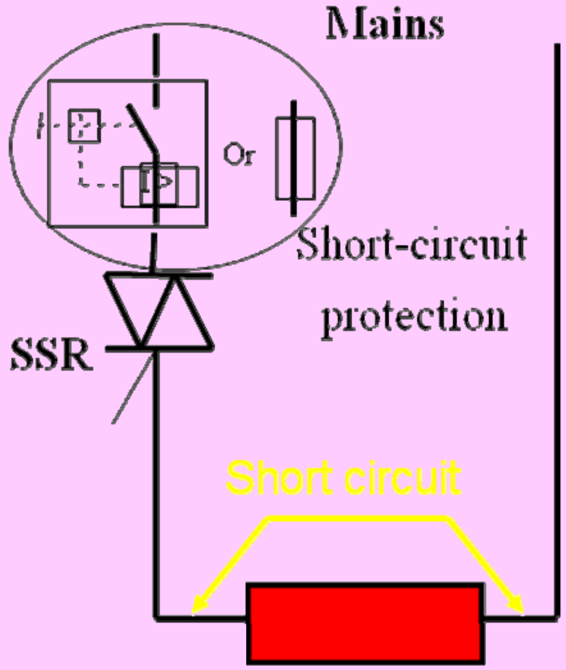
ISO 9001
N° 1993/1106b

Short Circuit Protection for Solid State Relays



Fuses

I^2t fuse < I^2t SSR

OR

Circuit Breakers

SSR with $I^2t \geq 5000A^2s$

SUMMURY

I- Coordination with short-circuit protective devices

According IEC60947-4-x, 2 types of coordination are allowed, type 1 or type 2.

- **Coordination Type 1** requires that, under short-circuit conditions, the device shall cause no danger to persons or to the installation and may not be suitable for further service without repair and replacement of parts.

⇨ **For loads where the risk of short circuit is low, coordination Type 1 can be used. In this case, the SSR is chosen in compliance with the load and the protection is chosen to protect the installation.**
But in case of short-circuit, the SSR can be in short-circuit and must be replaced for further service.

- **Coordination Type 2** requires that, under short-circuit conditions, the device shall cause no danger to persons or to the installation and shall be suitable for further use.

⇨ **For loads where the risk of short circuit is more important, coordination Type 2 must be used. In this case, the SSR is chosen in compliance with the load and the protection device to have the right protection for the installation and the SSR.**
That means the protection device must react before the SSR is damaged. In case of short circuit, the SSR will be correctly protected and will be suitable for further use.

II- Protection with fuses

Type 1 coordination:

Use standard fuse to protect the installation.
In case of short circuit on the load, SSR can be damaged and must be replaced.

Type 2 coordination:

Use a fuse with I^2t fuse < I^2t SSR

celduc SSR range.

Thanks to High performances Power thyristors (TMS^2 technology) , **celduc** has got the higher I^2t values of the market (> 20000A^2s for 125A SSRs)

Nominal current	12A	25A	35A	50A	75A	95A	125A
I2t min (A2s)	72	312	800	1500	5000	11250	20000
I2t typ (A2s)	128	600	1250	2500	7200	14400	24000

To have a correct margin with type 2 coordination, general rule is:
I^2t fuse < ½ I^2t typ of the SSR

celduc make lots of tests in FERRAZ laboratory.
Fuses specifications are given at the worst conditions means at maximum voltage, with a defined prospective short circuit current. Some coefficients can be applied to take voltage, …. into account. For more details contact your fuse supplier.

For fuses current rating selection an important point is the fuse life-time. For this reason the fuse current must have a good margin in compliance with the nominal current of the application.
Depending on the load, and inrush current of the load, different fuses are possible.

- General use (with fast , medium and time lag models)
- Fuses for semi-conductors ("GR" or "UR" models)
- Fuses for motor protection : "aM" types

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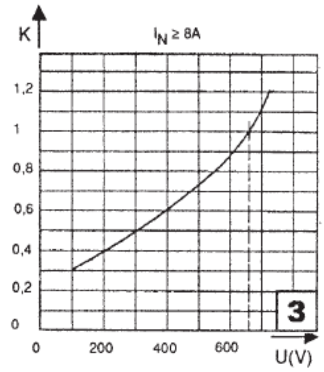


Fig 1

Examples with FERRAZ FAST fuses

(tested with **celduc** SSRs in FERRAZ laboratory)

Compare Total I^2t of the fuse given at Umax and I2t of the SSR (page 4)
With lower voltage, I2t of the fuse will be lower:
A multiplier coefficient K can be applied with the voltage (see fig 1)

