Protection discrimination

Contents

Using the tables

Two circuit breakers offer total discrimination when the corresponding box in the discrimination table is shaded or contains the letter T.
When discrimination is partial for the combination, the corresponding box indicates the maximum value of the fault current for which discrimination is provided. For fault currents above this value, the two circuit breakers trip simultaneously.

Protection discrimination

Protection discrimination is an essential element that must be taken into account starting at the design stage of a low voltage installation to ensure the highest level of availability for users.
Discrimination is important in all installations for the comfort of users, however it is fundamental in installations requiring a high level of service continuity, e.g. industrial manufacturing processes.
Industrial installations without discrimination run a series of risks of varying importance including:
- production deadline overruns
- interruption in manufacturing, entailing:
  - production or finished-product losses
  - risk of damage to production machines in continuous processes
- restarting of machines, one by one, following a general power outage
- shutdown of vital safety equipment such as lubrication pumps, smoke fans, etc.

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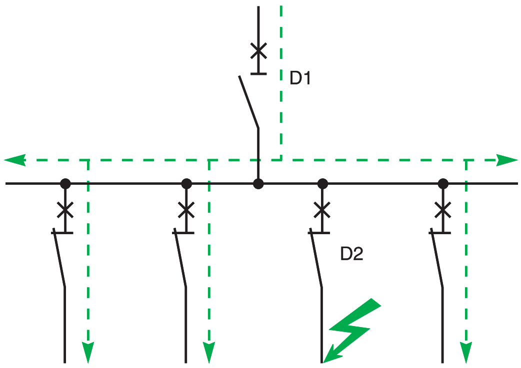

What is discrimination?

Discrimination, also called selectivity, is the coordination of automatic protection devices in such a manner that a fault appearing at a given point in a network is cleared by the protection device installed immediately upstream of the fault, and by that device alone.

- total discrimination

Discrimination is said to be total if, for all fault current values, from overloads up to the non-resistive short-circuit current, circuit breaker D2 opens and D1 remains closed.

- partial discrimination

Discrimination is partial if the above condition is not respected up to the full short-circuit current, but only to a lesser value termed the selectivity limit current (Is).

- no discrimination

In the event of a fault, both circuit breakers D1 and D2 open.

Total discrimination as standard with Masterpact NT/NW circuit breakers

Thanks to their highly innovative design and the exeptional performance of their control units, the Masterpact NT and NW circuit breakers offer total discrimination with downstream Compact NSX devices up to 630 A as standard [(1)].

Natural discrimination with Compact NSX circuit breakers

Due to the Roto-active breaking technique employed by the Compact NSX, the combined use of Schneider Electric circuit breakers provides an exceptional level of protection discrimination.
This is the result of the implementation and optimisation of three different techniques:
- current discrimination
- time discrimination
- energy discrimination.

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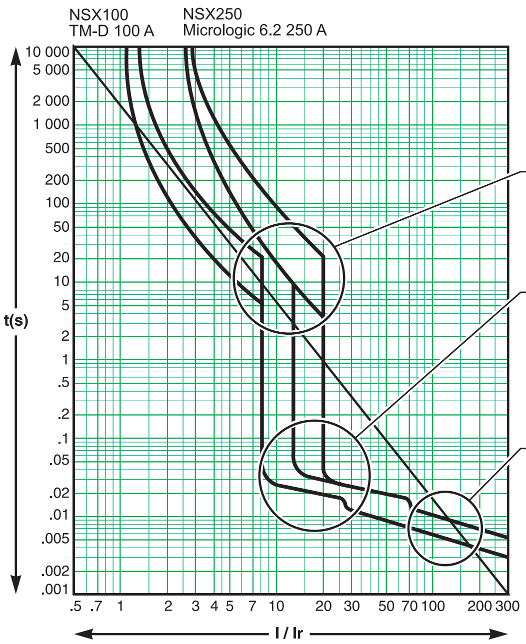


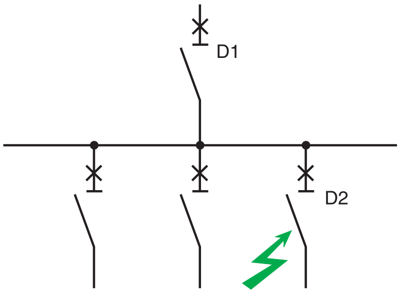
Overload protection: current discrimination
Discrimination is ensured if the ratio between setting thresholds is greater than 1.6 (for distribution circuit breakers).
Low short-circuit protection: current discrimination.

Tripping of the upstream device is slightly delayed to ensure that the downstream device trips first.
Discrimination is ensured if the ratio between the short-circuit thresholds is greater than 1.5.
High short-circuit protection: time discrimination.

***This protection system combines the exceptional** current limiting capacity of the Compact NS and the advantages of reflex tripping, sensitive to the energy dissipated in the device by the short-circuit. In the event of a high short-circuit detected by two circuit breakers, the downstream device limits it sharply. The energy dissipated in the upstream device is not sufficient to trip it, i.e. discrimination is total for all short-circuit currents.*
Discrimination is ensured if the ratio between the circuit breaker ratings is greater than 2.

(1) Except for the L1 performance level on Masterpact NT and subject to the discrimination rules on page 558E4300/7.

Protection discrimination



Discrimination between two distribution circuit breakers.

How to use the discrimination tables

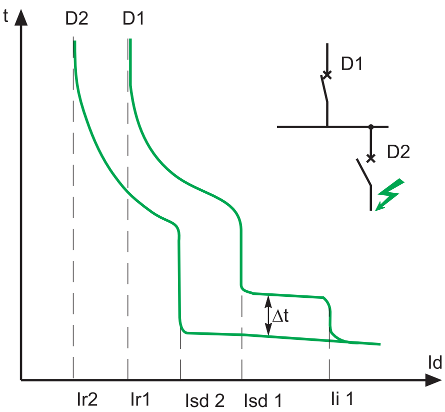
■ for discrimination between 2 distribution circuit breakers
Combinations providing full discrimination are indicated by the symbol T.
If discrimination is partial, the table indicates the maximum fault current value for which discrimination is ensured. For fault currents above this value, the 2 circuit breakers trip simultaneously.

