	I_i	[factor x I_{rated}]	10	4

The inverse-time delay L release (I_r) trips at the following overload currents when the settings shown in the table are applied:

- Setting at L release (I_r) of 100 A circuit breaker = 100 A
- Setting at L release (I_r) of 250 A circuit breaker = 250 A

The delay time of the L release (t_r) ensures that there is a sufficient distance (i.e. no contact) between the characteristics of the two circuit breakers in the overload zone.

The setting of the instantaneous I release (I_i) trips in the short-circuit zone. This value has been set to 1000 A for both circuit breakers. Since this parameter has no relevance in the overload zone, it will not be discussed in any detail until later on.

Note

Note the tolerance ranges

The tolerances of the setting values and the delay times must be taken into account when the parameters are set:

- Tolerances of setting values (I_r, I_{sd}, I_i): ± 10 %
- Tolerances of delay times (t_r, t_{sd}): ± 10 %

3.2.3 Tripping characteristics of circuit breakers

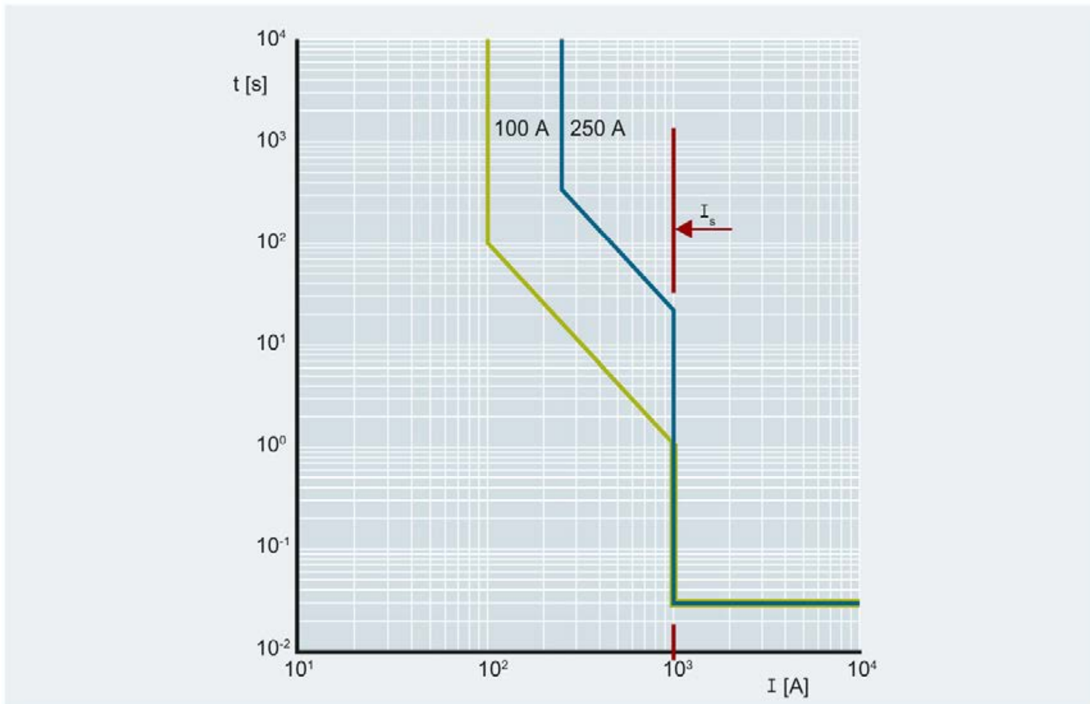


Figure 3-3 Current-time diagram: tripping characteristics of 100 A and 250 A circuit breakers with selectivity in the overload zone

In order to achieve successful selectivity in the overload zone, the overload tripping characteristics of the two circuit breakers must meet the following criteria:

- No contact or overlapping in the overload zone, including tolerance ranges.

  For the purpose of the selectivity evaluation, the characteristics of the upstream circuit breaker must be in the top, right-hand area (blue characteristic) and those of the downstream circuit breaker in the bottom, left-hand area (green characteristic).

- There is a sufficient distance between all tolerance ranges in branched power distribution boards.

  The distances are dependent on the overload protection setting values of the circuit breakers in the other branches.

The tripping characteristics fulfill these criteria in the overload zone. Selectivity is thus assured in this zone.

The selectivity limit current (I_s) equals 1000 A. When the current reaches this limit, both circuit breakers trip simultaneously. As a result, the selectivity in the overload zone is only partial.

3.3 Current selectivity

Current selectivity is a form of selectivity in which the (instantaneous) protective devices trip at different over-current values.

In the event of a fault, the following currents flow:

- A high current flows through the circuit breakers close to the infeed.
- A low current flows through the circuit breakers at a far distance from the infeed.

The tripping characteristics are plotted in a graph in order to determine current selectivity.

Advantages and limitations

Advantages of current selectivity:

- Simple to implement
- Inexpensive

Limitations of current selectivity:

- Equipment exposed to extreme current loads as a result of potentially prolonged flow of short-circuit currents:
  If the fault location is situated between the two protective devices, IEC 60364-4-41 states that it might take up to 5 seconds for the protective devices in TN systems to trip at a rated current of > 32 A.
- In order to reduce the thermal and mechanical loading of equipment by high short-circuit currents, the selectivity limit current is normally set to a relatively low value. As a general rule, only partial selectivity can be achieved with current selectivity.

Area of application

Circuit breakers can be combined to provide current selectivity in applications in which the maximum short-circuit currents between the upstream and downstream circuit breakers are very different.

Circuit breakers suitable for this application

Current selectivity can be implemented using air circuit breakers or molded case circuit breakers with an electronic and a thermal-magnetic trip unit.

The circuit breakers require neither short-time delay over-current releases nor dynamic selectivity coordination.

3.3.1 Circuit breaker parameters

The following parameters are important for current selectivity:

- Setting of the instantaneous I release (I_i)

Parameter			S3.3 100 A circuit breaker	S2.2 250 A circuit breaker
Rated current	I_{rated}	[A]	100	250
Settings at L release	I_r	[factor x I_{rated}]	1	1
Delay time of L release	t_r	[s]	3	10
Settings at S release	I_{sd}	[factor x I_r]	-	-
Delay time of S release	t_{sd}	[s]	-	-
Settings at I release	I_i	[factor x I_{rated}]	5	10

The parameters of the L release (I_r and t_r) remain unchanged from the example given in chapter "Selectivity in the overload zone (Page 15)".

The settings of the instantaneous I release (I_i) trip at different short-circuit currents in this case:

- Setting of I release (I_i) of 100 A circuit breaker = 500 A
- Setting of I release (I_i) of 250 A circuit breaker = 2500 A

The effects are clearly illustrated in the current-time curve diagram, see below.

Note

Note the tolerance ranges

The tolerances of the operating currents and the delay times must be taken into account when the parameters are set:

- Tolerances of setting values (I_r, I_{sd}, I_i): ± 10 %
- Tolerances of delay times (t_r, t_{sd}): ± 10 %.

3.3.2 Tripping characteristics of circuit breakers

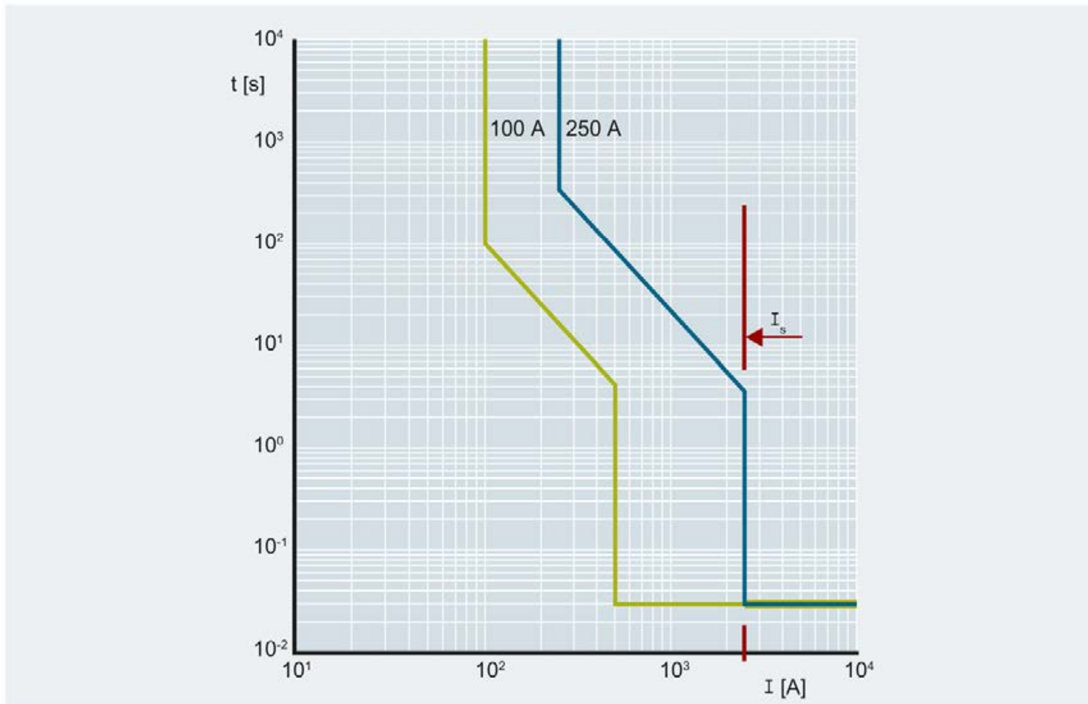


Figure 3-4 Current-time diagram: Tripping characteristics in current selectivity applications

In order to achieve successful current selectivity, the characteristics of the two circuit breakers must meet the following criteria:

- No contacts between the characteristics including tolerance ranges until the operating current of the I release at the upstream 2500 A circuit breaker is reached.

  For the purpose of the selectivity evaluation, the characteristics of the upstream circuit breaker must be in the top, right-hand area (blue characteristic) and those of the downstream circuit breaker in the bottom, left-hand area (green characteristic).

As a result of the changes to the parameters of the I release, a significantly higher degree of selectivity is achieved as compared to pure overload zone selectivity (see "Selectivity in the overload zone (Page 15)"), but selectivity in the overload zone is also assured.

The selectivity limit current (I_s) has been raised to 2500 A. The selectivity in the short-circuit zone up to 10,000 A is still only partial.

3.3.3 Different short-circuit currents at different fault locations

In order to demonstrate the principle of current selectivity, three further scenarios with different fault locations and short-circuit currents are presented below.

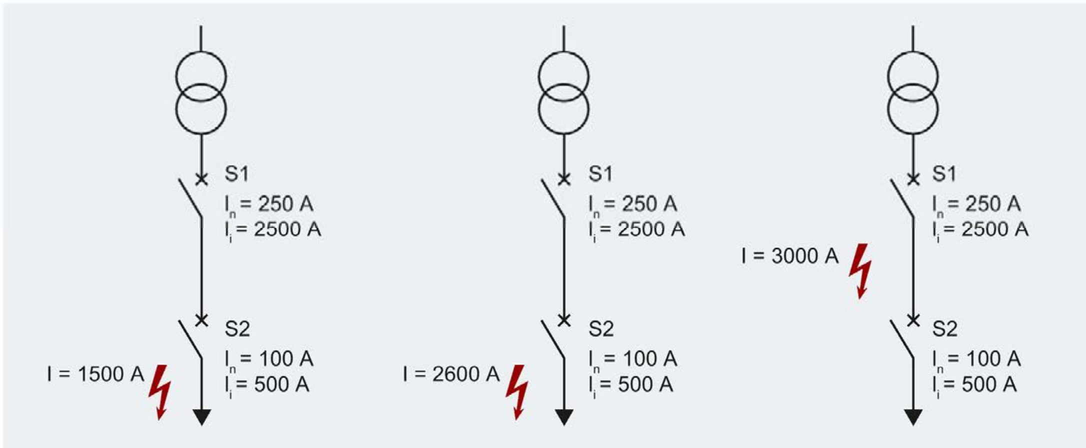


Figure 3-5 Examples of short-circuit currents at different fault locations

Parameter			S2	S1
Rated current	I_{rated}	[A]	100	250
Settings at I release	I_i	[factor x I_{rated}]	5	10

Fault location within protection zone of circuit breaker S2

Circuit breaker S1 is closer to the infeed. The impedances of the cables, etc. between the infeed and circuit breaker S1 are lower than those between the infeed and circuit breaker S2. A higher short-circuit current therefore flows through circuit breaker S1 than circuit breaker S2.

- Scenario 1:
  The short-circuit current at circuit breaker S2 reaches 1500 A.
  Circuit breaker S2 trips, but circuit breaker S1 does not. The circuit breakers operate selectively.
- Scenario 2:
  The short-circuit current at circuit breaker S2 reaches 2600 A.
  Both circuit breakers trip. The circuit breakers do not operate selectively.

Fault location within protection zone of circuit breaker S1

The short-circuit current at circuit breaker S1 reaches 3000 A. Circuit breaker S1 trips, but circuit breaker S2 does not. Since S1 is the upstream circuit breaker, the question of selectivity is irrelevant.

3.4 Time selectivity

Time selectivity is a form of selectivity in which the (time-delay) protective devices trip at different times in response to over-currents of the same magnitude. Starting at the lowest level of an electrical power distribution system, the time delay increases with each circuit breaker in the infeed direction.

Time selectivity is implemented in the short-circuit and overload zones. If suitable circuit breakers with an instantaneous short-circuit release with a sufficiently high setting range and possibly a short-circuit release that can be disabled (setting at I release $I_i = \infty$) are used, it is possible to provide total selectivity with the time selectivity concept.

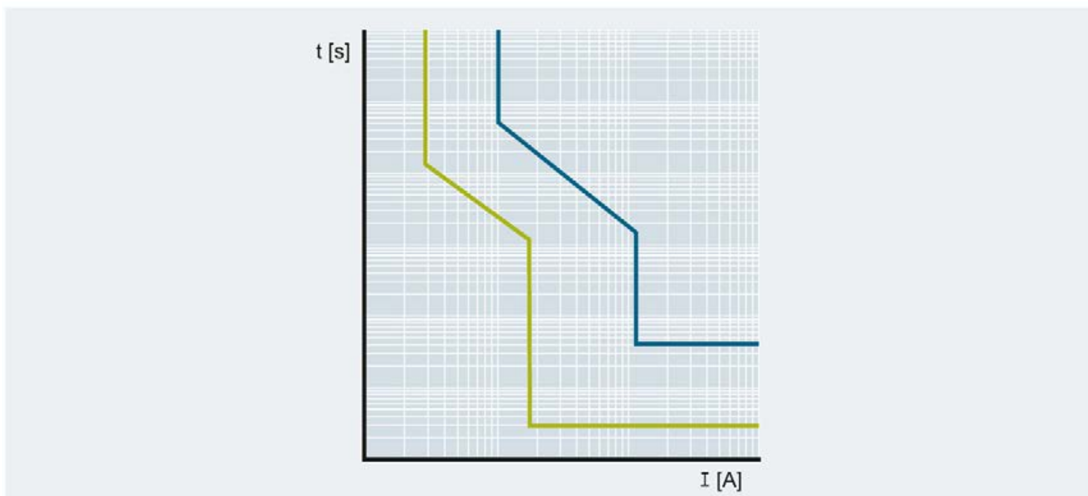


Figure 3-6 Tripping characteristics set for time selectivity

The electronic short-time delay over-current release (S release) is used to implement time selectivity. The delay time of the S release (t_{sd}) on upstream circuit breakers is set to a higher value in the current flow direction than it is on downstream circuit breakers. As a result, the circuit breaker situated directly at the fault location trips before the longer delay time of the circuit breakers further upstream has expired.

Time selectivity is determined by plotting the tripping characteristics in a graph, taking into account tolerances and delay times.

Grading times

Grading times are the intervals required between the delay times of individual circuit breakers in order to achieve time selectivity.

Grading times are based on the following times:

- Time until a fault is detected in the power distribution system
- Time until the contacts of the circuit breaker are completely open

The grading times between two circuit breakers can therefore equal between 70 and 100 ms.

Advantages and limitations

Advantages of time selectivity:

- Simple to implement
- High selectivity limit current values (I_s) or total selectivity can be achieved if the short-circuit current strength of the upstream circuit breakers is sufficiently high. Total selectivity can be achieved if the instantaneous short-circuit release of the upstream protective device can be disabled.

Limitations of time selectivity:

- Tripping is severely delayed when a fault occurs close to the infeed in power distribution systems with several grading levels. In the event of short-circuits, this delay can result in extreme thermal and mechanical loading of electrical equipment.

  In such cases, combining time selectivity with zone selective interlocking (see chapter "Zone selective interlocking (Page 30)") can shorten trip times and significantly reduce the thermal and mechanical loads on components.
- Voltage dips in the electrical network can occur if the short-circuit persists for a comparatively long period and causes the voltage to drop in the incoming cables and equipment. This might cause electrical equipment to malfunction and undervoltage protective devices to respond.

Circuit breakers suitable for this application

Time selectivity implemented with molded case circuit breakers is often only partial selectivity.

The reason for this is that a short-time delay with molded case circuit breakers can only be applied in the current zone in which the contacts cannot open by themselves as a result of forces caused by current flow. Since the upper limit of this zone is very low by comparison with the rated ultimate short-circuit breaking capacity (I_{cu}), the selectivity limit current (I_s) is also very low.

Time selectivity can be effectively implemented in most cases with air circuit breakers because the contact system of an air circuit breaker can conduct high short-circuit currents for a specific time period. Air circuit breakers of utilization category B in particular are characterized by a high rated short-time withstand current (I_{cw}).

Total selectivity can be achieved if the values for rated ultimate short-circuit breaking capacity (I_{cu}) and the high rated short-time withstand current (I_{cw}) are very similar.

Circuit breakers must have an electronic trip unit if they are to be used to implement time selectivity. As a general rule, the short-time delay on circuit breakers with a thermal-magnetic trip unit cannot be varied.

DIN EN 60947-2 Part 4.4 distinguishes between two utilization categories in relation to time selectivity in order to determine which circuit breakers fulfill the requirements for rated short-time withstand current I_{cw} with a short-time delay.