10x38 gRB - 690VAC

Voltage Rating (VAC)	Rated current In (A)	Pre-arcing I²t I²tp (A2s)	Total I²t at 660VAC I²tt (A2s)	Dissipated power at In (W)	Dissipated power at 0.8 In (W)	Peak arc voltage (V)	Breaking capacity I (kA)
690	1	0,075	0,28	0,9	0,52	2500	160 kA 690 V (IEC)
	1,25	0,115	0,36	1,25	0,7		
	1,5	0,185	0,57	1,5	0,81		
	2	0,42	1,3	2	1,1		
	2,5	0,88	2,7	2,1	1,15		
	3	1,55	4,6	2,3	1,25		
	4	4	12	2,6	1,35		
	5	8,6	25	2,7	1,4		
	6	15	44	2,9	1,5		
	8	3,3	33	2,4	1,35	1450	
	10	5,4	55	3,4	1,85		
	12,5	8,5	82	3,4	1,9		
	16	16	145	4,1	2,3		
	20	230	250	4,3	2,4		
	25	58	470	4,7	2,7		
	30 (32*)	96	740	5	2,9		

14x51 gRC(URC) - 600 V to 690 VAC

Main Characteristics

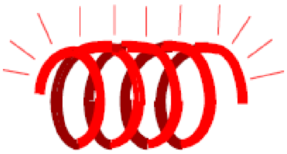
Voltage rating U_N U_V	Class	Current rating I_N(A)	Pre-arcing I²t @ 1 ms I²tp (A²s)	Total clearing I²t @ U_N I²tt (A²s)	Watts loss 0.8 I_N	Watts loss I_N	Tested Breaking capacity	Estimated Breaking capacity
690	gRC	1	0.8/0.31*	3.5/1.4*	0.17	0.35	100k A @ 690 V	300k A @ 690 V
		2	1.5/1*	6.7/4.3*	0.33	0.60		
		4	7.2/6.7*	33/30*	0.77	1.4		
		6	1.4	19	1.3	2.5		
		8	2.4	30	1.5	3.0		
		10	4.3	44	1.75	3.3		
		12	5.4	65	2.25	4.25		
		16	13	110	2.5	4.8		
		20	27	175	2.75	5.25		
		25	53	300	3.0	5.8		
		32	97	550	3.5	7.0		
		40	210	1210	4.5	8.8		
		50	390	2250	5.0	10		
600	URC	63	440	2200	8.0	16	100k A @ 600 V	300k A @ 600 V

22x58 gRC (URD) - 600 V to 690 VAC

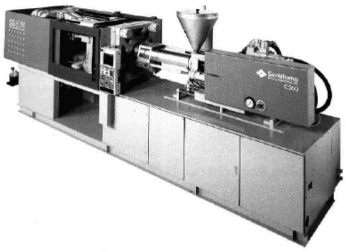
Voltage rating U_N(V)	Class	Current rating I_N(A)	Pre-arcing I²t @ 1 ms I²tp (A²s)	Total clearing I²t @ U_N I²tt (A²s)	Watts loss 0.8 I_N	Watts loss I_N	Tested Breaking capacity	Estimated Breaking capacity
690	gRC	20	17	125	4.0	6.5	100k A @ 690 V	300k A @ 690 V
		25	39	280	4.5	7.5		
		32	72	490	5.0	9.0		
		40	118	785	5.5	10		
		50	242	1390	7.0	11.5		
		63	430	2460	8.0	13.5		
		80	970	5565	9.0	15.5		
		100	2080	11950	10	17		
600	URD	125	2900	14000	14	22	100k A @ 600 V	300k A @ 600 V
		135	3360	17700	15	25		

Example: gRC50 14x51 : Total I^2t @ 690VRMS = 2250A²s
In case of using at 400VRMS, corrector coefficient K = 0.6 ➔ I^2t becomes 1350A²s

AC-51 Applications (Heating applications)



Fast fuse protection coordination type 2



Examples of choice

Load current	<8A	<15A	<25A	<30A	<55A	<70A	<90A
SSR nominal current	12A	25A	35A	50A	75A	95A	125A
I2t of SSR (A2s)	72	312	800	1500	5000	11250	20000
Example of fuse from FERRAZ	gRC12	gRC20	gRC32	gRC40	gRC63	gRC80	URD125
I2t of the Fuse (A2s) with 100KA @690VAC (*)	65	175	550	1210	2460	5565	14000

(*): at lower short circuit prospective current and lower Voltage: I^2t of the fuse will be lower
According curve I2t of the fuse at 400VAC K coefficient will be apply = 0.6

Similar fuses are available by other fuses manufacturers.