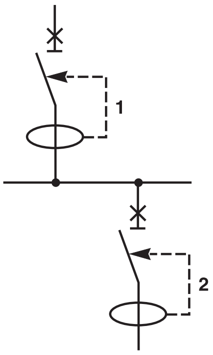
Requisite conditions

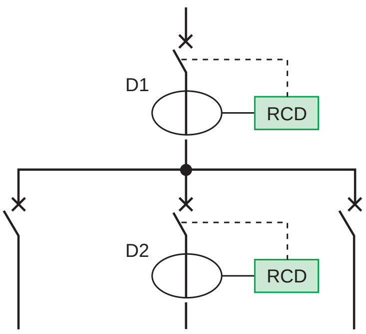
The values indicated in the tables are valid for operational rated voltages of 220, 380, 415 and 440V:

Upstream	Downstream	Frame up / Frame down	Thermal protection Ir up/Ir down	Magnetic protection Im up/Im down
TM	TM or Multi 9	⩾ 2.5	⩾ 1.6	⩾ 2
	Micrologic	⩾ 2.5	⩾ 1.6	⩾ 1.5
Micrologic	TM or Multi 9	⩾ 2.5	⩾ 1.6	⩾ 1.5
	Micrologic	⩾ 2.5	⩾ 1.3	⩾ 1.5

These conditions ensure that curves don’t overlap. Curves could also be checked with Curve Direct software tools







Additional Settings conditions according to trip unit type

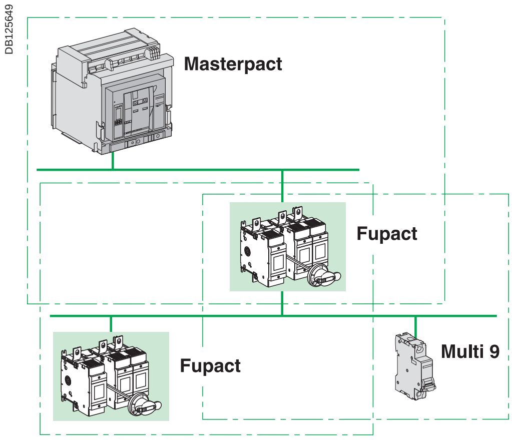
■ Short time pick up (Isd)
Tables indicate selectivity limits assuming Isd = 10 x Ir. In many cases when discrimination is Total lower thresholds could be used if ratio condition between two magnetic protections is fulfilled. When selectivity limit indicated in the tables is equal to 10xIr, the selectivity limit is upstream short time pick up (Isd).
■ Instantaneous pick up (Ii)
Tables indicate selectivity limits assuming instantaneous pick up is set at the maximum value and when it’s inhibited (Type B Circuit breaker only). With Masterpact, when selectivity limit indicated in the tables is equal to 15 x In, the selectivity limit is upstream instantaneous pick up (Ii). When upstream circuit Breaker is A type, and downstream circuit breaker is B type upstream instantaneous setting can be set lower than 15 In as far as it stay higher than downstream circuit breaker reflex tripping limit. When a Micrologic 5.x is used downstream a Micrologic 2.x Tsd shall be set at 0 and Ii shall be set at Isd.
■ Short time delay (Tsd)
When upstream and downstream breaker are equipped with Micrologic 5.x, 6.x, 7.x: the minimum non tripping-time of the upstream device must be greater than the maximum tripping time of the downstream device.
Tsd D1 > Tsd D2 (One Step)
■ I2t Off / On
Tables indicate selectivity limits assuming I2t Function is Off. If I2t function is ON user shall check curves.
■ Ground Fault protection (Ig, Tg)
When upstream and downstream breaker are equipped with Micrologic 6.x, user should implement current and time discrimination:
□ current sensing discrimination
Threshold setting of upstream GFP device tripping is greater than that of the downstream GFP device. Because of tolerances on the settings, a 30 % difference between the upstream and downstream thresholds is sufficient.
□ time graded discrimination
The intentional time delay setting of the upstream GFP device is greater than the opening time of the downstream device. Furthermore, the intentional time delay given to the upstream device must respect the maximum time for the elimination of insulation faults defined by the NEC § 230.95 (i.e. 1s for 3000 A).
Ig D1 >= 1,3 Ig D2 ***Tg D1 > Tg D2 (One Step)***
■ Earth Leakage Protection (IΔ, TΔ)
When upstream and downstream breaker are equipped with Micrologic 7.x or Vigi user should implement current and time discrimination:
□ current condition:
The RCD must trip between IΔn and IΔn/2, IΔn where In is the declared operating current. There must therefore exist a minimum ratio of 2 between the sensitivities of the upstream device and the downstream device. In practice, the standardised values indicate a ratio of 3.
□ time condition:
The minimum non-tripping time of the upstream device must be greater than the maximum tripping time of the downstream device for all current values.
IΔn D1 ⩾ 3 x IΔn D2 ***Δt D1 > Δt D1 (One Step)***

Note : *The tripping time of RCDs must always be less than or equal to the time specified in the installation standards to guarantee protection of people against indirect contacts.*

Compact NSX motor trip units

■ Compact NSX Trip units dedicated to motor protection ("M" type) can not be used to ensure discrimination with downstream circuit breaker.
■ Furthermore Compact NSX trip unit dedicated to distribution should not be used to protect motors, even motors wit soft starter or speed drive.

Protection discrimination with fuses



Principle

Schneider Electric offers a coordinated protection system

In an electrical installation, protection fuses are never used alone and must always be integrated in a system comprising circuit breakers.
Coordination is required between:

- upstream and downstream fuses
- upstream circuit breakers and downstream fuses
- upstream fuses and downstream circuit breakers.

Upstream fuse / Downstream fuse

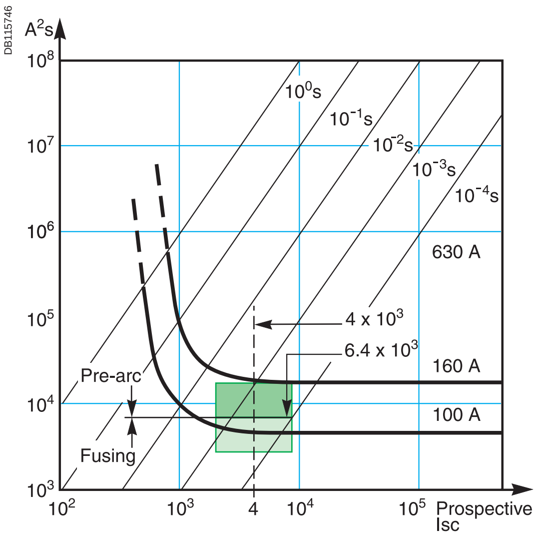
Discrimination is ensured when

Total energy of downstream fuse (Etav) < Pre-arcing energy of upstream fuse (Epam)

Note: If Etav is higher than 80 % of Epam, the upstream fuse may be derated.

- **upstream gG fuse-link / downstream gG fuse-link**

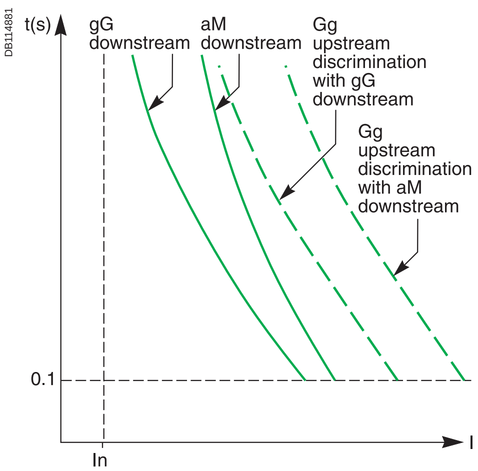
Standard IEC 60269-2-1 indicates limit values for pre-arcing and total energies for operation of gG and gM fuse-links, where the operating current is approximately 30 In.



Curves E = f (I) superimposed.