Excerpt from IEC 60947-2, 4.4:

"Selectivity category B comprises circuit breakers providing selectivity by having a short-time withstand current rating and an associated short-time delay according to 4.3.6.4. Selectivity of circuit breakers of selectivity category B is not necessarily ensured up to the ultimate short-circuit breaking capacity (e.g. in the case of operation of an instantaneous release) but at least up to the value specified in Table 3."

"Selectivity category A comprises all other circuit breakers. These circuit breakers may provide selectivity under short-circuit conditions by other means."

Section 4.3.6.4. of the standard stipulates that circuit breakers must fulfill the following requirements:

- Circuit breakers with a rated current I_{rated} of < 2500 A must have a rated short-time withstand current I_{cw} equal to 12xI_{rated}, but at least 5 kA.
- Circuit breakers with a rated current I_{rated} >of 2500 A must have a rated short-time withstand current I_{cw} of at least 30 kA.
- The short-time delay of the rated short-time withstand current must be at least 0.05 s.

This means that the molded case circuit breakers fulfill the requirements of utilization category A in most cases.

However, 3VA24 circuit breakers with a rated current I_{rated} = 400 A or above also fulfill the requirements of utilization category B because the electronic trip unit (ETU) of the 5 and 8 series allows a short-time delay of between 0.05 and 0.5 s and a rated short-time withstand current I_{cw} of at least 5 kA.

The 3WL air circuit breakers generally fulfill the requirements of utilization category B.

3.4.1 Circuit breaker parameters

The following parameters are important for time selectivity:

- Settings of the short-time delay S release (I_{sd})
- Delay time of the short-time delay S release (t_{sd})

Parameter			S3.3 100 A circuit breaker	S2.2 250 A circuit breaker
Rated current	I_{rated}	[A]	100	250
Settings at L release	I_r	[factor x I_{rated}]	1	1
Delay time of L release	t_r	[s]	3	10
Settings at S release	I_{sd}	[factor x I_r]	-	10
Delay time of S release	t_{sd}	[s]	-	0.1
Settings at I release	I_i	[factor x I_{rated}]	5	20

The parameters of the L release (I_r and t_r) remain unchanged from the fictitious example given in chapter "Selectivity in the overload zone (Page 15)".

The 100 A circuit breaker S3.3 need not trip with a time delay relative to another downstream circuit breaker. It is thus not necessary to use an S release or to set its parameters.

The 100 A circuit breaker S3.3 is tripped via the instantaneous I release in the event of a short-circuit current:

- Setting of I release (I_i) of 100 A circuit breaker = 500 A
- Delay time of I release (not adjustable) = 30 ms

The upstream 250 A circuit breaker is tripped via the short-time delay S release in the event of a short-circuit current:

- Setting of I release (I_{sd}) of 250 A circuit breaker = 2500 A
- Delay time of S release (I_{sd}) of 250 A circuit breaker = 100 ms

In other words, the 250 A circuit breaker trips when the current is in the range between I_{sd} = 2500 A and I_i = 5000 A and persists for the time period t_{sd} = 100 ms. If the current exceeds 5000 A within 100 ms, the instantaneous I release trips the circuit breaker.

The effects are clearly illustrated in the current-time curve diagram, see below.

Note

Note the tolerance ranges

The tolerances of the operating currents and the delay times must be taken into account when the parameters are set:

- Tolerances of operating currents (I_r, I_{sd}, I_i): ± 10 %
- Tolerances of delay times (t_r, t_{sd}): ± 10 %.

3.4.2 Tripping characteristics of circuit breakers

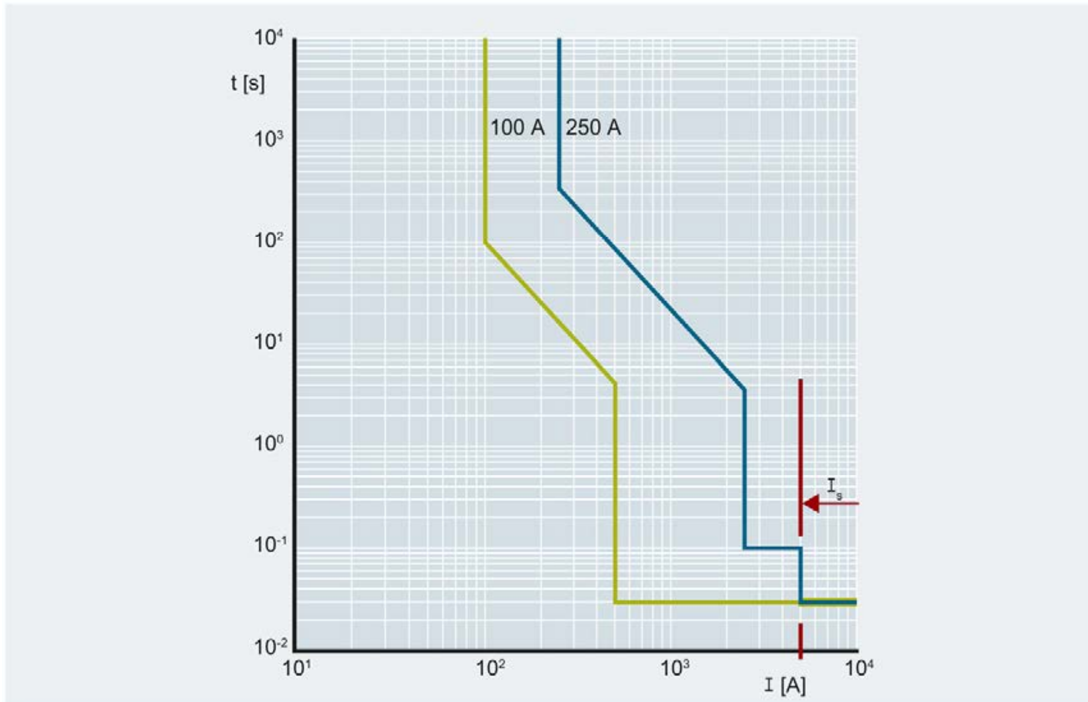


Figure 3-7 Current-time diagram: Tripping characteristics in time selectivity applications

In order to achieve successful time selectivity, the characteristics of the two circuit breakers must meet the following criteria:

- No contacts between the characteristics including tolerance ranges until the operating current of the I release at the upstream 250 A circuit breaker is reached.

  For the purpose of the selectivity evaluation, the characteristics of the upstream circuit breaker must be in the top, right-hand area (blue characteristic) and those of the downstream circuit breaker in the bottom, left-hand area (green characteristic).

As a result of the changes to the parameters of the I release or S release, a significantly higher degree of selectivity is achieved as compared to pure overload zone selectivity (see "Selectivity in the overload zone (Page 15)"), but selectivity in the overload zone is also assured.

The selectivity limit current (I_s) has been raised to 5000 A. Selectivity would still be only partial if the short-circuit current were to rise above 5000 A.

3.4.3 Implementation of total selectivity

If the upstream circuit breakers used have a sufficiently high rated short-time withstand current (I_{cw}) or an instantaneous short-circuit release with a sufficiently high setting, high values for the selectivity limit current (I_s) can be achieved. Total selectivity can be implemented if the instantaneous I release can also be disabled or if the breaker features an instantaneous short-circuit release with a sufficiently high setting.

The following Siemens circuit breakers are used to implement total selectivity in the following example:

- Q1, Q2, Q3: SENTRON 3WL air circuit breakers with rated short-time withstand current (I_{cw}):
  - up to 100 kA for a duration of 400 ms
  - The values for rated ultimate short-circuit breaking capacity (I_{cu}) and rated short-time withstand current (I_{cw}) are very similar
- Q4: SIRIUS 3RV circuit breaker

The instantaneous I release on circuit breakers Q1 and Q2 is disabled.

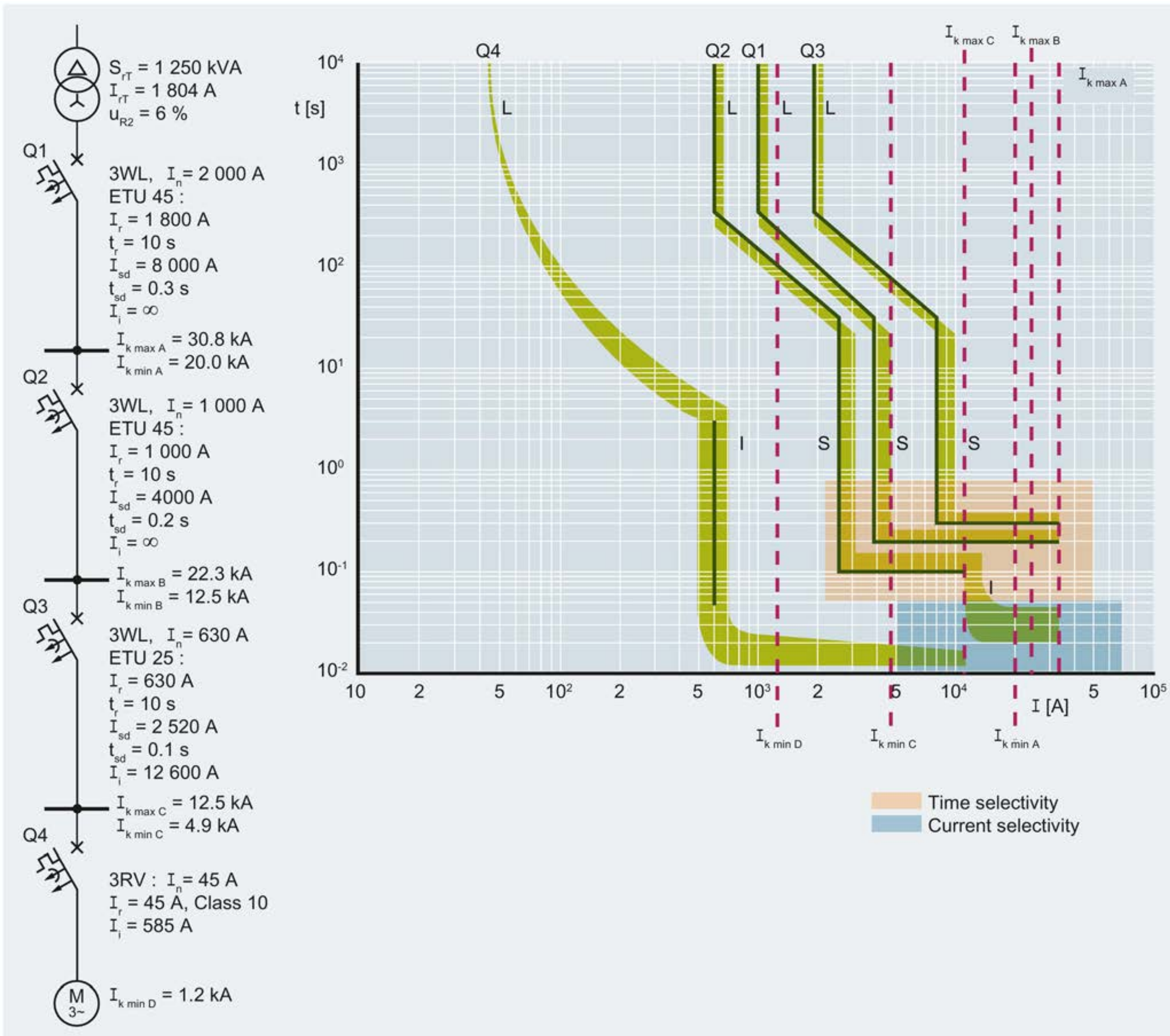


Figure 3-8 Example of total time selectivity (area marked orange) and total current selectivity (area marked blue) for one branch with four circuit breakers connected in series

The definitions for I_{kmin} and I_{kmax}, and the resultant settings for the circuit breakers can be found in chapter "Setting of circuit breakers (Page 36)".

3.5 Zone selective interlocking

With zone selective interlocking (ZSI), the protective devices are interconnected via separate control wires.

Two communication systems that use different communication channels are provided:

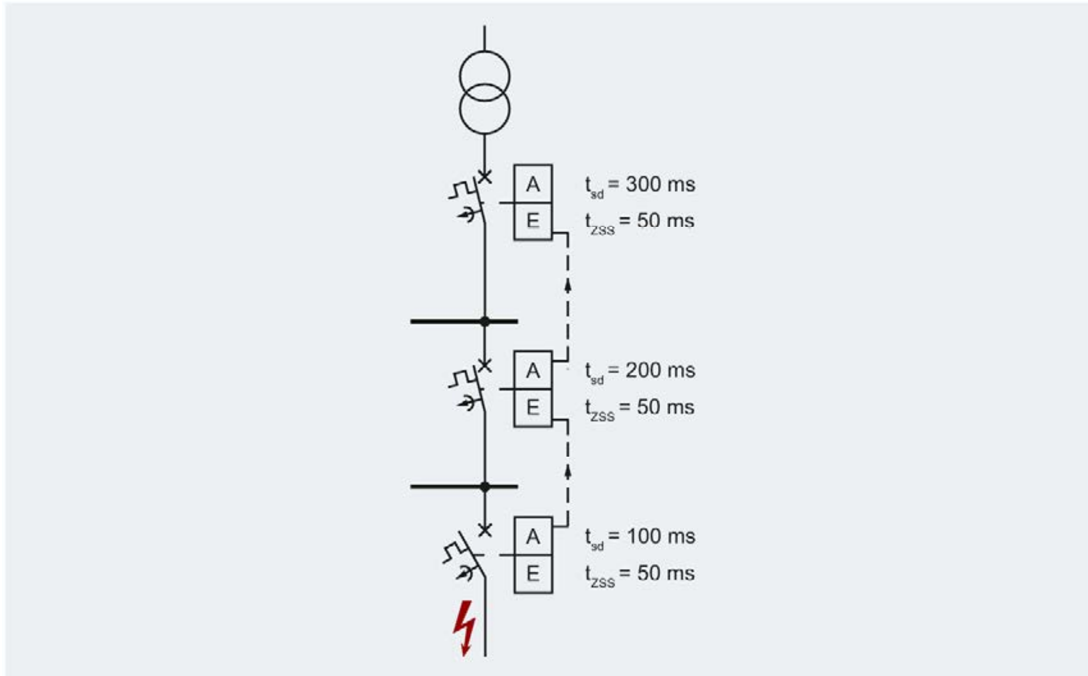
- Central system: The circuit breakers communicate via a central monitoring and control unit.
- Distributed system: The circuit breakers communicate directly with one another.

  The distributed system permits significantly shorter tripping times than the central system.

Since it is normally distributed systems that are used for low-voltage applications, this chapter shall only discuss zone selective interlocking as it is applied in distributed systems.

The following happens if a short-circuit current and/or a ground fault current is detected by a circuit breaker:

- The circuit breaker sends a "block" signal to the **upstream** circuit breaker.
- At the same time, the circuit breaker checks whether a **downstream** circuit breaker is sending a "block" signal.
  - If the circuit breaker receives a "block" signal, it is delayed by a time period corresponding to the set delay time t_{sd}.
  - If the circuit breaker does not receive a "block" signal, it trips.



A	Signal output
E	Signal input
- - -	Control wires
t_{sd}	Delay time setting for the short-circuit release
t_{ZSI}	Delay time (defined non-operation time) of all breakers that detect the short-circuit and/or ground fault current and do not receive a "block" signal when ZSI is activated

Figure 3-9 Zone selective interlocking

The tripping delays that can be implemented with zone selective interlocking are normally shorter than those achievable with time selectivity, even though selectivity still remains operative.

The control wires for the electronic trip units are connected to a separate communication module that is provided for each circuit breaker.

Advantages and limitations

Advantages of zone selective interlocking:

- Low electrical and mechanical loading of the electrical installation and the circuit breakers thanks to short tripping times
- The protective functions for an electrical power distribution network are highly reliable and predictable
- The short-circuit protection of circuit breakers can be selectively graded with a large number of hierarchical levels (in principle)

Limitations of zone selective interlocking:

- The maximum permissible length of control wires limits zone selective interlocking to a specific zone of an electrical power distribution network.

  The maximum permissible length of control wires for Siemens 3VA2 molded case circuit breakers is as follows:

  – < 600 m / 0.75 mm^2 (AWG 18)

  – < 1200 m / 1.5 mm^2 (AWG 16)

  – < 2000 m / 2.5 mm^2 (AWG 14)

Area of application

Zone selective interlocking is used for applications requiring short-time delay short-circuit protection as well as ground fault protection.

The 3WL air circuit breaker and the 3VA2 molded case circuit breaker have a delay time t_{ZSI} of 50 ms with short-circuits and a delay time t_{ZSI} of 100 ms for ground faults.