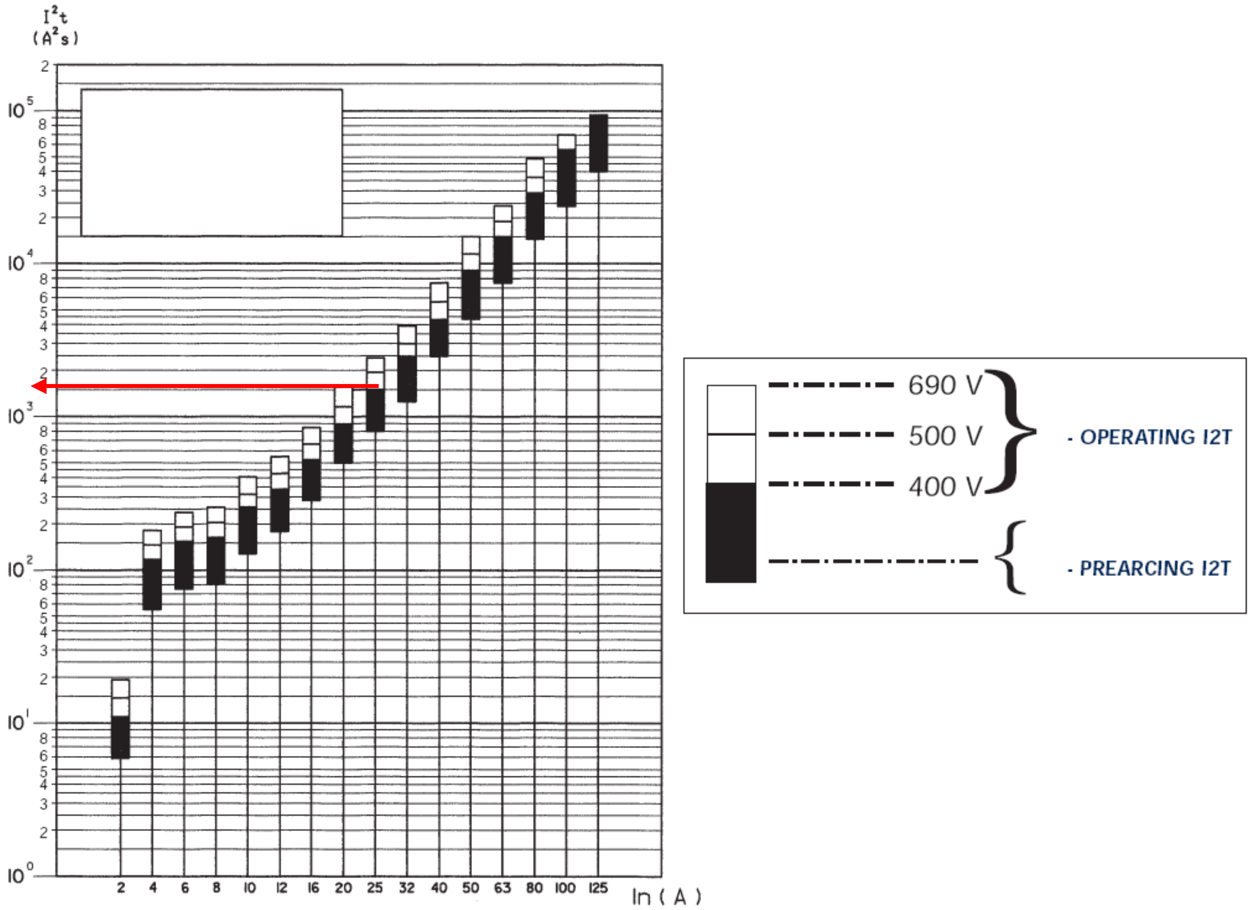
Examples with General fuses

General Purpose Fuses IEC

Ferrule Fuses
gG 400V to 690V
with/without Striker
gG 8x32, 10x38, 14x51, 22x58

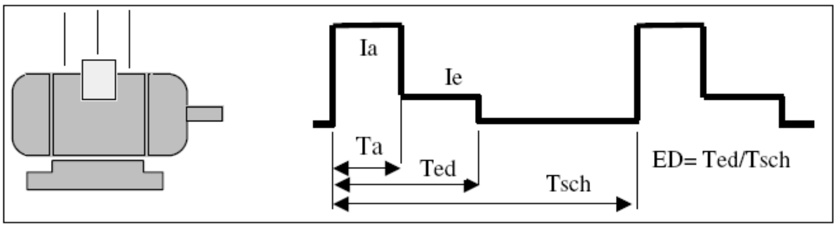
A correct protection can be made under the condition of a correct coordination between the I2t of the fuse and the I2t of the SSR.

Characteristics I2t



Example : with a 20A fuse and a 50A SSR (min I^2t 1500A^2s/typ 2500A^2s) the protection is correct for a coordination type 2 and a voltage of 400V (black limit)