I^2t limit and test currents for verification of discrimination

I_n (A)	Minimum values of pre-arcing I^2t		Maximum values of operating I^2t	
	Rms values of I prospective (kA)	I^2t (A^2s)	Rms values of I prospective (kA)	I^2t (A^2s)
16	0.27	291	0.55	1 210
20	0.40	640	0.79	2 500
25	0.55	1 210	1.00	4 000
32	0.79	2 500	1.20	5 750
40	1.00	4 000	1.50	9 000
50	1.20	5 750	1.85	13 700
63	1.50	9 000	2.30	21 200
80	1.85	13 700	3.00	36 000
100	2.30	21 200	4.00	64 000
125	3.00	36 000	5.10	104 000
160	4.00	64 000	6.80	185 000
200	5.10	104 000	8.70	302 000
250	6.80	185 000	11.80	557 000
315	8.70	302 000	15.00	900 000
400	11.80	557 000	20.00	1 600 000
500	15.00	900 000	26.00	2 700 000
630	20.00	1 600 000	37.00	5 470 000
800	26.00	2 700 000	50.00	10 000 000
1 000	37.00	5 470 000	66.00	17 400 000
1 250	50.00	10 000 000	90.00	33 100 000

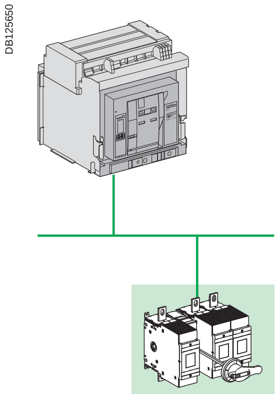


I = f(t) curves.

- **upstream gG fuse-link / downstream aM fuse-link**

The I = f (t) curve for an aM fuse-link is steeper. aM fuse-links are just as fast as gG fuse-links for short-circuit currents, but slower for low overloads.
That is why the discrimination ratio between gG and aM fuse-links is approximately 2.5 to 4.

Protection discrimination with fuses



Upstream circuit breaker / Downstream fuse

Upstream circuit breaker with delayed ST (short time) protection function

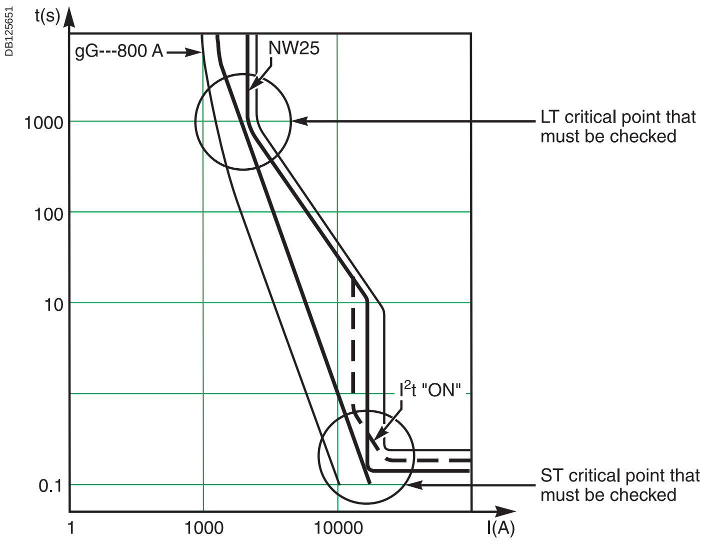
This is the situation for a MLVS (main low-voltage switchboard) or sub-distribution switchboard protected by an incoming circuit breaker.
The upstream circuit breaker has an electrodynamic withstand capacity Icw and ensures time discrimination.

Rule

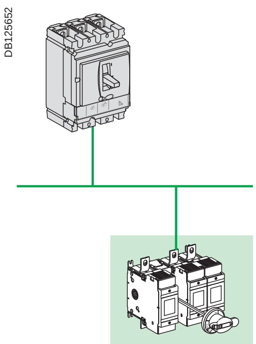
Examination of discrimination at the critical points on the LT (long time) and ST (short time) curves results in a discrimination table.
Analysis of the LT critical point indicates whether discrimination between the protection devices is possible or not.
Analysis of the ST (or Icw) critical point indicates whether the discrimination limit is greater than or equal to the ST (or Icw) value.

Note:

- *the LT critical point is the most restrictive*
- *for circuit breakers with a Icw value that is high and/or equal to Icu, the ST critical point is almost never a problem, i.e. discrimination is total.*



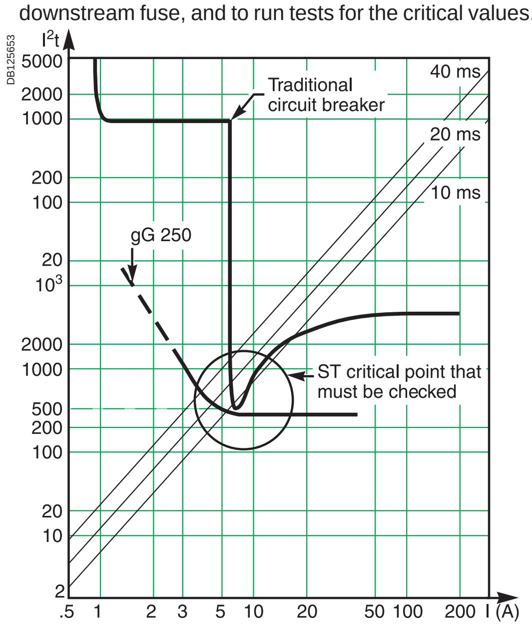
Time-current curves and critical points that must be checked.



Upstream circuit breaker with non-delayed ST (short time) protection and/or current-limiting function

To make sure the ST critical point is OK, it is necessary to compare:

- the energy curves of the protection devices
- the non-tripping curves of the upstream circuit breaker and the fusing curves of the downstream fuse, and to run tests for the critical values.



Energy curves and critical points that must be checked.

Protection discrimination with fuses

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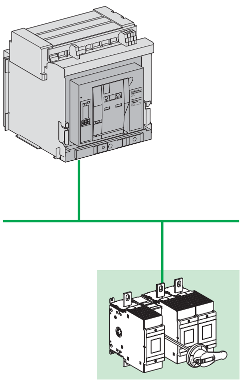

Feature exclusive to Schneider Electric

Masterpact NT or NW upstream of a Fupact equipped with a gG fuse-link

The new Micrologic control unit has a special LT delay setting for HVF very inverse time applications.
This curve is ideal for discrimination when fuse-based protection devices are installed downstream (LV distribution) or upstream (HV).

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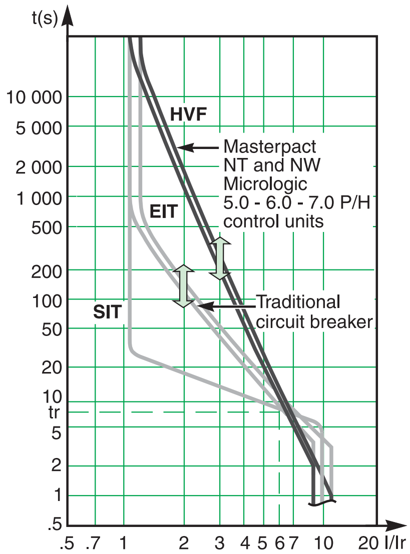

IDMTL curve.