Circuit breakers suitable for this application

Zone selective interlocking can be implemented using molded case circuit breakers and air circuit breakers,

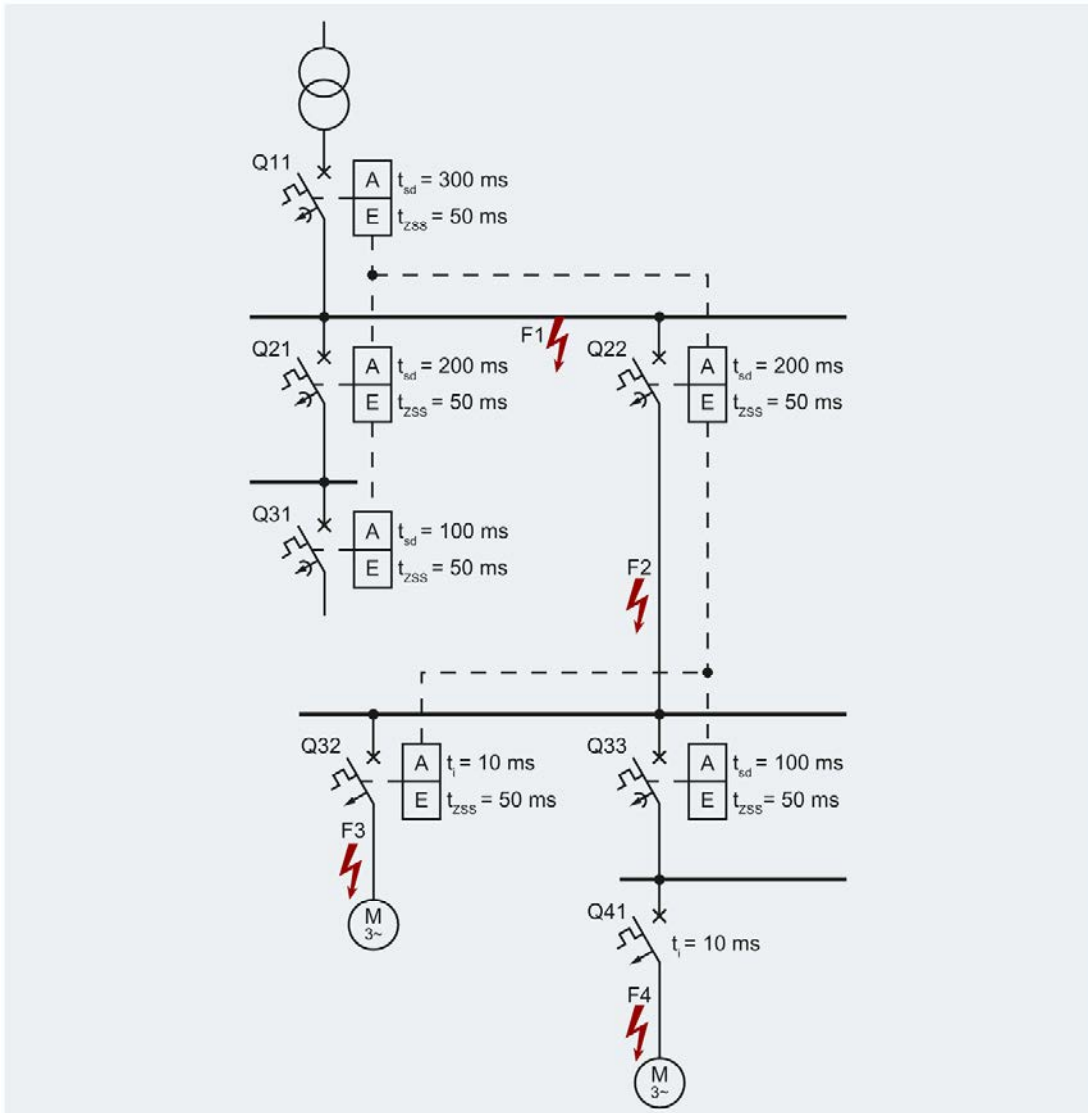
but the circuit breakers used must have an electronic trip unit. As a general rule, circuit breakers with a thermal-magnetic trip unit do not have a short-time delay.

3.5.1 Zone selective interlocking and time selectivity

If a circuit breaker detects a fault in a combined ZSI/time selectivity system, the following applies:

- A "block" signal is present:
  The original delay time t_{sd} remains valid.
- A "block" signal is not present:
  The original delay time t_{sd} is replaced by a delay time t_{ZSI} (defined non-operation time).

Example



A	Signal output	t_i	Delay time of the I release
E	Signal input	t_{sd}	Delay time setting of the short-time delay short-circuit release
- -	Control wires	t_{ZSI}	Shortened delay time (defined non-operation time)

Figure 3-10 Zone selective interlocking combined with time selectivity

Fault scenario F1

A fault occurs within the protection zone of circuit breaker Q11.

- If the short-circuit current is high enough, it is detected by the trip unit of circuit breaker Q11.
- Since Q11 does not receive a "block" signal from Q22, the original delay time t_{sd} = 300 ms is replaced by the shortened delay time t_{ZSI} = 50 ms.
- Q11 trips after t_{ZSI} = 50 ms.

Fault scenario F2

A fault occurs within the protection zone of circuit breaker Q22.

- If the short-circuit current is high enough, it is detected by the trip units of circuit breakers Q11 and Q22.
- The zone selective interlocking system causes Q22 to temporarily block Q11.
  - Q11 retains the original delay time t_{sd} = 300 ms.
  - Since Q22 does not receive a "block" signal, its original delay time t_{sd} = 200 ms is replaced by the shortened delay time t_{ZSI} = 50 ms.
- Q22 trips after t_{ZSI} = 50 ms.

Fault scenario F3

A fault occurs within the protection zone of circuit breaker Q32.

- If the short-circuit current is high enough, it is detected by the trip units of circuit breakers Q11, Q22 and Q32
- As a result of the zone selective interlocking system, Q32 temporarily blocks Q22 which in turn temporarily blocks Q11.
  - Q11 retains the original delay time t_{sd} = 300 ms.
  - Q22 retains the original delay time t_{sd} = 200 ms.
- Q32 trips after t_i = 10 ms if the short-circuit is within the range of the instantaneous short-circuit protection (I).
- Q32 trips after t_{ZSI} = 50 ms if the short-circuit is within the range of the short-time delay short-circuit protection (S).

Fault scenario F4

A fault occurs within the protection zone of circuit breaker Q41.

- If the short-circuit current is high enough, it is detected by the trip units of circuit breakers Q11, Q22, Q33 and Q41.

  Since Q41 already trips after t_i = 10 ms, however, none of the other circuit breakers trip.
- The zone selective interlocking and time selectivity systems have no influence on circuit breaker operation.

3.5.2 Setting of circuit breakers

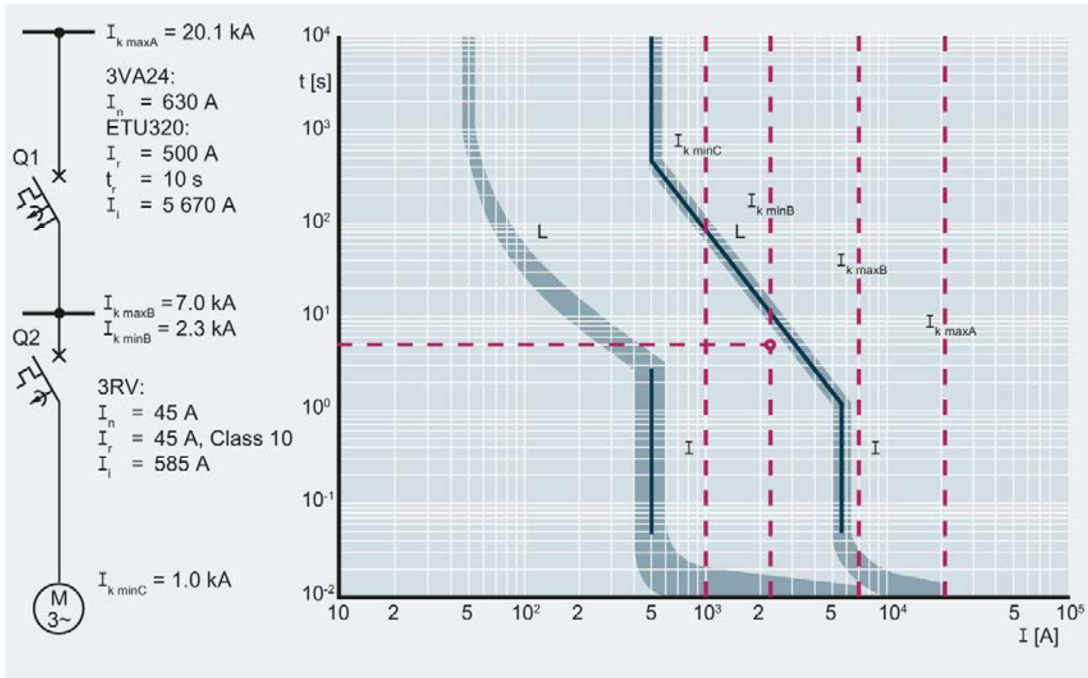
Simaris design, a software program published by SIEMENS, is recommended as a tool for setting circuit breakers. One of the capabilities of this program is to calculate network short-circuit values.

Two values – "I_{kmax}" and "I_{kmin}" – are required to select and set a circuit breaker at the installation point.

- I_{kmax} is the maximum potential short-circuit at the point of installation of a circuit breaker; it is determined on the basis of the 3-pole, 2-pole and 1-pole short-circuit calculations.
- I_{kmin} is the smallest possible short-circuit in the part of the network to be protected; it is determined on the basis of the 3-pole, 2-pole and 1-pole short-circuit calculations.
  This can refer, for example, to the zone to be protected extending from the circuit breaker up to the end of the cable/busbar at the load, or up to the next protective device (circuit breaker or fuse).

The following conditions apply to the selection and setting of circuit breakers:

1. A circuit breaker is selected in terms of its rated ultimate short-circuit breaking capacity I_{cu} according to the value of the highest potentially occurring short-circuit:
   I_{cu} is equal to or greater than I_{kmax}.
2. The short-circuit release is set according to the minimum potentially occurring short-circuit I_{kmin} in the relevant network, whereby the tolerances of releases must be taken into account. According to IEC 60947-2, 8.3.3.1.2, the maximum permissible tolerance of the short-circuit release is ±20 %.
3. DIN VDE 0100, Part 410 and IEC 60364-4-41 differentiate between break-times depending on whether the circuit is a distribution circuit or a final circuit.
   – In distribution circuits (from the main distribution board to the subdistribution board, for example), a break-time of 5 s applies in TN systems.
   – In final circuits (from the distribution board to loads/socket outlets), the break-time is as follows at a rated AC voltage U_o = 230 V AC phase conductor to ground:
   0.4 s at a rated current 32 A in a TN system
   and
   5 s at a rated current > 32 A in a TN system.



It is clear from this diagram that selective tripping behavior cannot be implemented using the highest possible setting of the instantaneous short-circuit release (I) of the upstream 3VA2 630A molded case circuit breaker. While the tripping characteristics in the short-circuit zone of the two circuit breakers only touch with short-circuits of 5 kA or higher so that partial selectivity up to 5 kA is afforded, the required protective functions are not provided.

Setting the 3VA2 630A molded case circuit breaker:

- The value of I_{kmaxA} has been calculated as 20.1 kA at the installation point A.

  The 3VA24 molded case circuit breaker for a rated operational current I_{rated} = 630 A has a rated ultimate short-circuit breaking capacity I_{cu} = 55 kA at 380 - 415 V AC, which means that this selection is correct.

- The value of I_{kmaxB} has been calculated as 7.0 kA and the value of I_{kminB} as 2.3 kA at the installation point B.

  However, the setting of the instantaneous short-circuit release of the 3VA2 630 A molded case circuit breaker is higher than the value of I_{kminB} (due to the partial selectivity up to 5 kA), and it is not possible to interrupt this I_{kminB} value of 2.3 kA within 5 s.

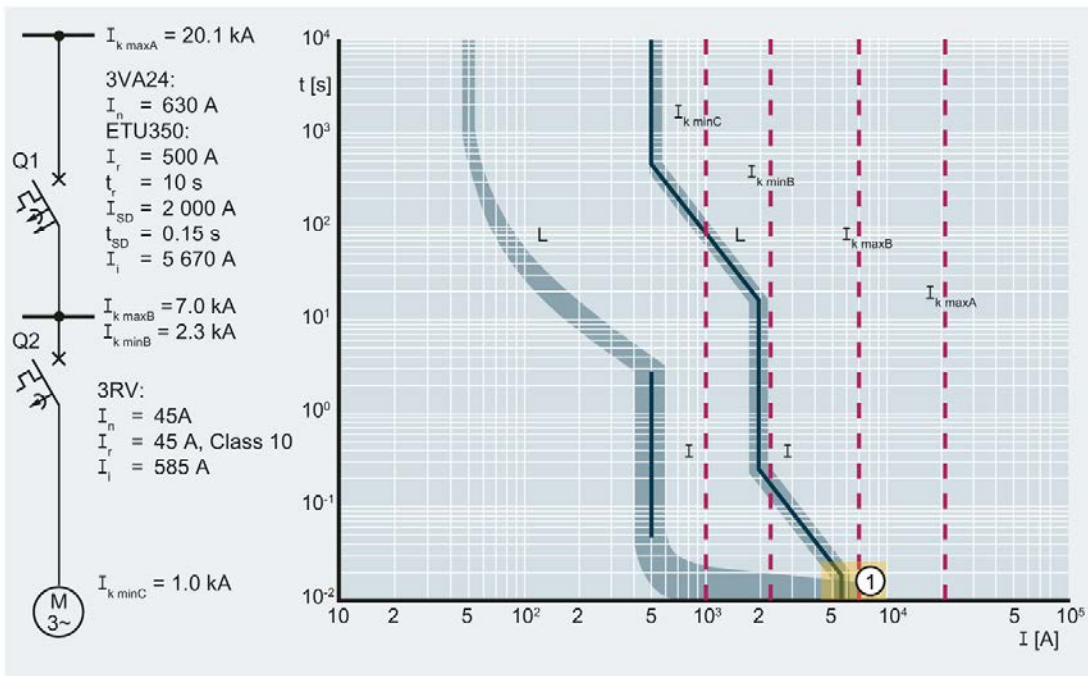
Setting the 3RV circuit breaker for motor protection (motor starter protector):

- The value of I_{kmaxB} has been calculated as 7.0 kA at the installation point B.

  The 3RV motor starter protector with a rated operational current I_{rated} = 45 A has a rated ultimate short-circuit breaking capacity I_{cu} = 50 kA at 400 V AC, which means that this selection is correct.

- The value of I_{kminC} has been calculated as 1.0 kA at the installation point C.

  The setting of the instantaneous short-circuit release of the 3RV motor starter protector is correct because – despite the current selectivity – the instantaneous short-circuit release is set to 585 A and the setting is thus lower than I_{kmin}. It is also ensured that the 3RV motor starter protector would interrupt this short-circuit within 5 s.



① Dynamic selectivity zone (more information about dynamic selectivity can be found in chapter "Dynamic selectivity (Page 40)")

In order to ensure that the two circuit breakers can fulfill the total selectivity conditions and also guarantee that both circuit breakers will trip within 5 s at the relevant I_{kmin} at installation points B and C, the following must be noted with respect to the upstream 3VA2 molded case circuit breaker.

The selectivity limit currents I_S and thus also total selectivity can only be implemented with the instantaneous short-circuit releases of the upstream circuit breakers set to their maximum values.

For this reason, the upstream 3VA2 molded case circuit breaker with its ETU 320 must be replaced by a 3VA2 molded case circuit breaker with an ETU 350. The protection of I_{kminB} can then be achieved using the short-time delay short-circuit release (S), and total selectivity can be implemented by the instantaneous short-circuit release (I) permanently set to its maximum value in the dynamic selectivity zone.

The selection of the circuit breakers and the overload release (L) setting of the upstream 3VA2 630A molded case circuit breaker are based directly on the first characteristic curves diagram.

The short-time delay short-circuit release (S) of the upstream 3VA2 630A molded case circuit breaker with ETU 350 is set to I_{sd} = 2000 A so that this breaker (when the tolerances of +10 % are also taken into account) can trip below I_{kminB} = 2.3 kA within 5 s at installation point B.

The short-time delay has been set to 0.15 s.

Nonetheless, the tripping characteristics with the relevant tolerances of the two circuit breakers overlap in the instantaneous short-circuit zone. In order to ensure that selectivity and prompt, reliable interruption of the potential short-circuits I_{kminB} can still be achieved, however, the dynamic selectivity within the zone marked in yellow is applied. Using the selectivity tables (see "FAQs (https://support.industry.siemens.com/cs/de/en/view/97493202)" in Siemens Industry Online Support (SIOS)), chapter 3.2, it is possible to implement total selectivity with the upstream 3VA2 630 A molded case circuit breaker and the downstream 3RV1 circuit breaker, size S2 for motor protection up to their rated ultimate short-circuit breaking capacity I_{cu} = 50 kA at 400 V AC.

This example demonstrates that dynamic selectivity can be used to achieve reliable tripping of the two circuit breakers on the basis of the short-circuit current calculation for this network while still implementing total selectivity.

3.6 Dynamic selectivity

Dynamic selectivity is fundamentally different to current and time selectivity.

Circuit breakers suitable for this application

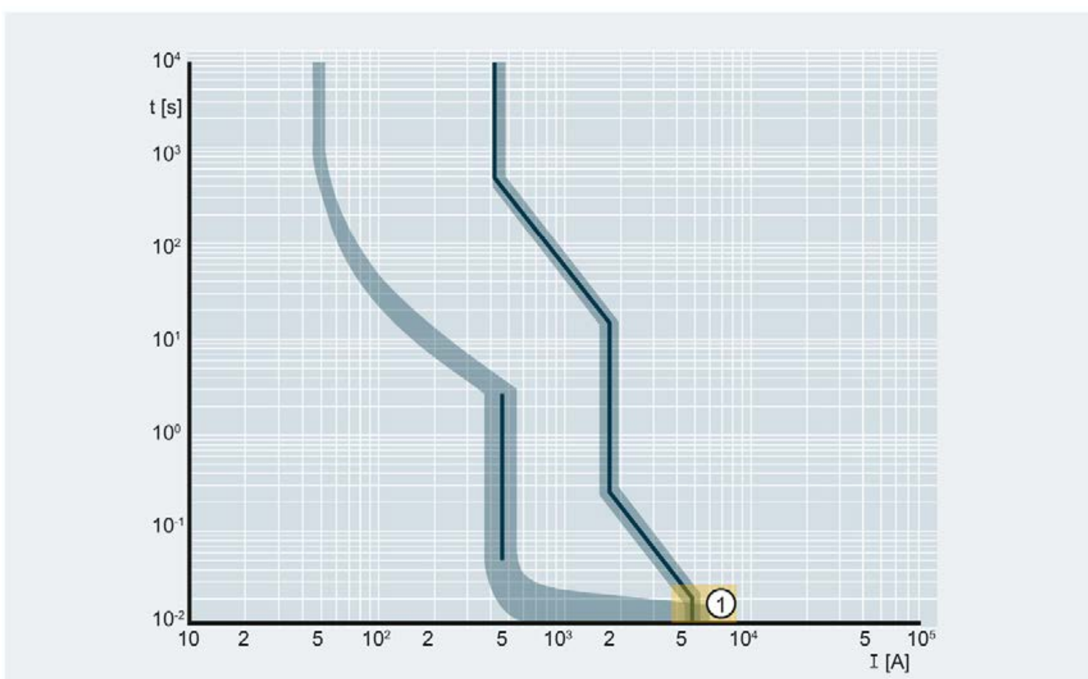
Molded case circuit breakers are used to implement dynamic selectivity because it is a concept that utilizes the current-limiting properties of these devices (see chapter "Implementation of dynamic selectivity (Page 41)").