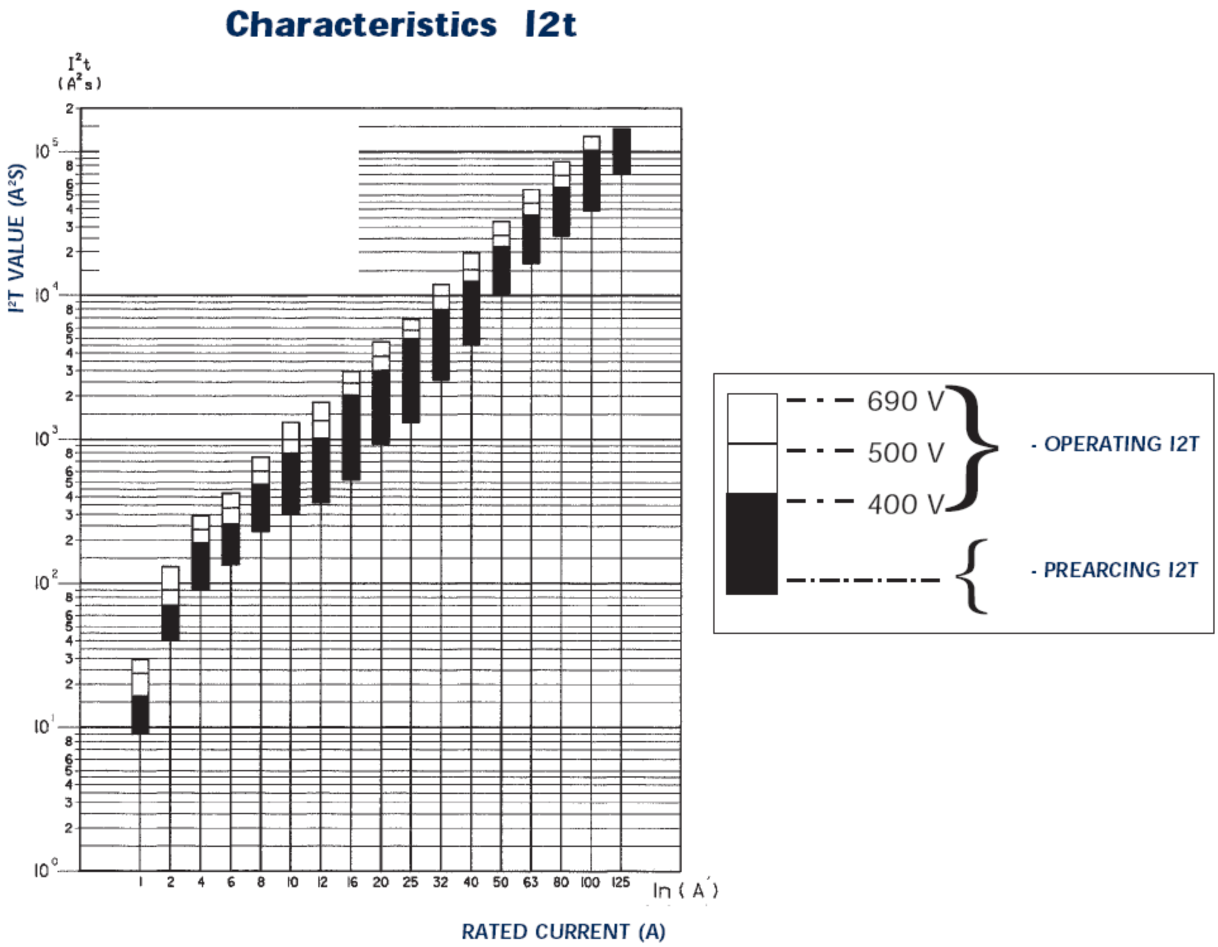
AC-53 Applications (Motors applications)



Ia : Starting current Ted : On time
Ta : Starting time Tsch : ON+OFF time
Ie=I AC-53 = Nominal current ED =Ted/Tsch : duty cycle

According IEC60947-4-x, starting current Ia must be 8 x Ie (nominal current of the motor) during Ta = 1.6 seconds.