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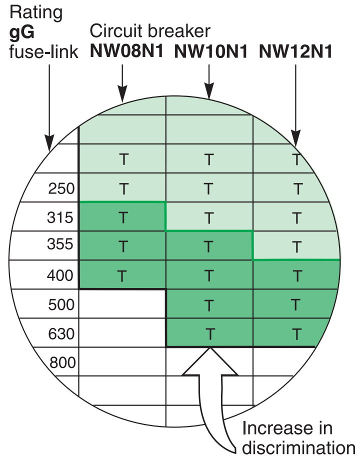

Traditional EIT curves

HVF curve

EIT discrimination limit

HVF discrimination limit

Increase in discrimination.

The new Micrologic 5.0 - 6.0 - 7.0 P / H control units are equipped as standard with four settings for LT inverse-time curves with adjustable slopes.
SIT: standard inverse time.
VIT: very inverse time.
EIT: extremely inverse time (traditional LT curve).
HVF: high-voltage fuse, inverse-time curve that follows the fuse thermal curve.

Protection discrimination with fuses

Masterpact NT or NW upstream of an aM fuse-link

The upstream protection circuit breaker must be coordinated with the thermal relay and the short-circuit protection aM fuse-link.

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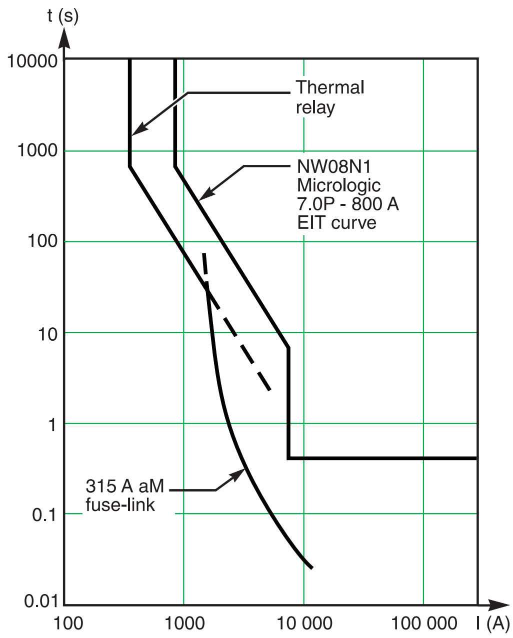

■ overload zone - coordination between Masterpact and the thermal relay
Masterpact offers an EIT long-time setting that is totally coordinated with the curves of the thermal relay. Discrimination is ensured as long as the setting ratio is greater than 1.6.

■ short-circuit zone - coordination between Masterpact and the aM fuse-link
Under short-circuit conditions > 10 In, the I = f (t) characteristic of an aM fuse-link is very similar to that of a gG fuse-link with the same rating.

Given the above and using the EIT long-time setting, Masterpact offers the same discrimination ratios for both gG and aM downstream fuse-links. This ratio is very similar to that for gG fuse-links installed upstream of aM fuse-links.

***Note:** if there are motor feeders protected by aM fuse-links and distribution lines protected by gG fuse-links downstream of a Masterpact circuit breaker, selection of HVF long-time curves is the means to ensure identical discrimination for both types of circuit.*

See pages 76 to 83 for the discrimination tables.

I²t ON setting

To significantly limit the stresses exerted on the installation (cables installed on trays, power supplied by an engine generator set, etc.), it may be necessary to set the ST protection function to a low value.
The I²t ON function, a constant-energy tripping curve, maintains the level of discrimination performance and facilitates total discrimination.

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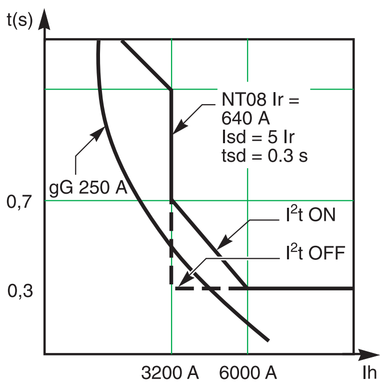

I²t ON curve.

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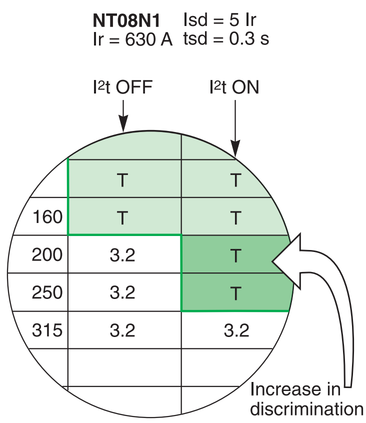

Increase in the discrimination limit.

Protection discrimination with fuses

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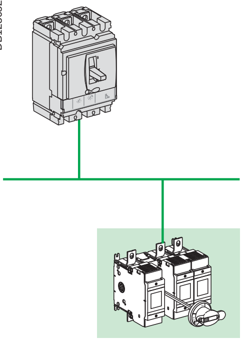

Compact NS/NSX upstream of gG or aM fuse-links

Compact NS/NSX is a current-limiting circuit breaker. Even without an ST (short time) delay setting, discrimination at the ST critical point is significantly improved because Compact NS/NSX has a mini-delay that considerably increases curve values at the ST critical point.

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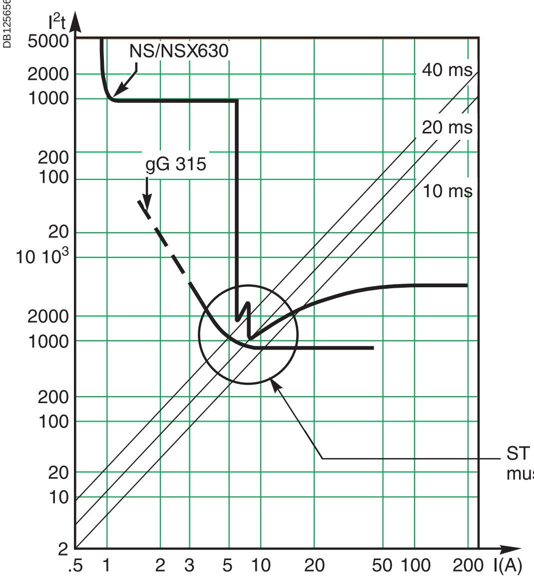

I^2t curve for Compact NS/NSX and a fuse.

See pages 80 and 82 for the discrimination tables.

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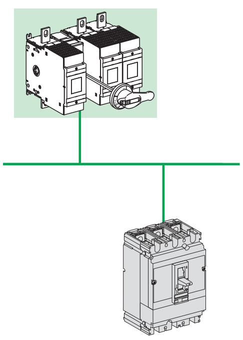

Compact NSX downstream of gG or aM fuse-links

Compact NSX offers an extremely high level of current-limiting performance due to the piston-based reflex tripping system. Again, discrimination is significantly improved with an upstream fuse.

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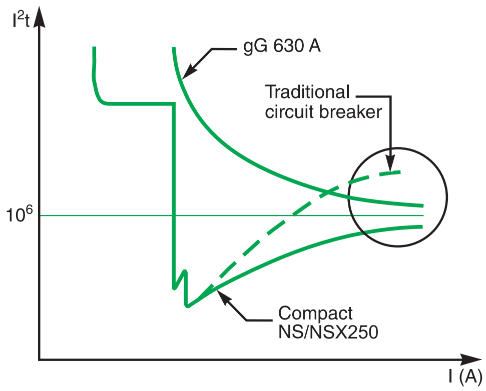

See page 83 for the discrimination tables.