It is not meaningful to deploy air circuit breakers in dynamic selectivity systems because these devices are so-called "zero-current interrupters" that are not capable of current-limiting tripping behavior. It is however possible to combine downstream molded case circuit breakers with upstream air circuit breakers and this solution can be beneficial in certain situations.

Combinations of current-limiting molded case circuit breakers with fuses or circuit breakers that also have current-limiting capabilities are also possible in dynamic selectivity systems.

Dynamic selectivity zone

In current and time selectivity systems, the parameters or tripping characteristics of the upstream and downstream current-limiting circuit breakers are set specifically for the purpose of implementing selectivity. Whether total or partial selectivity has been achieved can be verified by mapping the tripping characteristics. This verification is possible, however, only if the current curve does not deviate from the sinusoidal shape. This applies to tripping characteristics only in the zone above 100 ms.



① Dynamic selectivity zone

Figure 3-11 Tripping characteristics and dynamic selectivity

With the dynamic selectivity concept, current-limiting circuit breakers are not only coordinated according to their current-time response, but also on the basis of the energy that they let through in the event of a short-circuit. If the let-through energy exceeds the tripping energy assigned to a circuit breaker, the breaker will trip.

In order to implement selectivity between current-limiting circuit breakers, the let-through energy of the downstream device must be lower than the tripping energy of the upstream device. If the short-circuit current exceeds the selectivity limit current (I_s), however, both circuit breakers will trip.

Advantages of dynamic selectivity

- Fast tripping times (a few milliseconds)
- Low thermal and mechanical loading of power distribution equipment
- Selective response up to high values in the short-circuit zone, even with category A circuit breakers
- By contrast with time selectivity, molded case circuit breakers can be used to implement total selectivity up to the rated ultimate short-circuit breaking capacity I_{cu}.

3.6.1 Implementation of dynamic selectivity

Dynamic selectivity cannot be achieved using the LI/LSI protective function, but requires instead an additional tripping mechanism.

In order to implement dynamic selectivity with molded case circuit breakers, the short-circuit zone is divided into two ranges:

- Low short-circuit current range

  A tripping delay corresponding to a few milliseconds is permanently implemented in circuit breakers for low short-circuit currents.

- High short-circuit current range

  Accelerated instantaneous tripping is implemented as the breaker's response to high short-circuit currents.

  This ensures that the circuit breaker will not be irreparably damaged by the short-circuit current.

The resulting "dual tripping principle" is a feature of the new Siemens 3VA2 molded case circuit breakers for "Selectivity Applications". In the high short-circuit current range, an additional mechanical tripping mechanism (energy release) within the switching pole trips the circuit breaker.

This tripping mechanism exploits the fact that the forces caused by current flow at high short-circuit currents cause the contacts of current-limiting molded case circuit breakers to open by themselves. Arcs form at the contacts as they open. The arcing power generated in the pole cassettes of the circuit breakers can be evaluated. This arcing power correlates with the let-through energy and can therefore act as a criterion for the energy release.

A tripping mechanism is integrated in the switching poles of 3VA2 molded case circuit breakers. At very high short-circuit currents, this mechanism uses the resultant arcing power to move a mechanical lever. This lever trips the circuit breaker very quickly.

Dual tripping principle and selectivity

If a short-circuit produces a current lower than the selectivity limit current (I_s) in a combined circuit breaker arrangement, the instantaneous tripping mechanism in the downstream circuit breaker responds and trips the circuit breaker. From the viewpoint of the upstream circuit breaker, the short-circuit current is within the selectively-delayed short-circuit tripping zone. The minor delay in tripping is enough to ensure that the upstream circuit breaker does not trip. The behavior of the circuit breakers is thus selective.

If the short-circuit current is higher than the selectivity limit current (I_s), the instantaneous tripping mechanism in the upstream circuit breaker responds immediately and trips the circuit breaker.
In this case, the circuit breaker combination does not behave selectively.

Tripping energy is an intrinsic property of circuit breakers. Selectivity is calculated on the basis of close coordination between combined devices.

Further information about the mutual selective behavior of 3VA2 molded case circuit breakers as a function of the prospective current can be found in the FAQs (https://support.industry.siemens.com/cs/de/de/view/97493202) in the Siemens Industry Online Support (SIOS).

Note

Reduced selectivity limit currents

The high selectivity limit currents of the 3VA molded case circuit breakers can be attained only with combinations of devices from the 3VA series. Combinations of devices from other product ranges generally result in significantly reduced selectivity limit currents.

Further advantages of the dual tripping principle

- The dual tripping principle ensures that the upstream circuit breaker is capable of safely interrupting all short-circuit currents. This applies even if the upstream circuit breaker is not supported by the current-limiting action of a downstream circuit breaker and the upstream device must cope alone with all prospective short-circuit currents.
- Thanks to this principle, a 3VA2 molded case circuit breaker can be safely deployed as either an upstream or a downstream circuit breaker.
  In order to ensure that grading can be implemented across multiple rated operational current ranges, the breakers from the 3VA2 series are mutually harmonized in terms of all aspects of their tripping behavior. The selectively-delayed short-circuit tripping function, for example, is graded and set to longer delay times for higher rated operational currents.

3.6.2 Let-through energy diagram

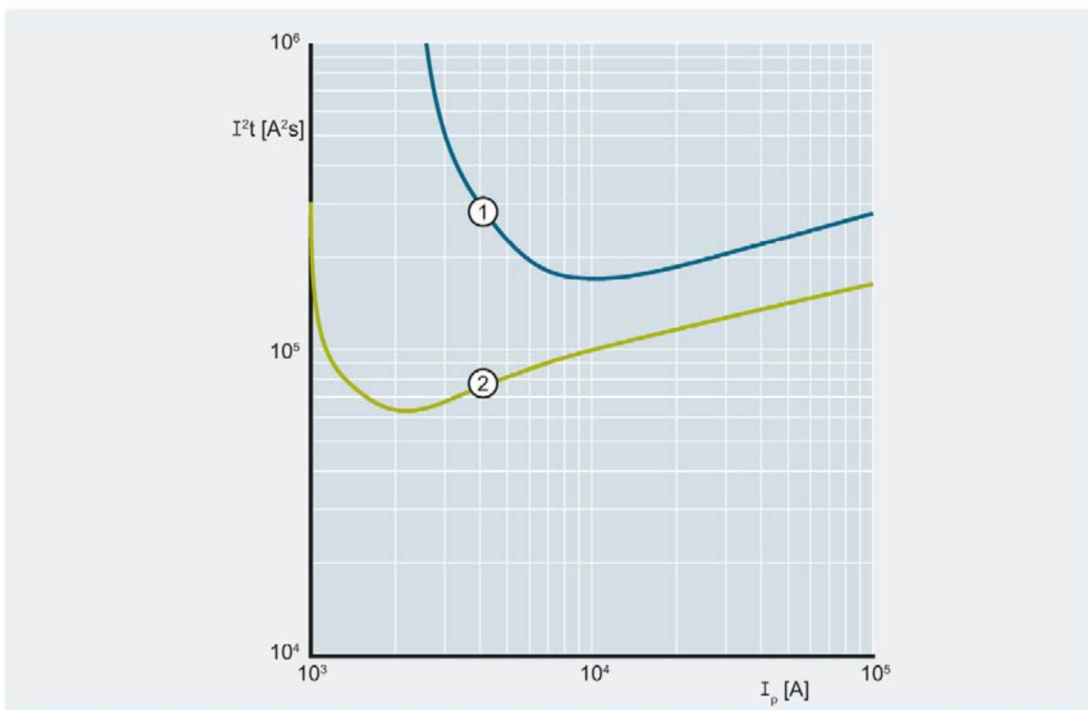
The current-limiting capabilities of molded case circuit breakers are a feature that is particularly utilized in dynamic selectivity systems.

According to IEC 60947-2, 2.3, the term "current-limiting circuit breaker" refers to a circuit breaker "with a break-time short enough to prevent short-circuit current reaching its otherwise attainable peak value". In other words, the let-through current and the other variables dependent on the let-through current (such as the let-through energy) are significantly reduced by the current-limiting capability of the circuit breaker.

It has become established practice to apply the integral of the square of the current over a given time, otherwise known as the Joule integral Q, as a unit of measure of current-limiting capability:

$Q = \int i^2 dt$

The I^2t characteristic of the circuit breaker is selected as a means of representing the let-through energy of a circuit breaker as a function of the prospective current (I_p) according to DIN EN 60947-2, 2.18.



① Let-through energy of the upstream 630 A circuit breaker
② Let-through energy of the downstream 250 A circuit breaker

Figure 3-12 I^2t diagram: Examples of let-through energy of 250 A and 630 A circuit breakers

Note

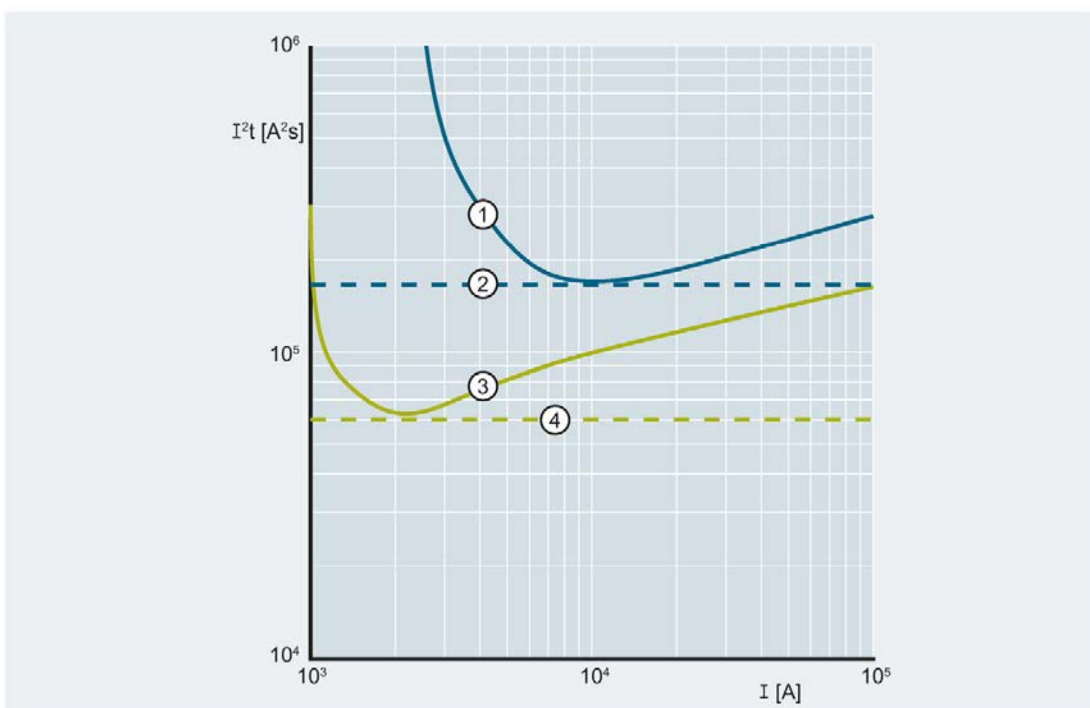
Calculation of let-through energy

The let-through energy is not only determined by the magnitude of the prospective current, but also by the line voltage, line frequency and type of short-circuit (one-pole, two-pole or three-pole). As a result, it can only be calculated on the basis of measurements taken at switching devices or at a specific combination of switching devices, or by simulation based on precise device data and characteristics.

3.6.3 Example

An example is given below to explain the principles of dynamic selectivity. The example is based on the let-through energy values of the circuit breakers from chapter "Let-through energy diagram (Page 43)".

The let-through energy of the 630 A circuit breaker is higher than the let-through energy of the 250 A circuit breaker as of a prospective current (I_p) of around 1100 A. A peak value or a tripping energy value for the let-through energy can thus be assigned to each of the two circuit breakers. When the peak value is exceeded, the circuit breaker must trip.

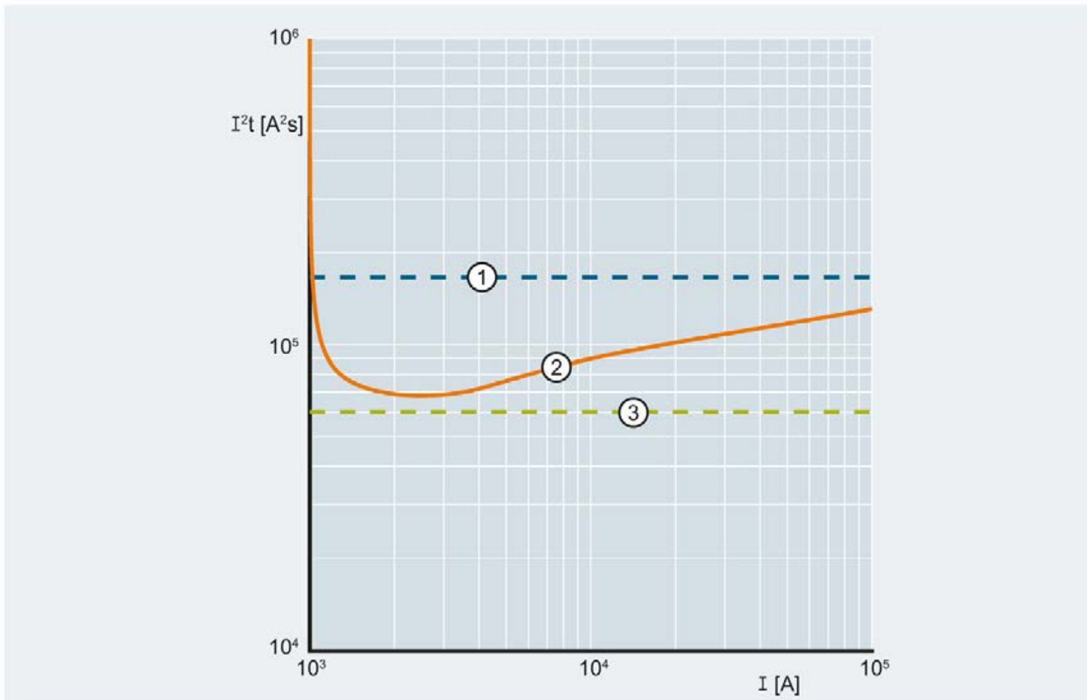


① Let-through energy of the 630 A circuit breaker
② Tripping energy of the 630 A circuit breaker
③ Let-through energy of the 250 A circuit breaker
④ Tripping energy of the 250 A circuit breaker

Figure 3-13 Examples of let-through/tripping energy values and peak values

The characteristic curves shown in the diagram indicate the let-through energy of the relevant circuit breaker if it is limiting and interrupting the short-circuit current on its own.

If the 630 A circuit breaker is located upstream of the 250 A circuit breaker, however, the current-limiting capabilities of both circuit breakers act cumulatively in the event of a short-circuit. The common let-through energy is reduced by an amount that is determined by the 630 A circuit breaker.



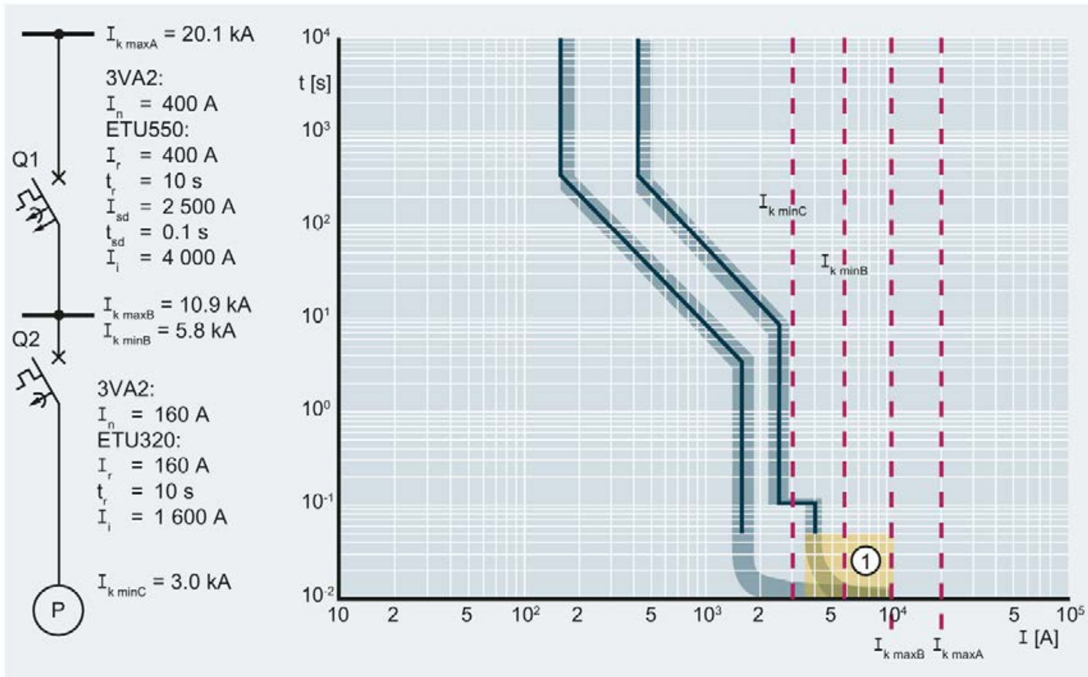
① Tripping energy of the 630 A circuit breaker
② Let-through energy for the combination of 250 A circuit breaker and 630 A circuit breaker
③ Tripping energy of the 250 A circuit breaker

Figure 3-14 Examples of let-through energy values for the combination of 250 A circuit breaker and 630 A circuit breaker

The I^2t diagram shows that the let-through energy of the circuit breaker combination for the prospective current (I_p) zone in this example is higher than the tripping energy of the downstream 250 A circuit breaker. Even at short-circuit currents of 100 kA, the downstream 250 A circuit breaker trips.