In Ferraz Laboratory celduc tested aM fuse size 14 x 51mm

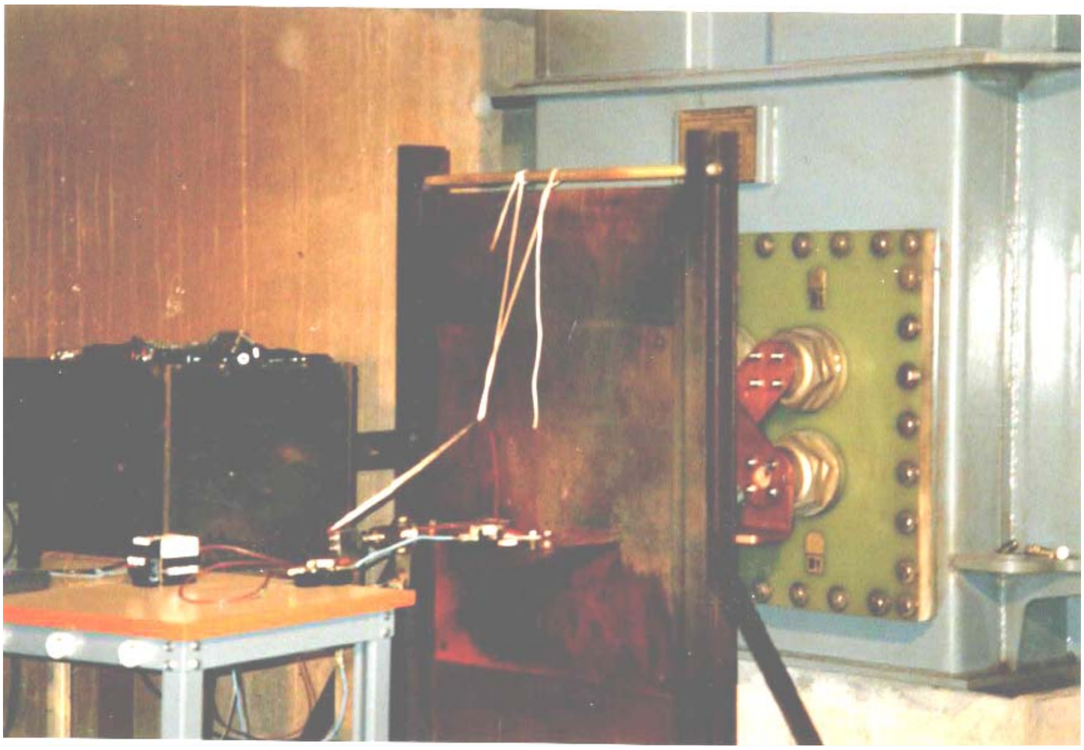


According these curves and tests celduc gives some advices:

Nominal motor current (AC-53)	< 7A	<12A	<16A	< 23A
Starting current	56A/1.6s	96A/1.6s	128A/1.6s	184A/1.6s
SSR	50A	75A	95A	125A
Fuse	aM 12	aM 20	aM32	aM50

All these tests have been passed with success in FERRAZ laboratory with a prospective current of 100KA and 500 VRMS. On request, celduc can give results with curves

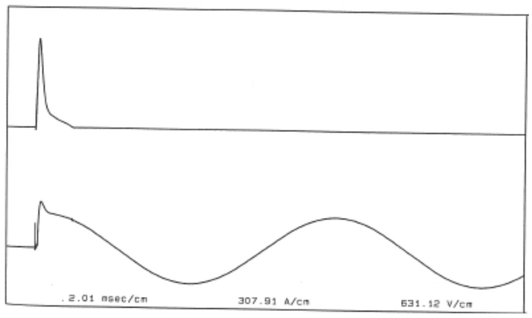
Examples of tests made in FERRAZ LABORATORY in FRANCE (report N°13610)



A part of transformer for short circuit test. Short circuit prospective current can reach 100KA

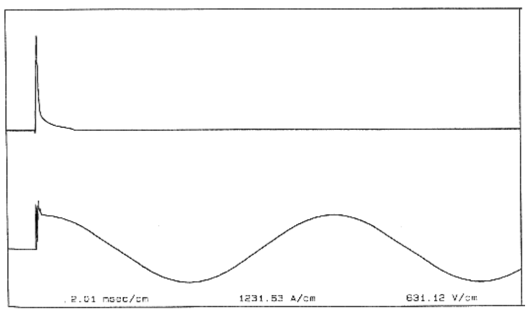
1) **Test with a fast fuse gRC 25A 14x51mm**
   with U = 525VRMS, cos phi =0.4 and a 50A Solid State Relay.
   Current at the end of pre-arcing : 874A
   Prearc I^2t : 47A2s and total I2t = 286A^2s
   Prearc time : 0.18ms Total operate time : 2.58ms

   - SSR stay alive

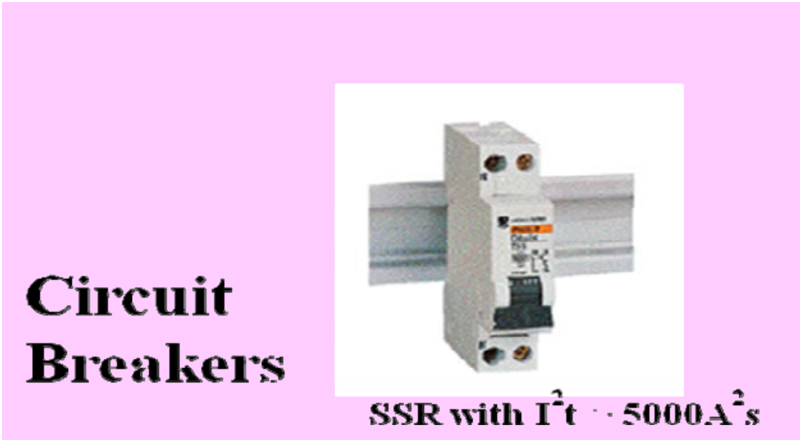


2) **Test with "aM" fuse for motor : am16A**
   with U = 525VRMS, prospective short circuit current of 106000A ; cos phi =0.19 and a 75A Solid State Relay.
   Current at the end of pre-arcing : 4024A
   Prearc I^2t : 657A2s and total I2t = 1858A^2s
   Prearc time : 0.12ms Total operate time : 2.75ms

   - SSR stay alive



III- Protection with miniatures circuits Breakers



Such Miniature Circuit-Breakers present two values of breaking capacities marked on the product:
- Icn according to IEC/EN 60898, means the maximum acceptable prospective current for the devices in a normal application
- Icu/Ics according to IEC/EN 60947-2 , means the maximum prospective current the MCB can open, but after a such short circuit, the MCB must be changed.