Cascading

Contents

Cascading

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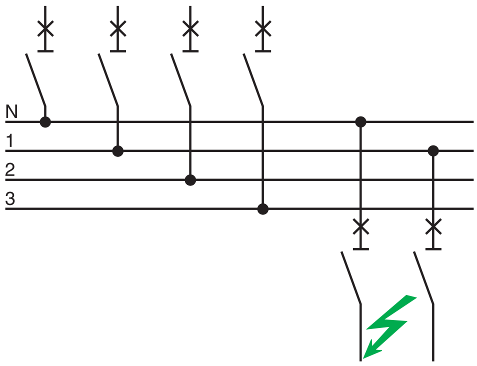

220/240 V network downstream from a 380/415 V network

For 1P + N or 2P circuit breakers connected between the phase and neutral on a 380/415 V network, with a TT or TNS neutral system, consult the 220/240 V cascading table to determinate cascading possibilities between upstream and downstream circuit breakers, for C60 upstream and consult the 380/415 V cascading table for iDPN.

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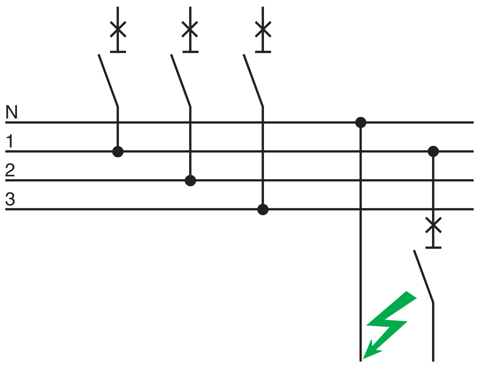

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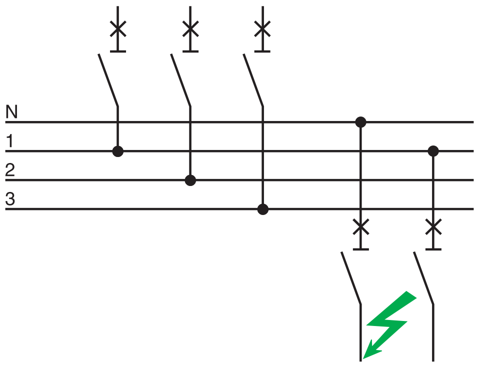

For 1P + N or 2P circuit breakers connected to one phase of a 380/415 V network used together with the neutral to supply a single-phase circuit, consult the cascading tables for 380/415 V networks to determine the cascading possibilities between upstream and downstream circuit breakers.

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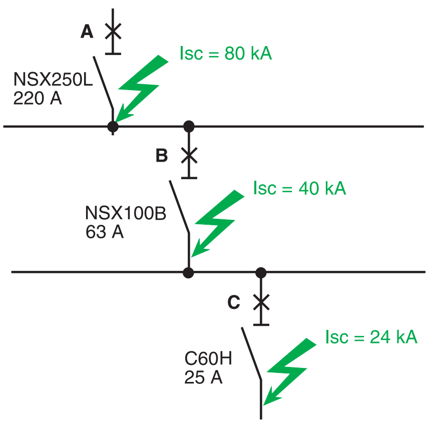


Example of three level cascading

Consider three circuit breakers A, B and C connected in series. The criteria for cascading are fulfilled in the following two cases:

- the upstream device A is coordinated for cascading with both devices B and C (even if the cascading criteria are not fulfilled between B and C). It is simply necessary to check that the combinations A + B and A + C have the required breaking capacity
- each pair of successive devices is coordinated, i.e. A with B and B with C (even if the cascading criteria are not fulfilled between A and C). It is simply necessary to check that the combinations A + B and B + C have the required breaking capacity.

The upstream breaker A is a NSX250L (breaking capacity 150 kA) for a prospective Isc of 80 kA across its output terminals.
A NSX100B (breaking capacity 25 kA) can be used for circuit breaker B for a prospective Isc of 40 kA across its output terminals, since the "reinforced" breaking capacity provided by cascading with the upstream NSX250L is 50 kA.
A C60H (breaking capacity 15 kA) can be used for circuit breaker C for a prospective Isc of 24 kA across its output terminals since the "reinforced" breaking capacity provided by cascading with the upstream NSX250L is 25 kA.
Note that the "reinforced" breaking capacity of the C60H with the NSX100B upstream is only 20 kA, but:

- A + B = 50 kA
- A + C = 25 kA.

Cascading and enhanced discrimination

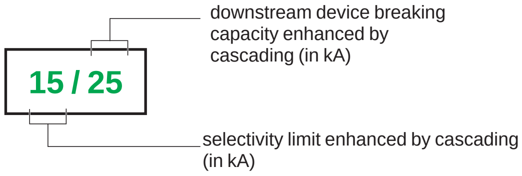
With traditional circuit breakers, cascading between two devices generally results in the look of discrimination.
With Compact circuit breakers, the discrimination characteristics in the tables remain applicable and are in some cases even enhanced. Protection discrimination is ensured for short-circuit currents greater than the rated breaking capacity of the circuit breaker and even, in some cases, for its enhanced breaking capacity. In the later case, **protection discrimination is total**, i.e. only the downstream device trips for any and all possible faults at its point in the installation.

Example
Consider a combination between:
- a Compact NSX250H with trip unit TM250D
- a Compact NSX100F with trip unit TM25D.

The discrimination tables indicate total discrimination. Protection discrimination is therefore ensured up to the breaking capacity of the NSX100F, i.e. **36 kA**.
The cascading tables indicate an enhanced breaking capacity of **70 kA**.
The enhanced discrimination tables indicate that in a cascading configuration, discrimination is ensured up to **70 kA**, i.e. for any and all possible faults at that point in the installation.

Enhanced discrimination tables - 380/415 V

For each combination of two circuit breakers, the tables indicate the:



In a table, a box containing two equal values indicates that discrimination is provided up to the reinforced breaking capacity of the downstream device.
These tables apply only to cases with combined discrimination and cascading between two devices. For all other cases, refer to the normal cascading and discrimination tables.

Technical principle

Enhanced discrimination is the result of the exclusive Compact NSX Roto-active breaking technique which operates as follows:
- due to the short-circuit current (electrodynamic forces), the contacts in both devices simultaneously separate. The result is major limitation of the short-circuit current
- the dissipated energy provokes the reflex tripping of the downstream device, but is insufficient to trip the upstream device.