The circuit breaker combination performs selectively across the entire short-circuit zone.

Dynamic selectivity in the short-circuit zone



① Dynamic selectivity zone

The diagram shows an example with two 3VA2 molded case circuit breakers (Q1 and Q2) connected in series.

The tolerance bands of the tripping characteristics of the L and I releases do not touch until the current reaches or exceeds 3600 A. In other words, current selectivity is provided up to 3600 A.

In the 3600 A short-circuit current zone or above, it is not possible to reach any clear conclusion about selectivity based on the tripping characteristics. For this reason, circuit breakers that support dynamic selectivity at short-circuit currents higher than 3600 A must be used.
The new 3VA2 molded case circuit breakers have been developed to meet the requirements of dynamic selectivity and do so with short-circuit currents of 3600 A or above. In this example, they also guarantee selectivity in the zone above 3600 A until the selectivity limit current (I_s) is reached.

You can find the selectivity tables as "FAQs (https://support.industry.siemens.com/cs/de/de/view/97493202)" in the Siemens Industry Online Support (SIOS).
According to chapter 2 of these tables, the total selectivity in this example is listed, i.e. the selectivity limit current I_s corresponds to the relevant rated ultimate short-circuit breaking capacity I_{cu} of the downstream 3VA2 160 A molded case circuit breaker.

Selectivity implemented by combinations of protective devices

4

4.1 Molded case circuit breakers and downstream fuse

Note

Tolerance ranges for fuses

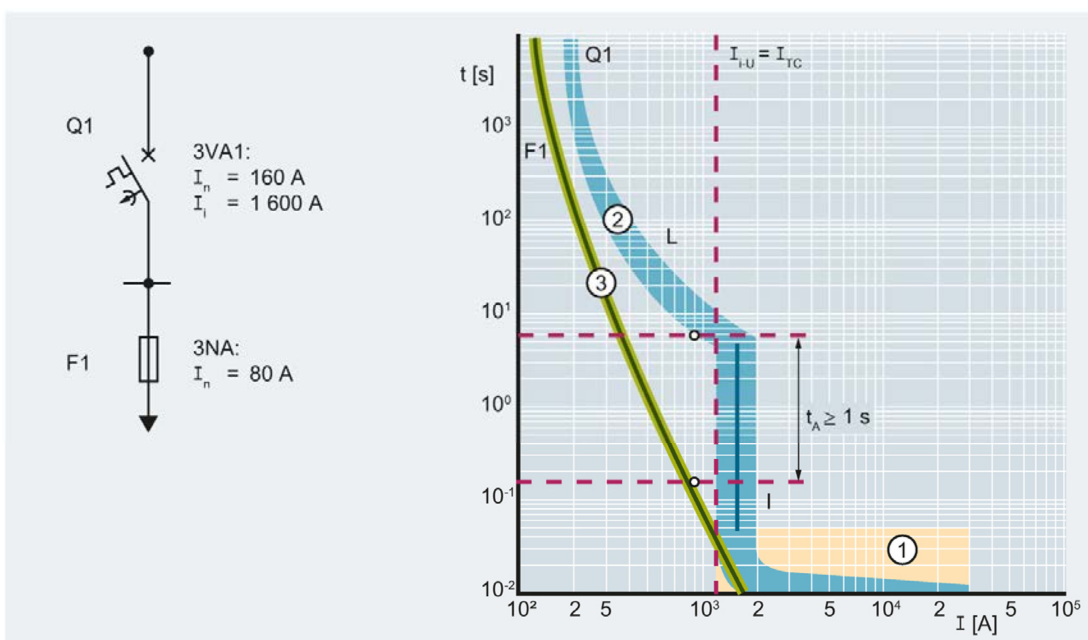
If the selectivity properties of a protective device combination comprising circuit breaker and fuse, it is clear that a permissible tolerance range of ±10 % must be applied to the current-time tripping characteristics of the circuit breakers.

The tolerance range is reduced to ±6 % if Siemens type 3NA LV HRC fuses are used.

Circuit breakers with LI or LSI releases behave selectively in the overload zone with respect to a downstream fuse if a safety margin t_A of around 1 s is provided between the top edge of the tolerance band of the time-current characteristics and the lower tripping characteristic of the L release.

The times specified are empirical values and also take into account the data for the products of other manufacturers.

Circuit breaker without an S release



① Dynamic selectivity zone
② Tripping characteristic
③ Time-current characteristic

The diagram demonstrates that no current selectivity is provided with a short-circuit current I_K ≥ 1000 A. Instead, the 3VA2 molded case circuit breaker is designed to afford dynamic selectivity. The selectivity limit current I_S is determined according to the selectivity table (see FAQs (https://support.industry.siemens.com/cs/de/de/view/97493202) in the Siemens Industry Online Support (SIOS)).

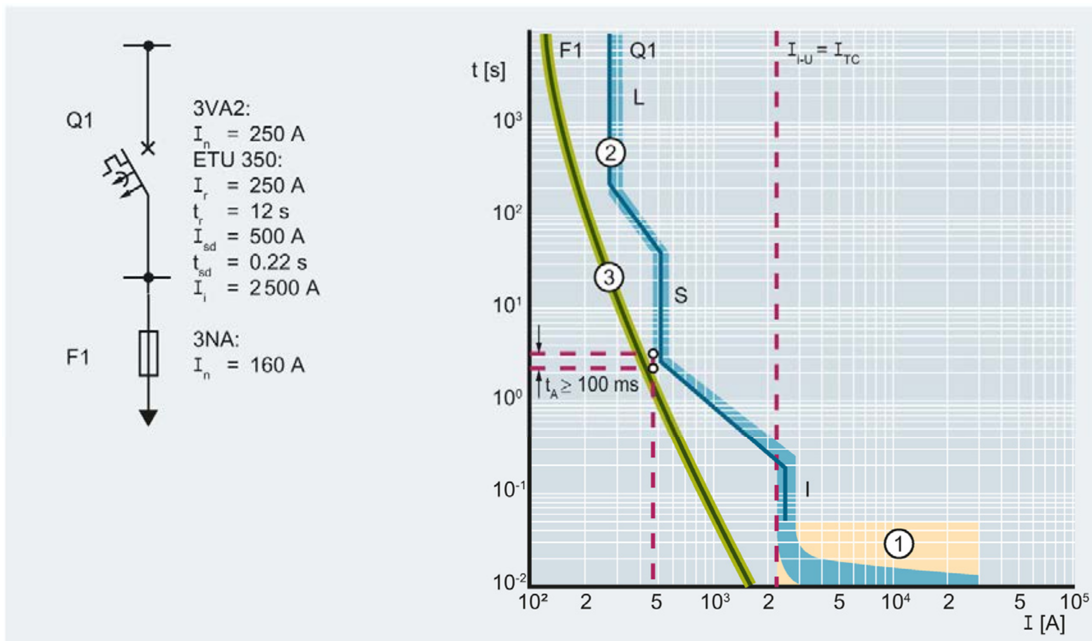
Total selectivity in the event of a short-circuit is afforded by circuit breakers without a time-delay short-circuit release (S release) only in cases where the let-through current I_D of the LV HRC fuse does not reach the lower tolerance value I_{sd-u} of the delay time of the I release.

Only a fuse with a very low rated current relative to the rated uninterrupted current of the circuit breaker can be expected to provide total selectivity. If the fuse does not meet this requirement, the rules applicable to dynamic selectivity must be observed. (See chapter "Dynamic selectivity (Page 40)")

This graph showing the time-current characteristics of fuses for calculation of selectivity applies only to tripping times in excess of 100 ms. For tripping times shorter than 100 ms, the I_2t values specified in DIN VDE 0636-2, Table 113 "Test currents and I_2t limits for selectivity testing" must be applied. For fuse operating times of < 100 ms, the pre-arcing times and the arcing time must be taken into account. For fuse operating times of > 100 ms, the other time-current characteristics can be applied.

Circuit breaker with an S release

In order to ensure selective interruption of short-circuits when circuit breakers with delayed short-circuit release are used, the safety margin between the lower tolerance value t_{sd-u} of the S release delay time and the upper tolerance band t_{S-O} of the time-current characteristic must be at least about 100 ms.



① Dynamic selectivity zone
② Tripping characteristic
③ Time-current characteristic

Further information

The characteristics for Siemens 3NA LV HRC fuses can be found in the Configuration Manual "Fuse Systems", order number 3ZW1012-3NW10-0AB1.

4.2 Fuse and downstream molded case circuit breaker

Note

Tolerance ranges for fuses

If we analyze the selectivity properties of a protective device combination comprising a fuse and circuit breaker, it is clear that a permissible tolerance range of ±10 % must be applied to the current-time tripping characteristics of the circuit breaker.

The tolerance range is reduced to ±6 % if Siemens type 3NA LV HRC fuses are used.

Overload

Circuit breakers with LI or LSI releases behave selectively in the event of an overload with respect to an upstream LV HRC fuse if a safety margin t_A of around 1 s is provided between the lower tolerance band of the time-current characteristic and the upper tripping characteristic of the inverse-time delay overload release (L release).

Short-circuit

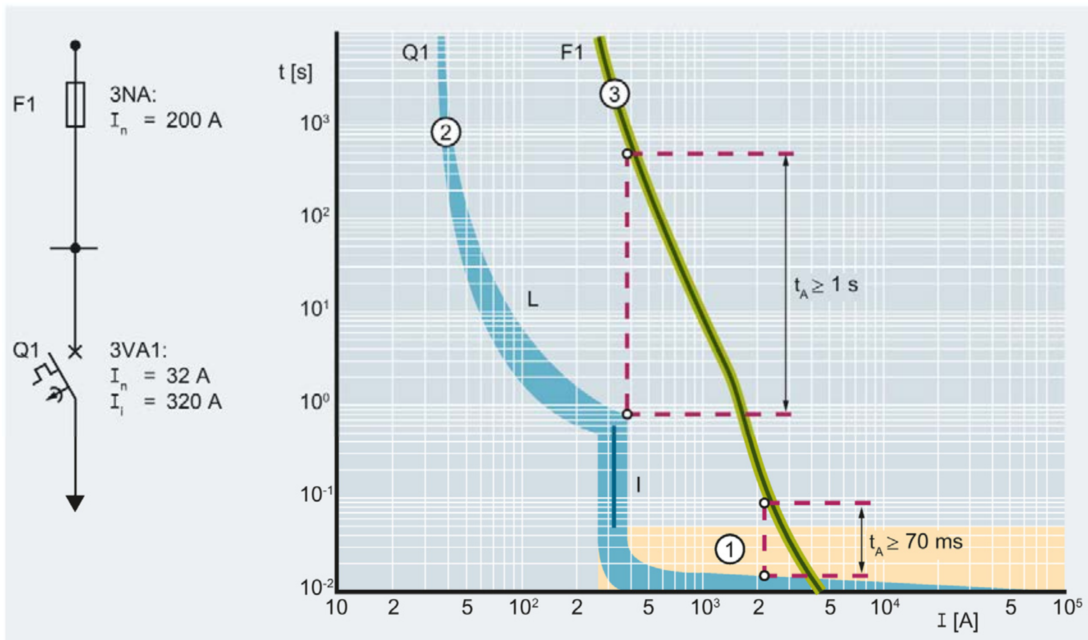
It must be taken into account that the fuse heats up during the arcing time in the event of a short-circuit. A time interval of approximately 70 ms in the short-circuit zone is sufficient in practice to afford total selectivity. As an alternative, the maximum let-through energy values of the molded case circuit breaker can be compared to the minimum pre-arcing energy of the fuse.

Selectivity limit current I_s

The selectivity limit current I_s cannot be graphically represented with any precision in the tripping characteristic. This is because the LV HRC fuse is heated by the short-circuit current during arc extinction.

Example

The selectivity limit current for selectivity implemented between a circuit breaker and an LV HRC fuse approximately corresponds to the value at which a safety margin t_A of not less than around 70 ms is maintained between the lower tolerance band of the time-current characteristic and the upper tolerance value of the operating time of the instantaneous over-current release (I release), or the delay time of the short-time delay over-current release (S release).



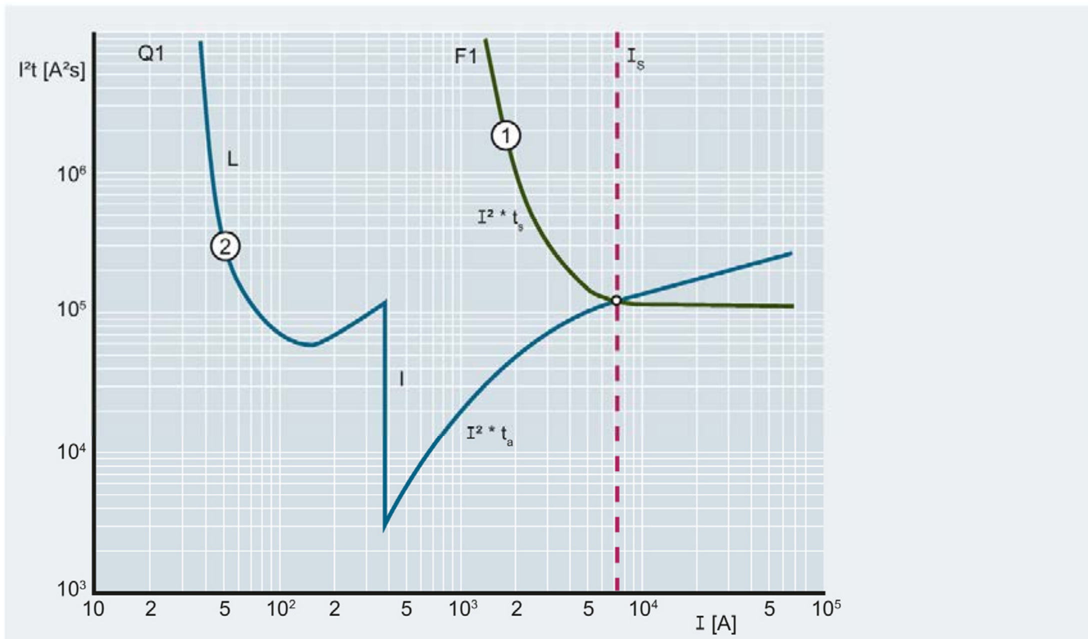
① Dynamic selectivity zone
② Tripping characteristic
③ Time-current characteristic

The diagram above indicates that the selectivity limit current (I_s) is approximately 2200 A.

According to the selectivity table, the selectivity limit value (I_s) is 7.9 kA (see "FAQs (https://support.industry.siemens.com/cs/de/de/view/97493202) chapter 7" in the Siemens Industry Online Support (SIOS)).

A safer, and in most cases, higher selectivity limit value (I_s) can be calculated from the I^2t diagram.

The maximum let-through I^2t_a value of the circuit breaker is compared to the minimum pre-arcing I^2t_S value of the fuse in this diagram. Since this diagram only compares extreme values, tolerances are not taken into account.



① Pre-arcing energy of the fuse
② Let-through energy of the circuit breaker

It is possible to read a far more precise selectivity limit current (I_s) value from the I^2t diagram. This value is approximately 7300 A in the above example.

Further information

The pre-arcing time-current characteristics for Siemens 3NA LV HRC fuses can be found in the Configuration Manual "Fuse Systems", order number 3ZW1012-3NW10-0AB1.

4.3 Fuse and downstream miniature circuit breaker

The behavior of a fuse relative to a downstream miniature circuit breaker corresponds to the behavior of a fuse relative to a downstream molded case circuit breaker with fixed thermal fixed magnetic trip unit (FTFM TMTU) at low short-circuit currents.

4.4 Fuse and downstream fuse

The incoming feeder currents are usually different from the outgoing feeder currents in electrical installations. Protective devices including fuses of different rated currents are therefore provided to protect them. In the event of a short-circuit, the same short-circuit current I_K flows through both fuses.

Total selectivity is provided if the I^2t_s pre-arcing value of the upstream fuse is higher than the I^2t_a operating value of the downstream fuse.

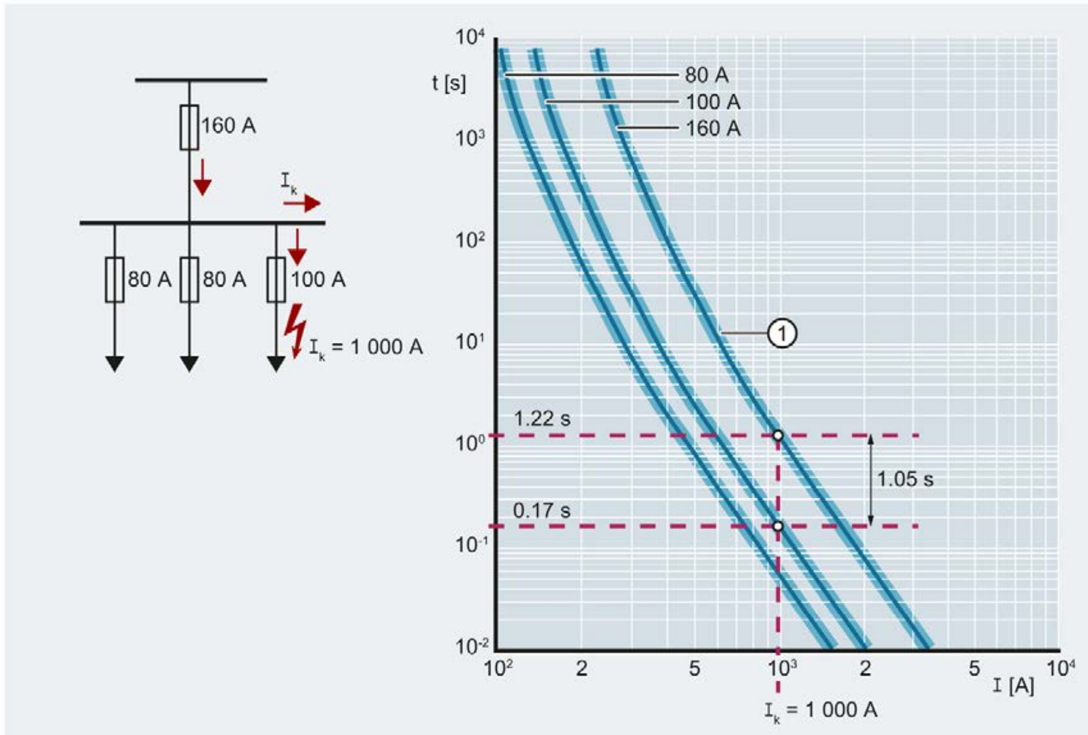
In order to fulfill this condition, the rated currents of the series-connected LV HRC fuses must differ by a factor of 1.6 or more. This relationship is also determined according to the tolerance ranges for characteristics of ±10 % defined in IEC 60269-1, the standard for low-voltage fuses, and the pre-arcing and operating I^2t values for selectivity assessment that are specified in this standard.