Generally, maximum prospective current of such small Breakers is limited at 10KA.

Different Tripping curves are possible : B, C, D , K and Z curves

Tripping characteristics

Acc. to	Tripping characteristic and rated current		Thermal release [3] Current: conventional non-tripping c.	conventional tripping c.	Tripping time	Electromagnetic release [1] Currents: hold current surges	trip at least at	Tripping time
IEC/EN 60898	B	6 to 63 A	$1.13 \cdot I_n$	$1.45 \cdot I_n$	> 1 h < 1 h	$3 \cdot I_n$	$5 \cdot I_n$	> 0.1 s < 0.1 s
	C	0.5 to 63 A	$1.13 \cdot I_n$	$1.45 \cdot I_n$	> 1 h < 1 h	$5 \cdot I_n$	$10 \cdot I_n$	> 0.1 s < 0.1 s
	D	0.5 to 63 A	$1.13 \cdot I_n$	$1.45 \cdot I_n$	> 1 h < 1 h	$10 \cdot I_n$	$20 \cdot I_n$	> 0.1 s < 0.1 s
DIN VDE 0660/9.82	K	0.5 to 63 A	$1.05 \cdot I_n$	$1.2 \cdot I_n$	> 1 h < 1 h	not applicable		
IEC/EN 60947-2 DIN VDE 0660 8/69 Part 101			$1.05 \cdot I_n$	$1.2 \cdot I_n$ $1.5 \cdot I_n$ $6.0 \cdot I_n$	> 2 h < 1 h [4] < 2 min. [5] > 2 s (T1)	$10 \cdot I_n$	$14 \cdot I_n$	> 0.2 s < 0.2 s
DIN VDE 0660/9.82	Z	0.5 to 63 A	$1.05 \cdot I_n$	$1.2 \cdot I_n$	> 1 h < 1 h	not applicable		
IEC/EN 60947-2 DIN VDE 0660 8/69 Part 101			$1.05 \cdot I_n$	$1.2 \cdot I_n$ $1.5 \cdot I_n$ $6.0 \cdot I_n$	> 2 h < 1 h [4] < 2 min. [5] > 2 s (T1)	$2 \cdot I_n$	$3 \cdot I_n$	> 0.2 s < 0.2 s

REMINDER :

coordination Type 1:

Adapt the MCB to the installation. In case of short circuit on the load, SSR can be damaged and must be replaced.

Coordination Type 2: let-through energy I^2t of the MCB must be < i2t of the SSR

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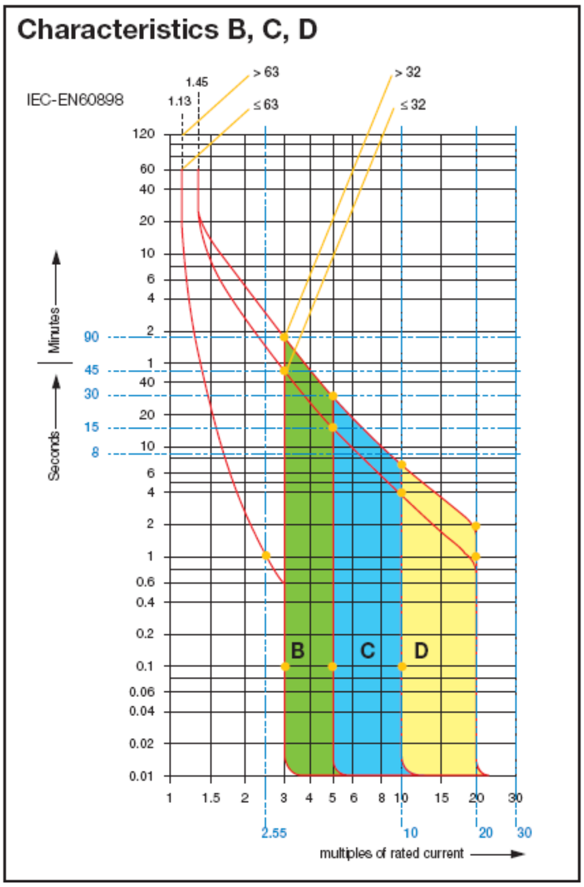
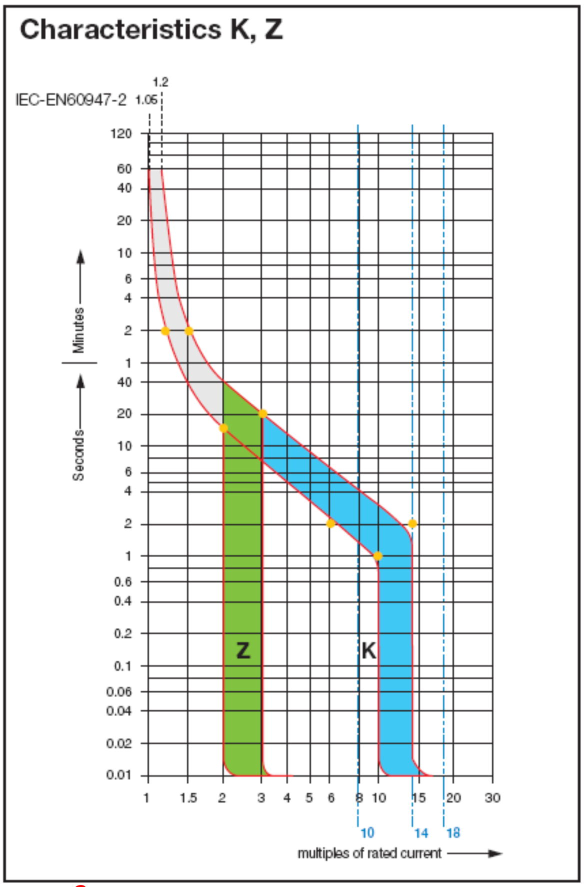
Tripping curves of MCB