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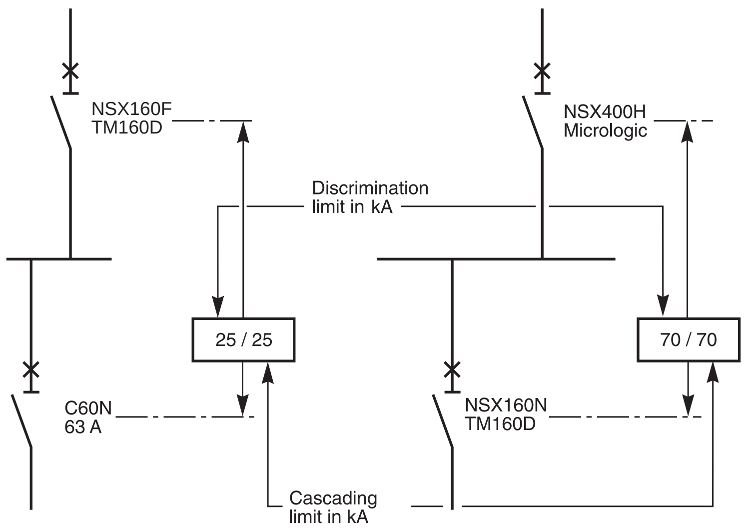

Note: respect the basic rules of discrimination, in terms of overload, short-circuit, see page 6, or check curves with Curve Direct software.

Motor protection discrimination

Contents

Using the tables

Two circuit breakers offer total discrimination when the corresponding box in the discrimination table is shaded or contains the letter T.
When discrimination is partial for the combination, the corresponding box indicates the maximum value of the fault current for which discrimination is provided.
For fault currents above this value, the two circuit breakers trip simultaneously.

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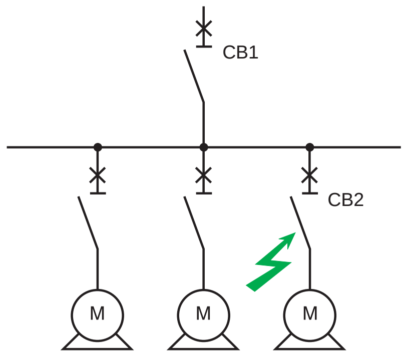

Discrimination between circuit breakers used for motor protection.

How to use the discrimination tables

■ **for discrimination between a circuit breaker and a motor control and protection assembly**

If discrimination is partial, the table indicates the maximum fault current value for which discrimination is ensured. For fault currents above this value, the 2 devices trip simultaneously.

Requisite conditions

The values indicated in the tables (for 220, 380, 415 and 440 V) are guaranteed if the following conditions are respected:

Upstream	Downstream	Thermal protection Ir up/Ir down	Magnetic protection Im up/Im down
TM	MA + separate therm. relay	⩾ 3	⩾ 2
	Thermal-magnetic motor type	⩾ 3	⩾ 2
Micrologic	MA + separate therm. relay	⩾ 3	⩾ 1.5
	Thermal-magnetic motor type	⩾ 3	⩾ 1.5

Protection of motor circuits

Circuit breaker/contactor coordination

A circuit supplying a motor may include one, two, three or four switchgear or controlgear devices fulfilling one or more functions.

When a number of devices are used, they must be coordinated to ensure optimum operation of the motor.

Protection of a motor circuit involves a number of parameters that depend on:

- the application (type of machine driven, operating safety, starting frequency, etc.)
- the level of service continuity imposed by the load or the application
- the applicable standards to ensure protection of life and property.

The necessary electrical functions are of very different natures:

- protection (motor-dedicated for overloads)
- control (generally with high endurance levels)
- isolation.

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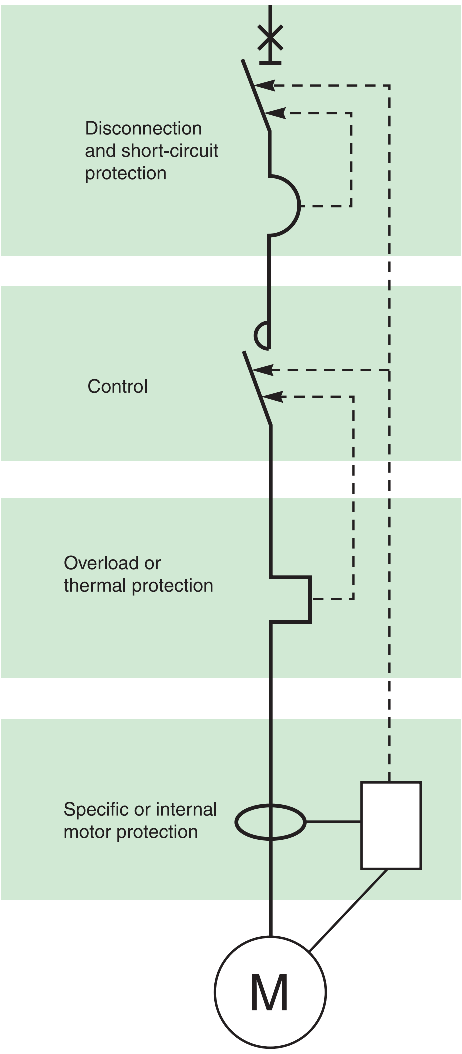


Protection functions

Disconnection functions:
- Isolate a motor circuit prior to maintenance operations.

Short-circuit protection:
Protect the starter and the cables against major overcurrents (> 10 In).

Control:
Start and stop the motor, and, if applicable:
- gradual acceleration
- speed control.

Overload protection:
Protect the starter and the cables against minor overcurrents (< 10 In).

Additional specific protection:
- limitative fault protection (while the motor is running)
- preventive fault protection (monitoring of motor insulation with motor off).

Overloads (I < 10 In).
An overload may be caused by:
- an electrical problem, for instance on the mains (loss of a phase, voltage outside tolerances, etc.)
- a mechanical problem, for instance excessive torque due to abnormally high demands by the process or motor damage (bearing vibrations, etc.)

A further consequence of these two origins is excessively long starting.

Impedant short-circuit (10 < I < 50 In)
Deterioration of motor-winding insulation is the primary cause.

Short-circuit (I > 50 In)
This type of fault is relatively rare. A possible cause may be a connection error during maintenance.

Overload protection
Thermal relays provide protection against this type of fault. They may be:
- integrated in the short-circuit protective device
- separate.

Short-circuit protection
This type of protection is provided by a circuit breaker.

Protection against insulation faults
This type of protection may be provided by:
- a residual current device (RCD)
- an insulation monitoring device (IMD).

Protection of motor circuits
Circuit breaker/contactor coordination

Applicable standards
A circuit supplying a motor must comply with the general rules set out in IEC standard 60947-4-1 and in particular with those concerning contactors, motor starters and their protection as stipulated in IEC 60947-4-1, notably:
■ coordination of the components of the motor circuit
■ trip class for thermal relays
■ contactor utilisation categories
■ coordination of insulation.

Coordination of the components of the motor circuit
Two types of coordination
The standard defines tests at different current levels. The purpose of these tests is to place the switchgear and controlgear in extreme conditions. Depending on the state of the components following the tests, the standard defines two types of coordination:
■ **type 1:**
Deterioration of the contactor and the relay is acceptable under two conditions:
□ no danger to operating personnel
□ no danger to any components other than the contactor and the relay
■ **type 2:**
Only minor welding of the contactor or starter contacts is permissible and the contacts must be easily separated.
□ following type-2 coordination tests, the switchgear and controlgear functions must be fully operational.