Note

Siemens fuses

Siemens fuses have a tolerance band of only ±6 %, a positive feature which is also beneficial with respect to selectivity. For 400 V applications, Siemens fuses are even selective in the 1:1.25 ratio between rated currents.

Example



① Tolerance range of characteristic

Figure 4-1 Current-time diagram for LV HRC fuse tripping characteristics

The characteristics and their tolerance ranges do not touch. Total selectivity is assured.

Since the rated currents of the two affected fuses in this example are graded in a ratio of 100:160 = 1:1.6, it can be assumed that the system is totally selective even without analysis of the current-time diagram.

Sources of information and other documentation

Fuse Systems
BETA Low-Voltage Circuit Protection
Technology Primer
Order No.: E10003-E38-10T-G3021

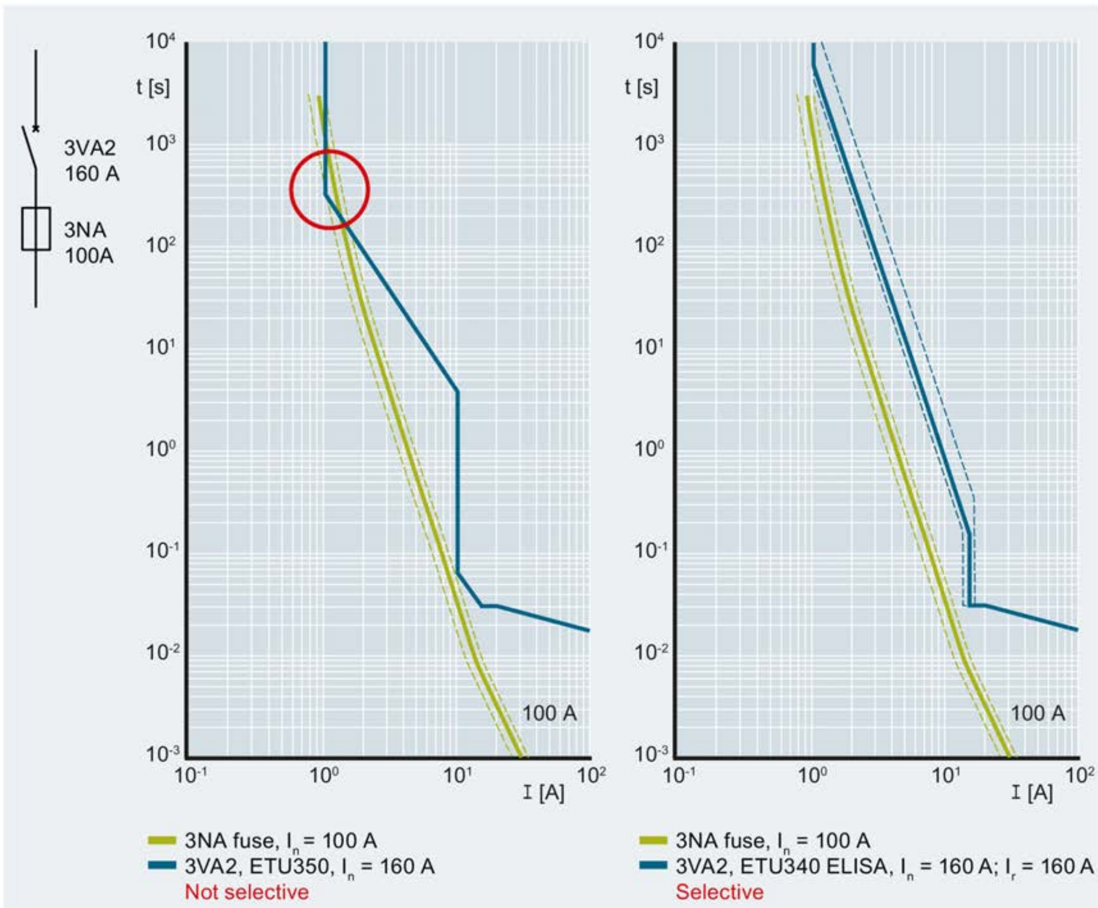
3VA2 molded case circuit breaker with ELISA

The 3VA2 molded case circuit breaker with the electronic trip unit (ETU) 340 ELISA has been specially developed for implementing selectivity with LV HRC fuses.

As described in previous chapters, there are many conditions that need to be fulfilled in order to implement selectivity between an LV HRC fuse and a molded case circuit breaker because the characteristic curves of these two devices are different.

Siemens has now succeeded in developing a tripping characteristic for the ETU 340 of the 3VA2 molded case circuit breaker that has a similar characteristic curve to LV HRC fuses over the entire over-current zone. It has thus been possible to minimize the margin between the rated current of the fuse and the rated current I_{rated} of the molded case circuit breaker and it is within this margin that selectivity is implemented.

Previous selectivity assessments indicated that an upstream molded case circuit breaker with a rated current I_{rated} of at least 250 A would be required if a 100 A LV HRC fuse were installed downstream.



Thanks to the ELISA function of the ETU340 of the 3VA2 molded case circuit breaker, for example, total selectivity is afforded between an upstream 3VA2 molded case circuit breaker with a rated current I_{rated} of just 160 A and a downstream 100 A LV HRC fuse. This advantageous feature allows users to choose cheaper circuit breakers and configure additional grading levels more easily in low-voltage networks.

Selectivity with parallel incoming feeders 5

Selectivity with parallel incoming feeders can be implemented in various different scenarios. The following scenarios are presented in this chapter:

- Selectivity with two identical incoming feeders
- Selectivity with three identical incoming feeders
- Selectivity with incoming feeders connected in parallel via bus-couplers

Total short-circuit current and current scale

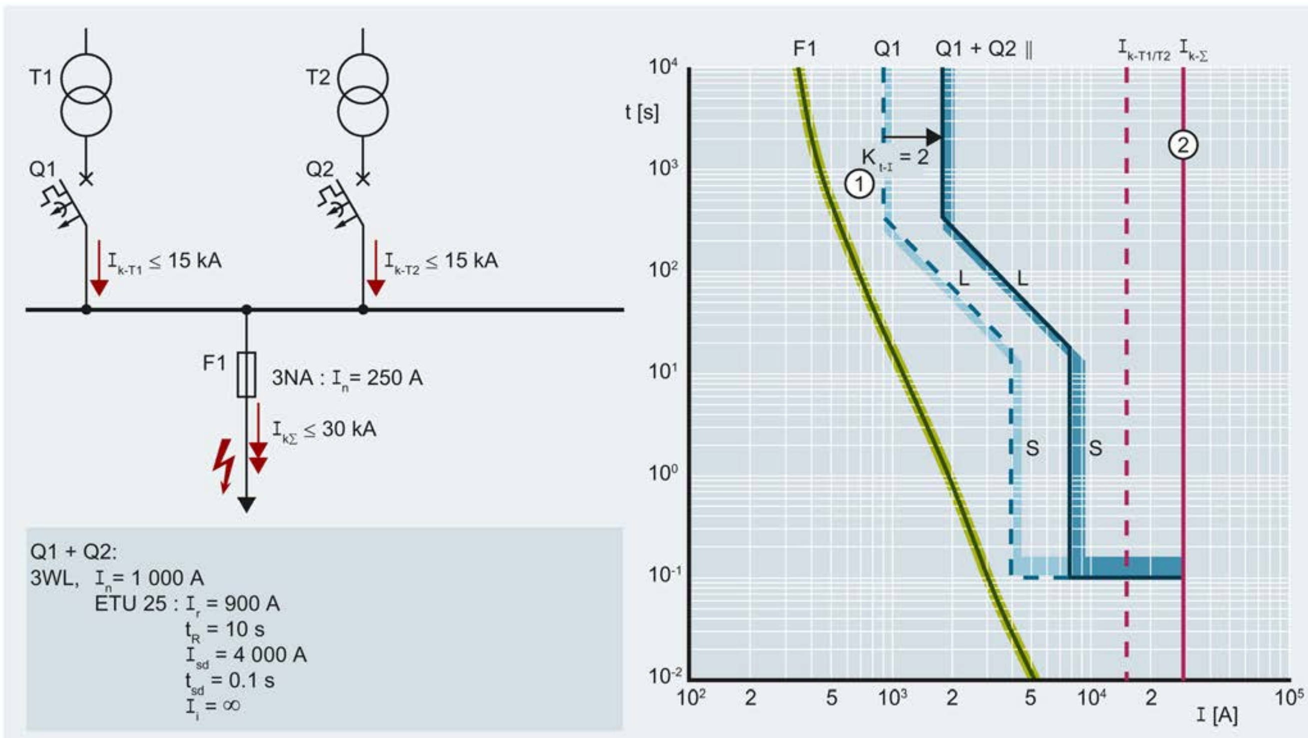
If multiple transformers are operated on a common busbar, the following applies:

The partial short-circuit currents $I_{K\text{-}Ti}$ of the incoming feeders are added together to produce the total short-circuit current $I_{k\Sigma}$ in a faulty feeder.

The total short-circuit current $I_{k\Sigma}$ forms the basis for the current scale in the grading diagram. This offers the advantage of making the selectivity conditions more favorable for all protective devices downstream of the incoming feeder circuit breaker. This applies to all types of fault.

5.1 Selectivity with two identical incoming feeders

The figure below shows an example of the distribution of short-circuit currents in a faulty outgoing feeder that is supplied by two parallel-connected transformers with the same power rating.



① Characteristic displacement factor
② Total short-circuit current

Figure 5-1 Selectivity with two parallel-connected transformers with the same power rating

A total short-circuit current $I_{k\Sigma}$ which is the sum of the partial short-circuit currents $I_{k\text{-}T1}$ and $I_{k\text{-}T2}$ flows through the fuse F1.

5.1.1 Symmetrical distribution (ideal scenario)

Symmetrical distribution of the short-circuit current occurs when the following conditions are fulfilled:

- The load feeder is positioned exactly in the center.
- The load currents in other feeders are disregarded.

In this ideal scenario, the total short-circuit current is evenly distributed between both incoming feeders.

As a result, the tripping characteristic of the circuit breakers Q1 and Q2 can be shifted by the characteristic displacement factor $K_{t-I} = 2$ to the right on the current scale to the basis for the fault scenario $I_{k\Sigma}$.

By moving the tripping characteristic to the right, it becomes possible to implement time selectivity and improve the quality of current selectivity.

5.1.2 Asymmetrical distribution

If the incoming and outgoing feeders are not arranged symmetrically on the busbar, there will be variations in the distribution of the short-circuit current.

Depending on the impedance ratio of the transformers and incoming feeders, the characteristic displacement factor K_{t-I} can be calculated as follows:

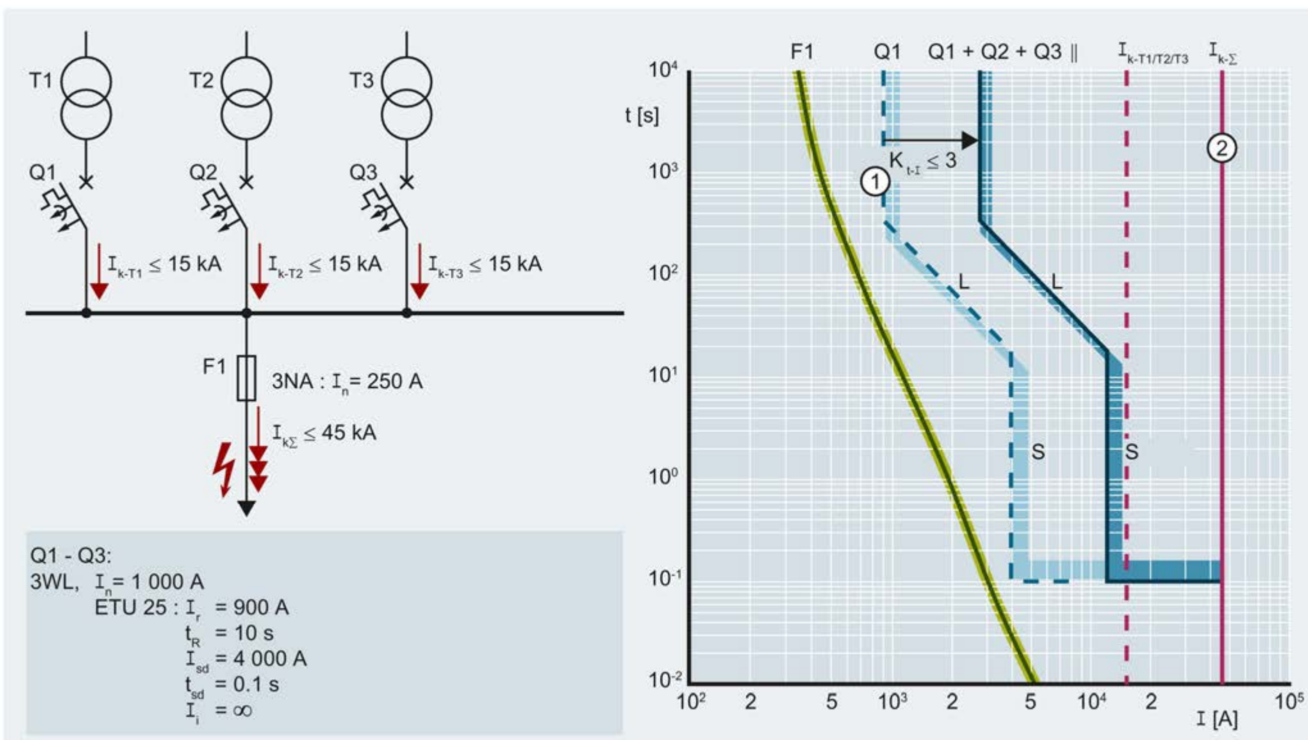
$$K_{t-I} = \frac{I_{k\Sigma}}{I_{k-T_i}}$$

$I_{k\Sigma}$ Total short-circuit current
I_{k-T_i} Partial short-circuit current i proportional to $I_{k\Sigma}$ across transformer circuit breaker

5.2 Selectivity with three identical incoming feeders

5.2.1 Fault within the protection zone of the downstream protective device

With three parallel-connected transformers, effective current selectivity can be achieved because the characteristic displacement factor for the incoming feeder circuit breakers Q1, Q2 and Q3 is within the range $2 < K_{t-I} \leq 3$.



① Characteristic displacement factor

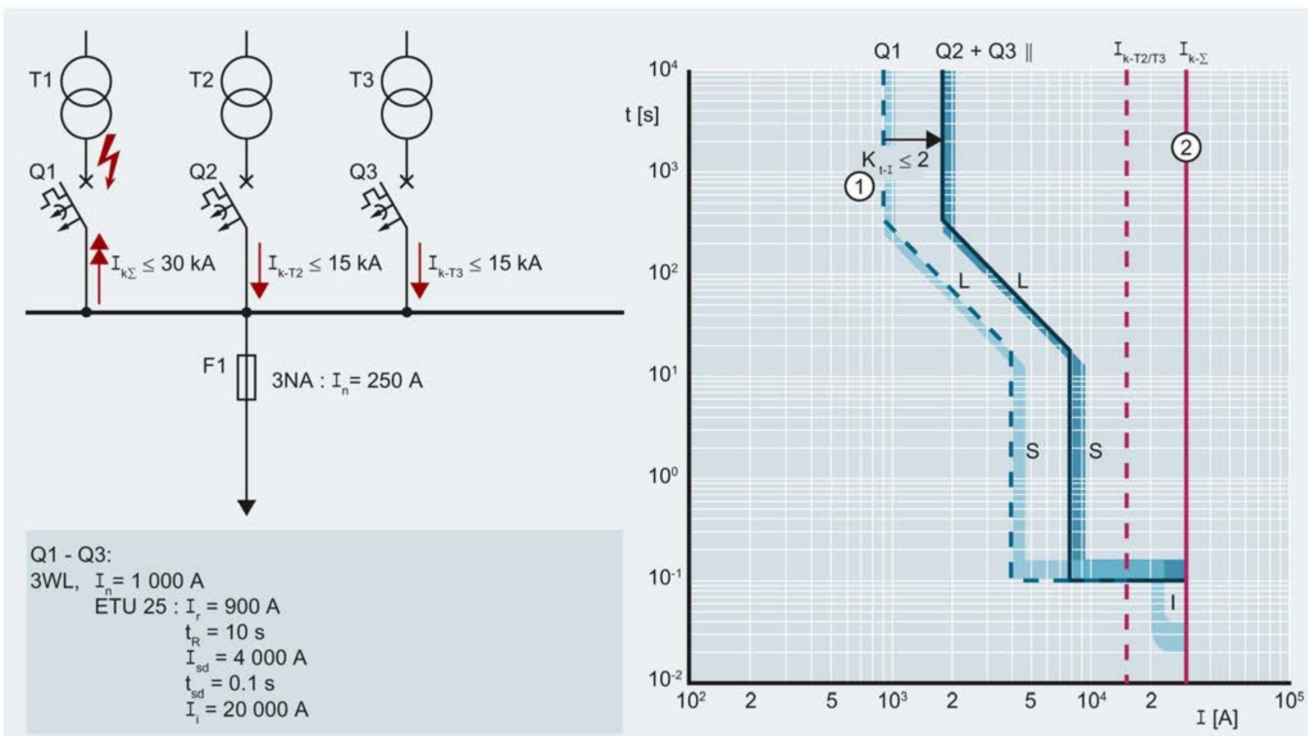
② Total short-circuit current

5.2.2 Fault between transformer terminals and incoming feeder circuit breaker

Symmetrical fault current distribution

The instantaneous short-circuit release (I release) must be set in such a way that its value is higher than the partial short-circuit currents $I_{k\text{-}Ti}$ of a transformer. This means that only that incoming feeder circuit breaker carrying the total short-circuit current $_{k\Sigma}$ ever trips instantaneously on a secondary-side terminal short-circuit on the transformer. The circuit breakers in the incoming feeders without a fault remain closed because of the delay time t_{sd} set on the S release.