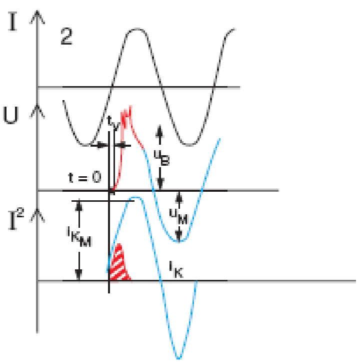


Limitation of specific let-through energy I^2t

Tripping of an installation circuit by circuit-breaker when there is a short-circuit requires a certain time depending on the characteristics of the circuit-breaker and the value of the short-circuit current.
During this period of time, part or all of the short-circuit current flows into the installation; the parameter I2t defines the “specific let-through energy”, ie. the specific energy that the breaker allows through when there is a short-circuit current Icc during the tripping time t.

In this way, we can determine the capacity of a circuit-breaker to limit, ie. break high currents up to the rated breaking power of the device, by reducing the peak value of the above-mentioned currents to a value which is considerably lower than the estimated current.
This can be achieved using mechanisms which open very rapidly and have the following advantages:

- they limit the thermal and dynamic effects both on the circuit-breaker and on the protected circuit;
- they reduce the dimensions of the current-limiting circuit-breaker without reducing breaking capacity;
- they considerably reduce ionized gases and sparklers emitted during the short-circuit and therefore
- they avoid the danger of ignition and fires.



Current limiting circuit-breaker

Short-circuit current

red = effective short-circuit current squared

blue = estimated short-circuit current squared (shunted circuit-breaker)

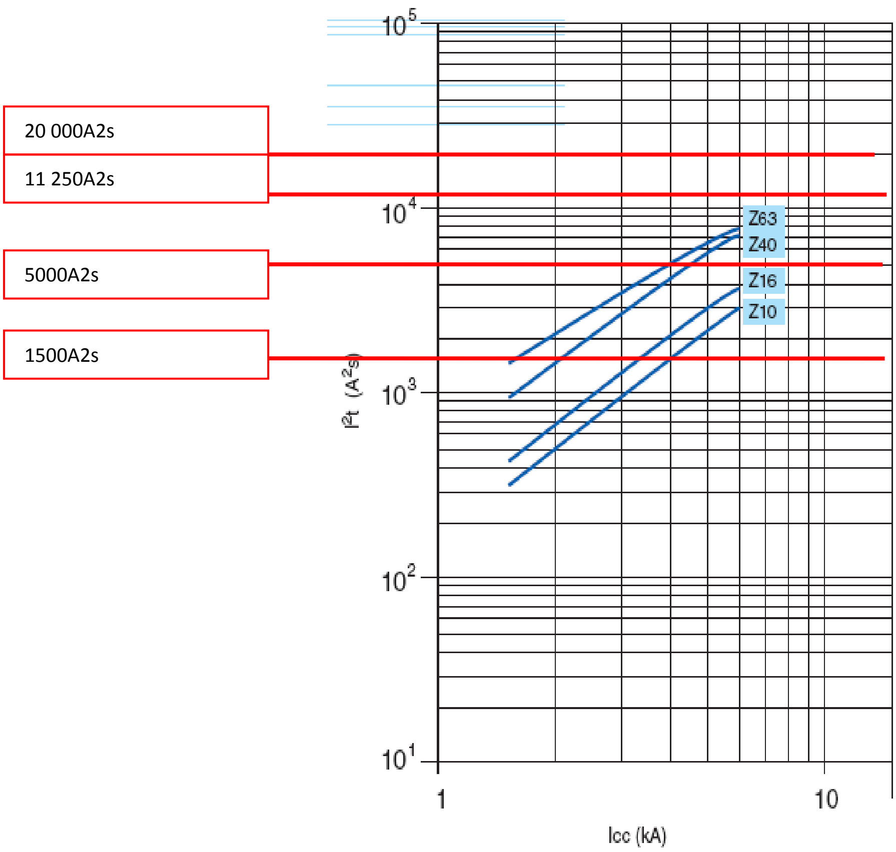
iK_M = maximum values of symmetrical component of short-circuit current squared