Which type of coordination is needed?
Selection of a type of coordination depends on the operating conditions encountered.
The goal is to achieve the best balance between the user’s needs and the cost of the installation.
■ **type 1:**
qualified maintenance service
□ low cost of switchgear and controlgear
□ continuity of service is not imperative or may be ensured by simply replacing the faulty motor drawer
■ **type 2:**
□ continuity of service is imperative
□ limited maintenance service
□ specifications stipulating type 2.

Protection of motor circuits
Circuit breaker/contactor coordination

The different test currents

"Ic", "r" and "Iq" test currents
To qualify for type-2 coordination, the standard requires three fault-current tests to check that the switchgear and controlgear operates correctly under overload and short-circuit conditions.

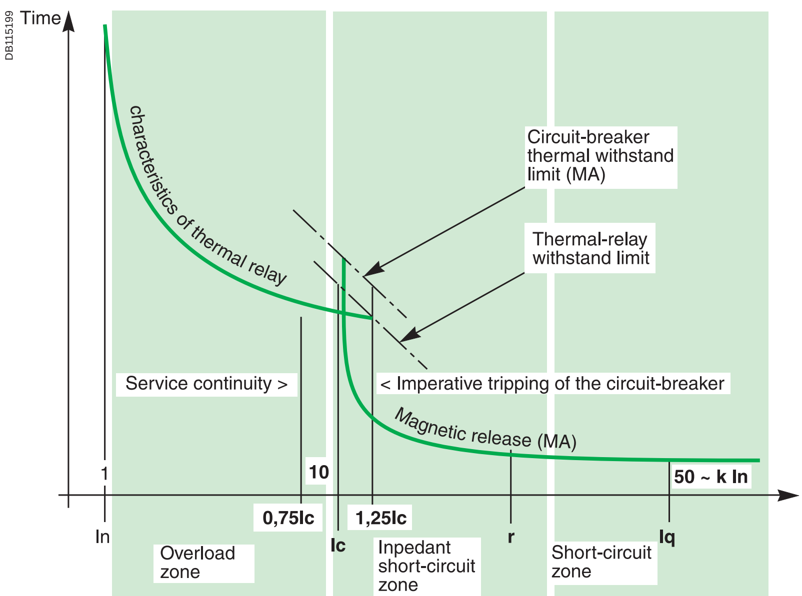
"Ic" current (overload I < 10 In)
The thermal relay provides protection against this type of fault, up to the Ic value (a function of Im or Isd) defined by the manufacturer.
IEC standard 60947-4-1 stipulates two tests that must be carried out to guarantee coordination between the thermal relay and the short-circuit protective device:
- at 0.75 Ic, only the thermal relay reacts
- at 1.25 Ic, the short-circuit protective device reacts.

Following the tests at 0.75 and 1.25 Ic, the trip characteristics of the thermal relay must be unchanged. Type-2 coordination thus enhances continuity of service. The contactor may be closed automatically following clearing of the faul.

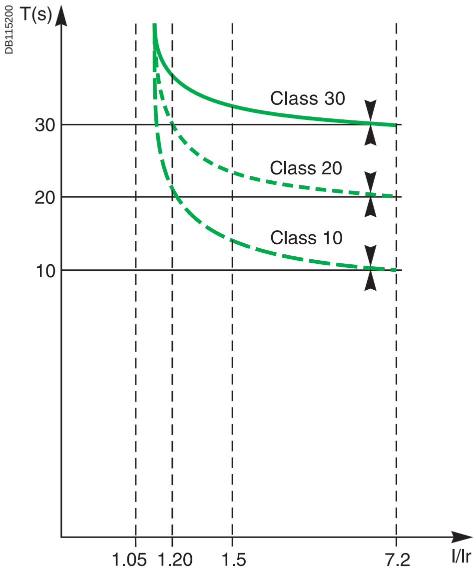
"r" current
(Impedant short-circuit 10 < I < 50 In)
The primary cause of this type of fault is the deterioration of insulation. IEC standard 60947-4-1 defines an intermediate short-circuit current “r”. This test current is used to check that the protective device provides protection against impedant short-circuits.
There must be no modification in the original characteristics of the contactor and the thermal relay following the test.
The circuit breaker must trip in y 10 ms for a fault current u 15 In.

Operational current Ie (AC3) of the motor (in A)	"r" current (kA)
Ie ≤ 16	1
16 < Ie ≤ 63	3
63 < Ie ≤ 125	5
125 < Ie ≤ 315	10
315 < Ie < 630	18

“Iq” current
(short-circuit I > 50 In)
This type of fault is relatively rare. A possible cause may be a connection error during maintenance.
Short-circuit protection is provided by devices that open quickly.
IEC standard 60947-4-1 defines the “Iq” current as generally ≥ 50 kA.
The “Iq” current is used to check the coordination of the switchgear and controlgear installed on a motor supply circuit.
Following this test under extreme conditions, all the coordinated switchgear and controlgear must remain operational.



Protection of motor circuits
Circuit breaker/contactor coordination



Trip class of a thermal relay.

Trip class of a thermal relay

The four trip class of a thermal relay are 10 A, 10, 20 and 30 (maximum tripping times at 7.2 Ir).
Classes 10 and 10 A are the most commonly used. Classes 20 and 30 are reserved for motors with difficult starting conditions.
The diagram and the table opposite can be used to select a thermal relay suited to the motor starting time.

Class	1.05 Ir	1.2 Ir	1.5 Ir	7.2 Ir
10 A	t > 2 h	t < 2 h	t < 2 min.	2 ⩽ t ⩽ 10 s
10	t > 2 h	t < 2 h	t < 4 min.	4 ⩽ t ⩽ 10 s
20	t > 2 h	t < 2 h	t < 8 min.	6 ⩽ t ⩽ 20 s
30	t > 2 h	t < 2 h	t < 12 min.	9 ⩽ t ⩽ 30 s

Protection of motor circuits

Circuit breaker/contactor coordination

The four utilisation categories of contactors (AC1 to AC4)

The four utilisation categories of contactors (AC1 to AC4)The utilisation category determines the operating frequency and endurance of a contactor. The category depends on the type of load. If the load is a motor; the category also depends on the service classification.

Main characteristics of the controlled electrical circuits and applications

Category	Type of load	Contactor usage	Typical applications
AC1	no-inductive (cos φ 0.8)	energisation	heating, distribution
AC2	slip-ring motors (cos φ 0.65)	starting switching off during running regenerative braking inching	wire drawing machines
AC3	squirrel-cage motors (cos φ 0.45 for le y 100A) (cos φ 0.35 for le > 100A)	starting switching off during running	compressors, lifts, mixing pumps, escalators, fans, conveyers, air-conditioning
AC4	squirrel-cage motors (cos φ 0.45 for le y 100A) (cos φ 0.35 for le > 100A)	starting switching off during running regenerative braking plugging inching	printing machines, wire

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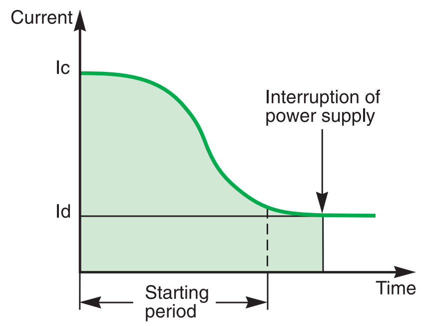

AC3 utilisation category. The contactor interrupts the rated current of the motor.