$K_{t\text{-}I}$ = 30 kA / 15 kA = 2 is the ideal characteristic displacement factor for the transformer circuit breakers Q2 and Q3 of the fault-free incoming feeders.



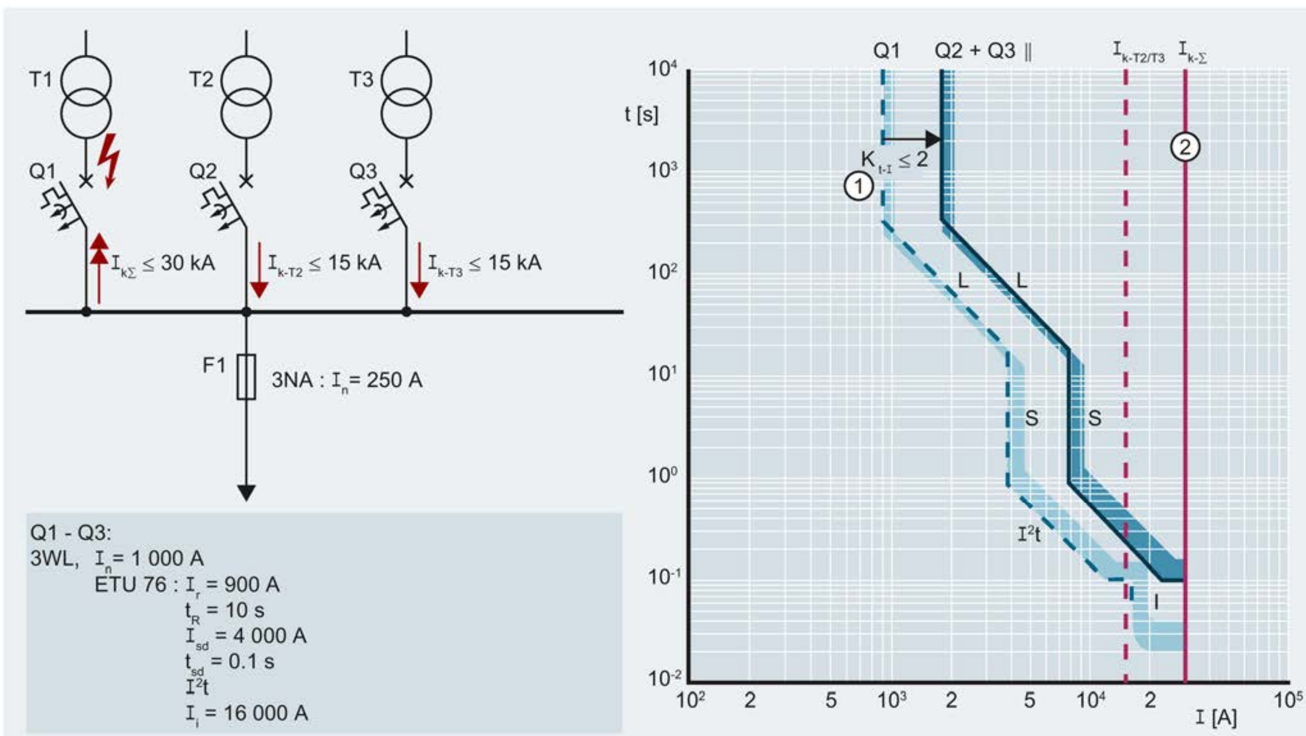
① Characteristic displacement factor

② Total short-circuit current

Asymmetrical fault current distribution

Asymmetrical fault current distribution is the norm as a result of variations in fault impedance among multiple incoming feeders. With sufficient damping by the fault impedance, the total short-circuit current $I_{k\Sigma}$ can be kept so small that instantaneous short-circuit tripping of the transformer circuit breaker in the incoming feeder in which the fault occurred is no longer certain. In such cases, all incoming feeders are tripped simultaneously and thus non-selectively.

In order to prevent non-selective tripping as a result of wide variations in fault impedance, infeed circuit breakers that have an S release with an I^2t-dependent tripping characteristic must be used. The gain in selectivity that can be achieved using S releases with an I^2t-dependent tripping characteristic is shown in the following diagram:



① Characteristic displacement factor
② Total short-circuit current

Figure 5-2 Selectivity with 3 parallel-connected transformers with the same output ratings (terminal short-circuit on secondary side of a transformer, I^2t-dependent fault clearance)

Using S releases with an I^2t-dependent tripping characteristic allows a much improved current-time selectivity to be achieved because there is no contact between the tripping characteristics of the two short-time delay short-circuit releases of circuit breakers Q2 and Q3 over the tripping range of the instantaneous short-circuit release of circuit breaker Q1.

5.3 Selectivity with bus-couplers

If circuit breakers with over-current releases are installed in bus-couplers, the following can be achieved:

- Fastest possible clearance of busbar faults
- Fault restriction to the respective busbar section
- Relieving the feeders of the effects of high total short-circuit currents.

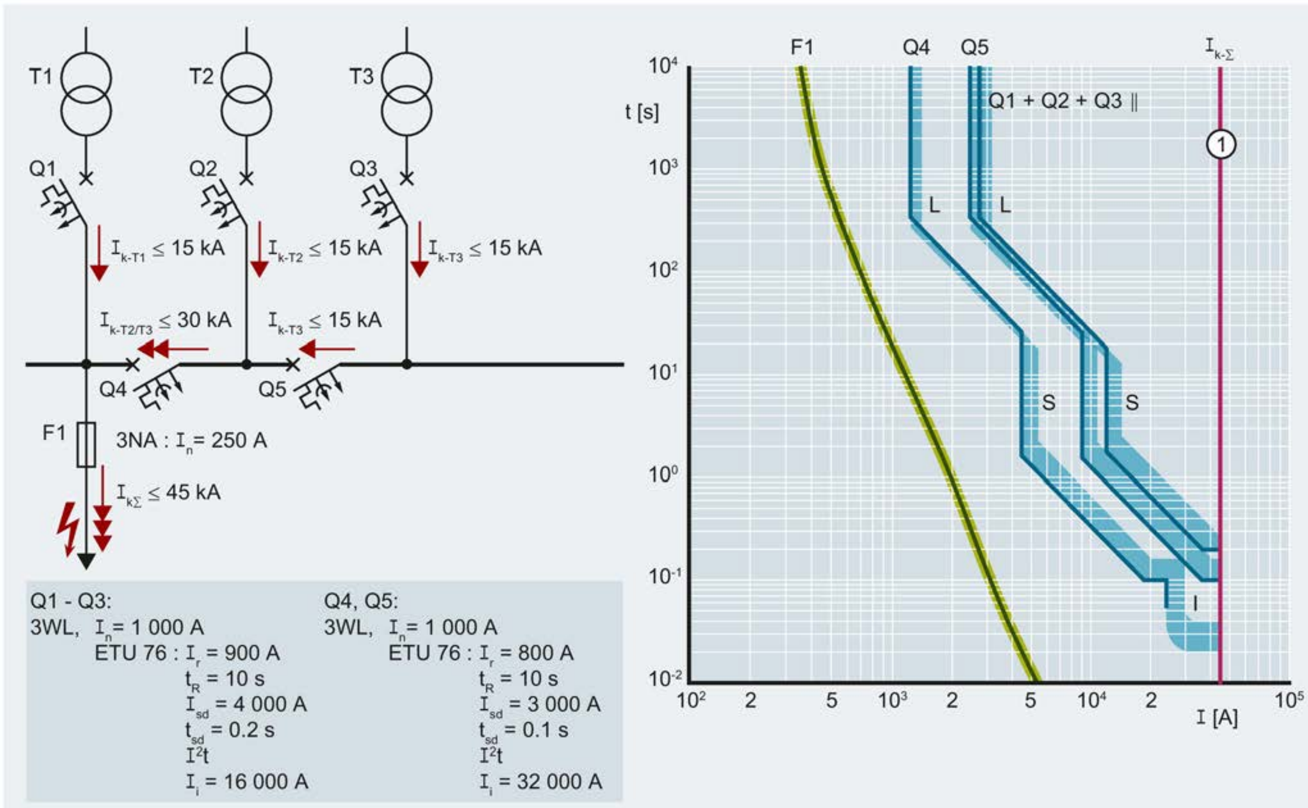
Two parallel incoming feeders

With two parallel incoming feeders, only the partial short-circuit current of one transformer ever flows through the bus-coupler. Selectivity between an incoming feeder circuit breaker and the bus-coupler can thus only be achieved by time grading.

Three parallel incoming feeders

In configurations with three parallel incoming feeders or more, the partial short-circuit currents flowing through the bus-couplers are dependent on the fault location (fault in the outer or center section of the busbar).

The following diagrams show the protective response of the transformer and bus-couplers in reaction to feeder faults in the outer and center sections of the busbar:



① Total short-circuit current

Figure 5-3 Selectivity with an outgoing feeder short-circuit in the outer busbar section

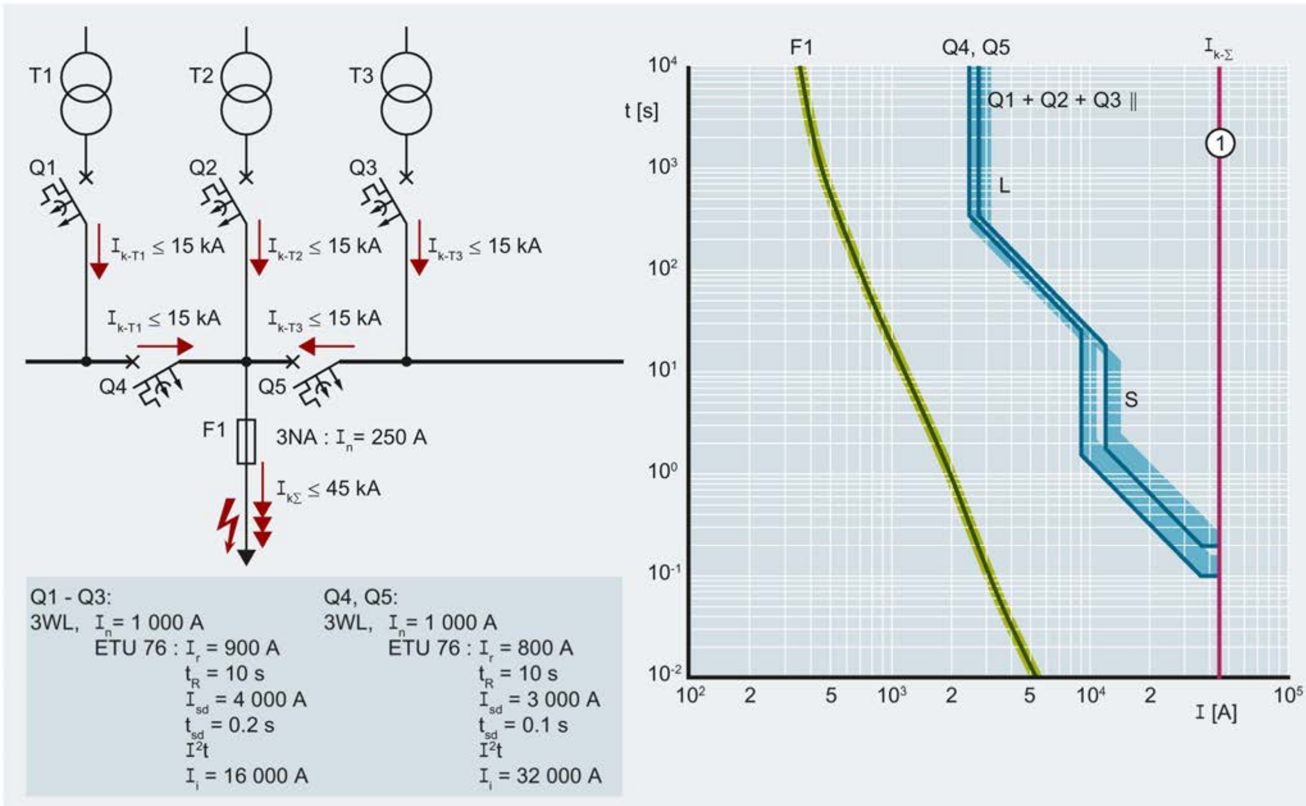
The displacement factor of the tripping characteristics K_{t-I} is as follows:
With a total short-circuit current = 45 kA and
the partial short-circuit currents of the circuit breakers Q1 - Q3, Q5 = 15 kA,
the displacement factor K_{t-I} = 3

The displacement factor K_{t-I} = 1.5 for the bus-coupler Q4, however, because
the total short-circuit current = 45 kA and
the partial short-circuit current of the bus-coupler Q4 = 30 kA

The tripping characteristics of the instantaneous releases are far to the right of the total short-circuit current in the case of circuit breakers Q1 - Q3 and Q5 and are therefore not shown in the diagram.

Protective response

Fuse F1 trips selectively, the circuit breakers Q1 - Q5 remain closed.



① Total short-circuit current

Figure 5-4 Selectivity with an outgoing feeder short-circuit in the center busbar section

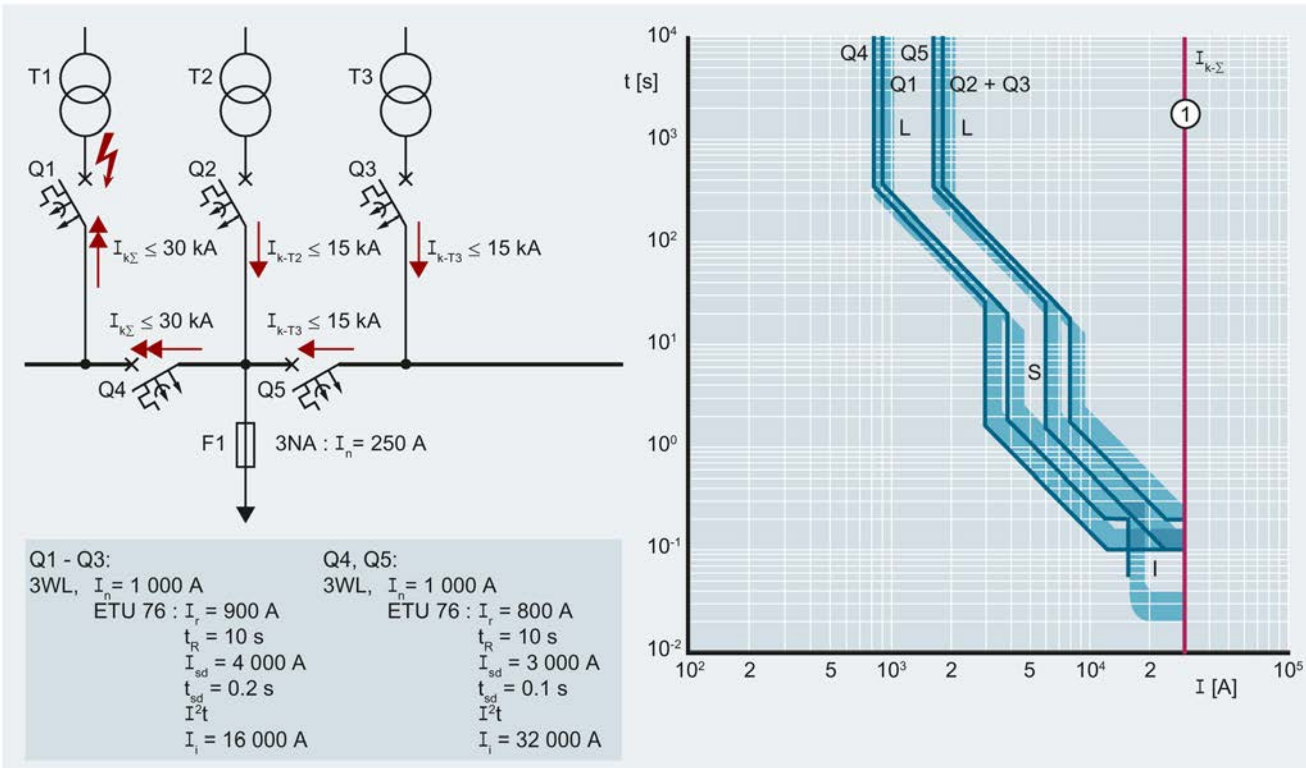
The displacement factor of the tripping characteristics K_{t-I} is as follows:
With a total short-circuit current = 45 kA and
the partial short-circuit currents of all of the circuit breakers Q1 - Q5 = 15 kA,
the displacement factor K_{t-I} = 3

The tripping characteristics of all of the instantaneous releases are far to the right of the total short-circuit current in the case of circuit breakers Q1 - Q5 and are therefore not shown in the diagram.

Protective response

Fuse F1 trips selectively, the contacts of circuit breakers Q1 - Q5 remain closed.

The following diagrams show the protective response in reaction to incoming feeder faults in the outer and center sections of the busbar:



① Total short-circuit current

Figure 5-5 Selectivity with an incoming feeder short-circuit in the outer busbar section

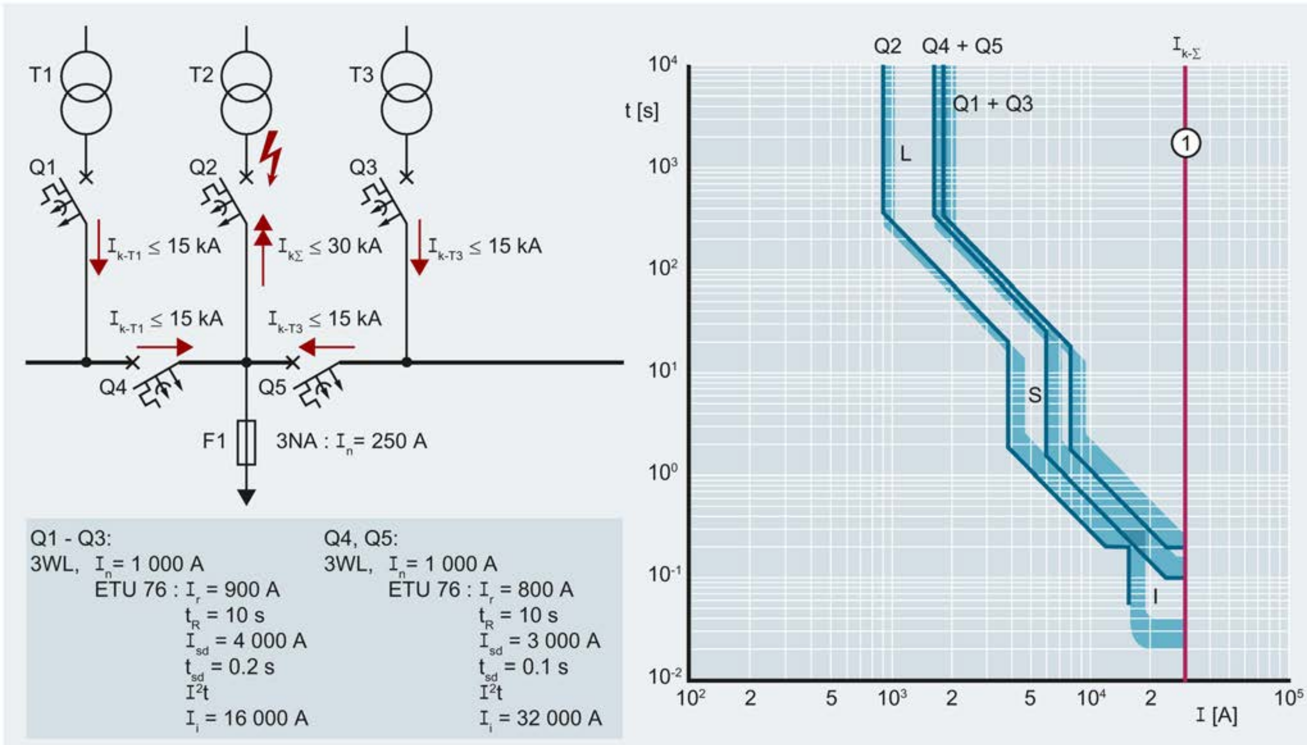
The displacement factor of the tripping characteristics K_{t-I} is as follows:
With a total short-circuit current = 30 kA and
the partial short-circuit currents of the circuit breakers Q2, Q3 and Q5 = 15 kA,
the displacement factor K_{t-I} = 2

The displacement factor K_{t-I} = 1 for the incoming feeder and bus-couplers Q1 and Q4, because
the total short-circuit current = 30 kA and
the partial short-circuit current of the incoming feeder and bus-couplers Q1 and Q4 = 30 kA

The tripping characteristics of the instantaneous releases are far to the right of the total short-circuit current in the case of circuit breakers Q2, Q3 and Q5 and are therefore not shown in the diagram.

Protective response

Circuit breaker Q1 trips instantaneously, the contacts of circuit breakers Q2 - Q5 remain closed.



① Total short-circuit current

Figure 5-6 Selectivity with an incoming feeder short-circuit in the center busbar section

The displacement factor of the tripping characteristics K_{t-I} is as follows:
With a total short-circuit current = 30 kA and
the partial short-circuit currents of the circuit breakers Q1, Q4, Q3 and Q5 = 15 kA,
the displacement factor K_{t-I} = 2

The displacement factor K_{t-I} = 1 for the incoming feeder circuit breaker Q2, however, because
the total short-circuit current = 30 kA and
the partial short-circuit current of the incoming feeder circuit breaker = 30 kA

The tripping characteristics of the instantaneous releases are far to the right of the total short-circuit current in the case of circuit breakers Q1, Q3, Q4 and Q5 and are therefore not shown in the diagram.

Protective response

Circuit breaker Q2 trips instantaneously, the contacts of circuit breakers Q1, Q3 – Q5 remain closed.

The transformer and bus-couplers in the multiple incoming feeder configurations of industrial networks are normally connected in series with other over-current protective devices. As a result, the inclusion of bus-couplers in the selective time grading system may unduly extend the clearance time for near-to-infeed short-circuits.

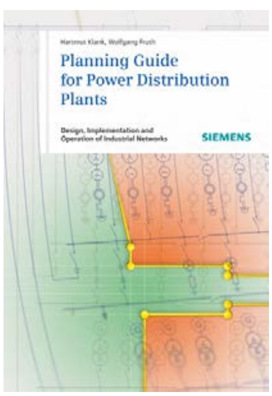
Since a user may have reservations about implementing zone selecting interlocking (ZSI) for reasons of cost, the alternative solution is to dispense with time grading of the S releases of the transformer and bus-couplers.

Apart from setting identical time delays t_{sd}, it is also usual practice to completely eliminate over-current releases from the bus-couplers. In this case, selectivity is afforded as of the range 12 kA and 100 ms - 200 ms if tolerances of +10 % for the circuit breakers are taken into account.

5.4 Sources of information and other documentation

Hartmut Kiank, Wolfgang Fruth: Planning Guide for Power Distribution Plants,
Publicis Publishing
ISBN 978-3-89578-359-3

available from Publicis Publishing, www.publicis.de/books



Selectivity and undervoltage protection 6

In the event of a short-circuit, the line voltage at the short-circuit location collapses to a residual voltage that is dependent on the fault impedance. If the short-circuit is dead, the voltage at the short-circuit location drops to virtually zero.

Short-circuits normally generate arcs with a peak arc voltage U_{LB} within the range of $30 V \leq U_{LB} \leq 70 V$. The residual voltage that persists following a short-circuit increases in the opposite direction to current flow in proportion to the impedance between the fault location and the power source.

It can be seen from the diagram below that the residual voltage at the low-voltage main distribution board (LV-MDB) is higher if the short-circuit is far from the infeed than if it is close to the infeed. If we assume that the residual voltage U_{Res} = 30 V at the fault location, the resultant voltage conditions are as follows:

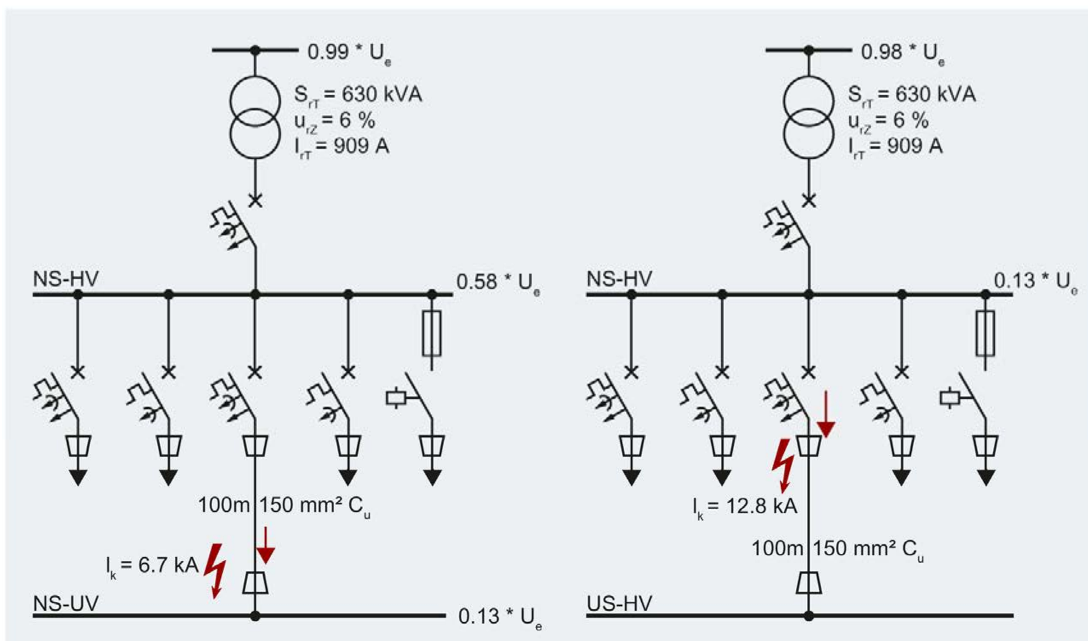


Figure 6-1 Example of voltage conditions after a short-circuit in a low-voltage network
left: far-from-infeed short-circuit, right: near-to-infeed short-circuit

The protective response of circuit breakers with an undervoltage release can be evaluated by measuring the residual voltage at the network nodes (LV-MDB, LV-SDB).

If the rated operational voltage U_e drops to a residual voltage of $0.35 \times U_e \leq U_{Res} \leq 0.70 \times U_e$ and the voltage dip persists for longer than $t_{\Delta u'}$ = 20 ms, all circuit breakers that are equipped with an undervoltage release interrupt the power supply to the loads. No selectivity is afforded in this case.

Implementation of selectivity

Assuming that the operating time of the undervoltage releases $t_{\Delta u'}$ = 20 ms, instantaneous over-current protective tripping must be implemented in $t_a \leq 20$ ms. This applies both to near-to-infeed and far-from-infeed short-circuits. This instantaneous protective tripping ensures that the fault location is selectively disconnected from the network before the undervoltage releases can respond. If instantaneous protective tripping in $t_a \leq 20$ ms cannot be implemented for all the relevant fault locations, the feasibility of using undervoltage releases with drop-out delay must be assessed.

Contactors

In the event that the voltage dips as a result of short-circuits, it is probable that contactors will drop out. Contactors can be expected to drop out if the control supply voltage falls below 80 % of its rated value for longer than 5 - 30 ms.

If instantaneous protective tripping in $t_a \leq 20$ ms cannot be implemented, the feasibility of using contactors with drop-out delay must be assessed.

3VA selectivity tables 7

To ease and speed up the selection of appropriate devices, the most common device combinations are always available on the Internet in the form of regularly updated FAQs:

(https://support.industry.siemens.com/cs/de/en/view/97493202)

More information

The selectivity limit currents for these combinations can also be found in SIMARIS design, the software tool from Siemens for the sizing and protection coordination of low-voltage radial networks: (www.siemens.com/simaris)

For users who only require the tripping characteristics, Siemens offers the software tool SIMARIS curves: (www.siemens.com/simariscurves)

List of abbreviations

A

A.1 List of abbreviations

Overview

Table A- 1 Meaning of abbreviations used in this document

Abbreviation	Meaning
AC	Alternating voltage
AWG	American Wire Gauge: standardized wire gauge system used in North America
DC	Direct voltage
DIN	Deutsches Institut für Normierung e. V. (German Institute for Standardization)
EN	European Standard
ETU	Electronic Trip Unit
FTFM	Fixed thermal fixed magnetic trip unit (permanently set thermal overload trip unit, permanently set magnetic trip unit with short-circuit protection)
I	Instantaneous (short-circuit protection)
IEC	International Electrotechnical Commission
L	Long-time delay (overload protection)
L	Overload release
LI	Overload protection (L) and instantaneous short-circuit protection (I)
LSI	Overload protection (L), short-time delay short-circuit protection (S) and instantaneous short-circuit protection (I)
MTU	Magnetic trip unit with short-circuit protection (I)
LV	Low voltage
LV-MDB	Low-voltage network main distribution board
LV-SDB	Low-voltage network subdistribution board
LV fuse	Low-voltage fuse
S	Short time delay (short-time delay short-circuit protection)
S	Short-time delay over-current release
T	Total selectivity up to the rated ultimate short-circuit breaking capacity of the upstream/downstream protective device
TN [TN system]	French: Terre Neutre
TMTU	Thermal Magnetic Trip Unit
VDE	Verein Deutscher Ingenieure (Association of German Engineers)
ZSI	Zone Selective Interlocking

Table A- 2 Meaning of symbols and abbreviations

Symbol/abbreviation	Meaning
I^2t	Let-through energy
I_{cn}	Rated breaking capacity; rated short-circuit breaking capacity
I_{cu}	Maximum short-circuit breaking capacity (total selectivity); rated ultimate short-circuit breaking capacity
I_{cw}	Rated short-time withstand current; rated short-time current
I_D	Let-through current
I_i	Instantaneous tripping current; instantaneous short-circuit protection; instantaneous magnetic protection; rated tripping current of instantaneous trip
I_k	Short-circuit current
$I_{K\ MAX}$	Maximum short-circuit current
I_{rated}	Rated operational current
I_P	Prospective current
I_r	Thermal protection; setting current; response value; current setting value of adjustable overload protection (pickup value overload protection)
I_s	Selectivity limit current; maximum short-circuit current for selectivity limit
I_{sd}	Short-time delay tripping current; response current of S release; short-time delay short-circuit release; short-time delay short-circuit protection; delay time of S release
K_{t-I}	Characteristic displacement factor
t_A	Safety margin
t_i	"Virtual" trip time of I protection; highest trip time associated with rated tripping current of instantaneous trip
t_r	Trip time associated with current setting value of adjustable overload release
t_{sd}	Trip time associated with short-time delay tripping current; delay time of S release
t_S	Fuse pre-arcing time
t_{ZSI}	Delay time of all molded case circuit breakers which detect the short-circuit but do not receive a "block" signal when ZSI is activated.
U_{LB}	Peak arc voltage

Glossary

Coupler circuit breaker

Current-limiting circuit breaker

According to EN 60947-2, 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".

Delay time t_{ZSI}

Defined non-operation time of all circuit breakers that detect a short-circuit current and/or a ground fault current and do not receive a "block" signal when Zone Selective Interlocking (ZSI) is activated.

Grading time

Grading times are the intervals required between the delay times of individual circuit breakers in order to achieve time selectivity.

Ground fault

An unintentional electrically conducting connection, potentially caused by an arc, between an outer conductor or a normally isolated neutral conductor to ground or to grounded components.

Ground fault current

Current resulting from a ground fault due to a fault or an incorrect connection in an electric circuit

I release

Instantaneous electromagnetic over-current release for instantaneous short-circuit protection in the event of a dead short-circuit

I^2t value

The I^2t value is the thermal value of a prospective or a limited short-circuit current (let-through current).

L release

Inverse-time delay over-current release as overload current protective device

LSI protective function

The LSI protective function is a combination of multiple release types. Circuit breakers with LSI protective function have the following releases:

- Inverse-time delay over-current release (L release) as overload current protection
- Electronic short-time delay over-current release (S release) for delayed short-circuit protection
- Instantaneous electromagnetic over-current release (I release) for instantaneous short-circuit protection in the event of a dead short-circuit

Over-current

Current that exceeds the rated current as defined by IEC / DIN EN 60947-1, 2.1.4

Overload

Operating conditions in an electrically undamaged circuit which cause an over-current as defined by IEC / DIN EN 60947-1, 2.1.7

Overload current

Over-current that flows in an electrically undamaged circuit as defined by IEC / DIN EN 60947-1, 2.1.8

Prospective current Ip

The (prospective) current that would flow if the circuit breaker were to be replaced by a conductor with negligible impedance. The prospective current expresses the value of the short-circuit current that would flow without the circuit breaker.

Rated current In

The rated current for circuit breakers is equivalent to the rated uninterrupted current (I_u) (see 4.3.2.4 of IEC 60947-1) and to the conventional free-air thermal current (I_{th}).

Rated operational current Ie

The rated operational current of a device is specified by the manufacturer and is related to the rated operational voltage, the rated frequency, the rated duty, the utilization category and the enclosure type (if applicable).

Rated operational voltage U_e

Voltage value to which the making capacity, the breaking capacity and the utilization categories of a circuit breaker are referred.

A circuit breaker can have more than one rated operational voltage.

Rated short-circuit breaking capacity I_{cn}

A short-circuit current specified by the manufacturer that a circuit breaker can safely interrupt at the rated operational voltage U_e, the rated frequency and a defined power factor (or defined time constant).

The rated short-circuit breaking capacity is applicable to alternating voltages or to a defined time constant in the case of direct voltages. It is expressed by the prospective current I_p (or by the rms value of the AC component) under specified conditions.

Rated short-time withstand current I_{cw}

Value of the AC component of the prospective short-circuit current which a circuit breaker is capable of conducting for a specific time period, e.g. from 0.05 s to 1 s (1 s current).

A high rated short-time withstand current is typical of a circuit breaker of utilization category B.

Rated ultimate short-circuit breaking capacity I_{cu}

Limit value of rated short-circuit breaking capacity I_{cn}.

The rated ultimate short-circuit breaking capacity is the maximum value of the short-circuit current which the protective device is capable of interrupting in accordance with regulations.

Rated uninterrupted current I_u

The rated uninterrupted current of a device is specified by the manufacturer and refers to the current that the device can conduct continuously.

Response current, I release

When this current limit is exceeded, the circuit breaker trips instantaneously.

Response current, L release

When this uninterrupted current limit is exceeded within a predefined time period, the circuit breaker trips (inverse-time delay tripping!).

Response current, S release

When this current limit is exceeded, the circuit breaker trips after a predefined time delay.

Response current, short-time delay

When this current limit is exceeded, the circuit breaker trips after a predefined time delay.

S release

Electronic short-time delay over-current release for delayed short-circuit protection

Short-circuit

Accidental or intentional conductive path between two or more conductive parts forcing the electric potential differences between these conductive parts to be equal to or close to zero as defined by IEC / DIN EN 60947-1, 2.1.5

Short-circuit current

Over-current resulting from a short-circuit due to a fault or an incorrect connection in an electric circuit as defined by IEC / DIN EN 60947-1, 2.1.6

Trip unit

Unit connected to the switching device (circuit breaker) which operates the breaker's mechanical release system and so opens the breaker when certain specified variables (e.g. current, voltage) are exceeded.

Tripping current of overload release

The current value at which a release trips within a certain time.

Tripping current, instantaneous

When this current limit is exceeded, the circuit breaker trips instantaneously.

Tripping current, overload

When this uninterrupted current limit is exceeded within a predefined time period, the circuit breaker trips (inverse-time delay tripping!).

Tripping time

Period of time from the instant of commencement of trip command output to the moment at which the command becomes irrevocable (timing concept for the tripping of circuit breakers).

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