AC3 utilisation category

This category covers asynchronous squirrel-cage motors that are switched off during running. This is the most common situation (85 % of all cases).
The control device establishes the starting current and interrupts the rated current at a voltage equal to approximately one-sixth of the rated value.
Current interruption is carried out with no difficulty.

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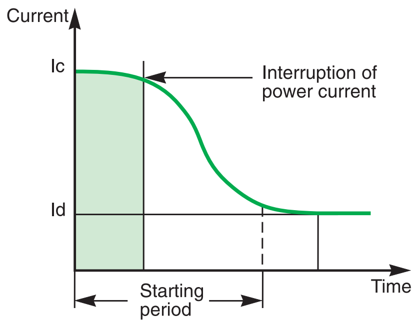


AC4 utilisation category. The contactor must be capable of interrupting the starting current id.

AC4 utilisation category

This category covers asynchronous squirrel-cage or slip-ring motors capable of operating under regenerative-braking or inching (jogging) conditions.
The control device establishes the starting current and is capable of interrupting the starting current at a voltage that may be equal to that of the mains.
Such difficult conditions require oversizing of the control and protective devices with respect to category AC3.

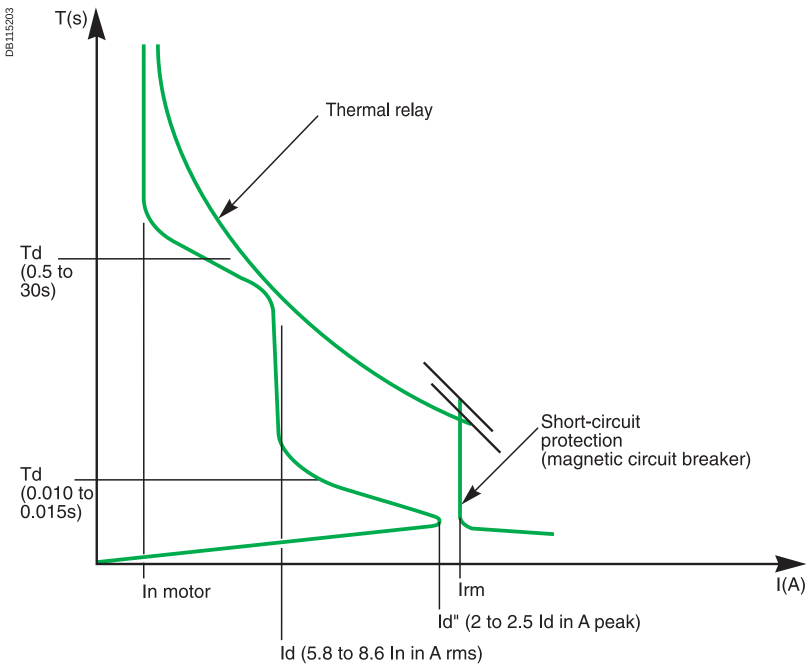
Protection of motor circuits

Using the circuit breaker/contactor

Subtransient phenomena related to direct on-line starting of asynchronous motors

Subtransient phenomena occurring when starting squirrel-cage motors:
A squirrel-cage motor draws a high inrush current during starting. This current is related to the combined influence of two parameters:
- the high inductance of the copper stator winding
- the magnetisation of the iron core of the stator.

In motor: current drawn by the motor at full rated load (in A rms)
Id: current drawn by the motor during starting (in A ms)
Id'': subtransient current generated by the motor when it is energised. This very short subtransient phenomenon is expressed as k x Id x r2 (in A peak).
td: motor starting time, from 0.5 to30 seconds depending on the application.
td'': duration of the subtransient current, from 0.010 to 0.015 seconds when the motor is energised.
Irm: magnetic setting of the circuit breakers.



Typical upper and lower limits for these subtransient currents:
These values, not covered by standards, also depend on the type of motor technology used:
- mordinary motors Id'' = 2 Id to 2.1 Id (in A peak)
- high-efficiency motors Id'' = 2.2 Id to 2.5 Id (in A peak).
- variation of Id'' as a function of Id:

Type of motor	d (in A rms)	Id'' (in A peak)
Ordinary motor	5.8 to 8.6 In motor	Id'' = 2 Id = 11.5 In (A peak) to Id'' = 2.1 Id = 18 In (A peak)
High-efficiency motor	5.8 to 8.6 In motor	Id'' = 2.2 Id = 12.5 In (A peak) to Id'' = 2.5 Id = 21.5 In (A peak)

***Example**: Upon energisation, a high-efficiency motor with an Id of 7.5 In produces a subtransient current with a value between (depending on its characteritics):*
- *minimum = 16.5 In (in A peak)*
- *maximum = 18.8 In (in A peak).*

Protection of motor circuits

Using the circuit breaker/contactor coordination tables

Subtransient currents and protection settings:

■ as illustrated in the above table, subtransient currents can be very high.
■ If they approach their upper limits, they can trip short-cicuit protection devices (nuisance tripping)
■ circuit breakers are rated to provide optimum short-circuit protection for motor starters (type 2 coordination with thermal relay and contactor)
■ combinations made up of circuit breakers and contactors and thermal relays are designed to allow starting of motors generating high subtransient currents (up to 19 In motor peak)
■ the tripping of short-circuit protective devices when starting with a combination listed in the coordination tables means:
□ the limits of certain devices may be reached
□ the use of the starter under type 2 coordination conditions on the given motor may lead to premature wear of one of the components of the combination.

In event of such a problem, the ratings of the starter and the associated protective devices must be redesigned.

Using the coordination tables for circuit breaker and contactors:

■ ordinary motor:
The starter components can be selected directly from the coordination tables, whatever the values of the starting current (Id from 5.8 to 8.6 In) and the subtransient current
■ **high-efficiency motors with Id ≤** 7.5 In:
The starter components can be selected directly from the coordination tables, whatever the values of the starting current and the subtransient current
■ **high-efficiency motors with Id > 7.5 In:**
When circuit breakers are used for motor currents in the neighbourhood of their rated current, they are set to provide minimum short-circuit protection at 19 In motor (A peak).
There are two possibilities:
■ the subtransient starting current is known (indicated by the motor manufacturer) and is less than 19 In motor (A peak).
In this case, the starter components can be selected directly from the coordination tables, whatever the value of the starting current (for Id > 7.5 In).
Example: for a 110 kW 380/415 V 3-phase motor, the selected components are: NSX250-MA220/LC1-F225/LR9-F5371.
■ the subtransient starting current is unknown or greater than 19 In motor (A peak).
In this case, the value used for the motor power in the coordination tables should be increased by 20 % to satisfy optimum starting and coordination conditions.
Example: for a 110 kW 380/415 V 3-phase motor, the selected components are those for a motor power of 110 + 20 % = 132 kW:
NSX400 Micrologic 4.3M/LC1-F265/LR9-F5371

Reversing starters and coordination

The starter components can be selected using the tables for direct-on-line starting. Replace contactors LC1 by LC2.

Star-delta starting and coordination

■ the components should be sized according to the current flowing in the motor windings
■ the mounting locations and connections of the various components of star-delta starters should be selected according to the type of coordination required and the protective devices implemented.