shaded in red = specific let-through energy in two cases

celduc made different tests in ABB laboratory and the conclusion is a short-circuit protection is possible with Fast miniature circuit Breaker at condition the short circuit prospective current is not too high and with High I^2t of SSRs.

First tests have been made with S280 Z curves from ABB. Tests results can be sent to customers.

S280 characteristics Z 230/400V let-through energy

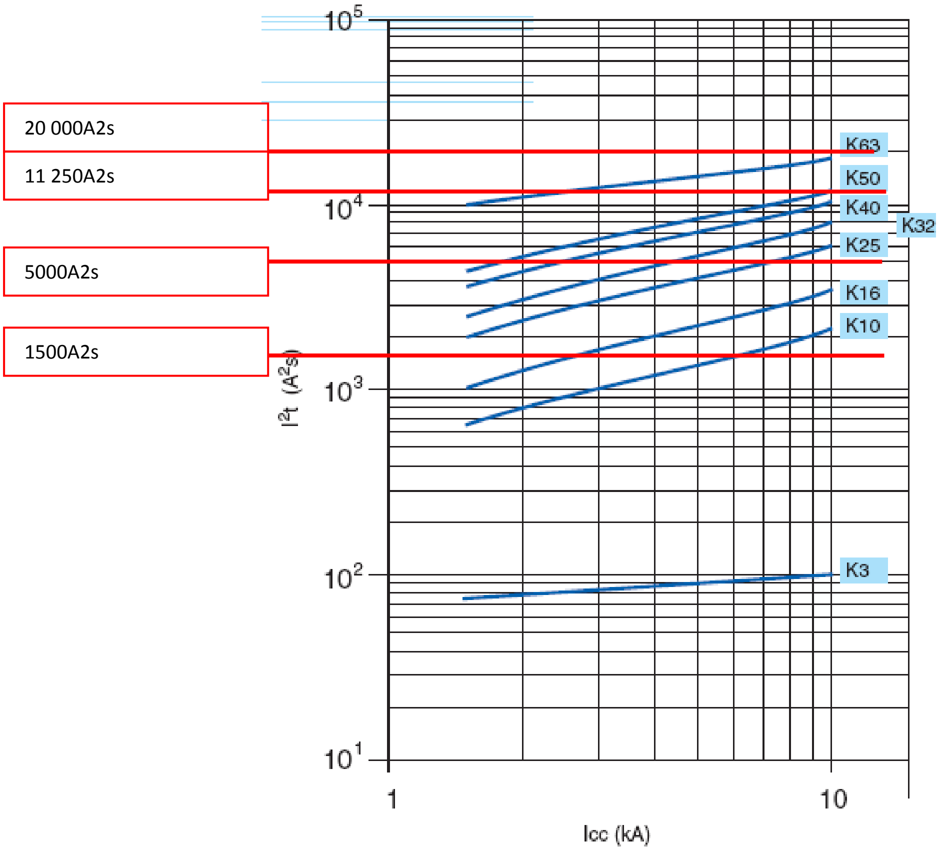


We can see with a 5000A2s SSR, we protect correctly with Z10 and Z16 for Icc > 7kA
With Z40 we are limited at 4500A. To reach 10kA it is necessary to use a 95A SSR with 11250A2s
With a 1500A2s SSR (50A model) prospective short circuit currents are limited (2kA with a Z16)

Conclusion

Z curves specially designed for semiconductors protection are adapted with high I2t celduc SSRs.
But Z curve is not very well adapted to load with inrush current.
For such loads it is better to use K curves

S280 characteristics K 230/400V let-through energy



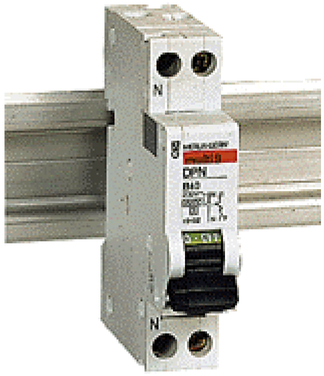
We can see with a 5000A2s SSR, we protect up to 10kA with k10 and K16
Etc……………

Conclusion

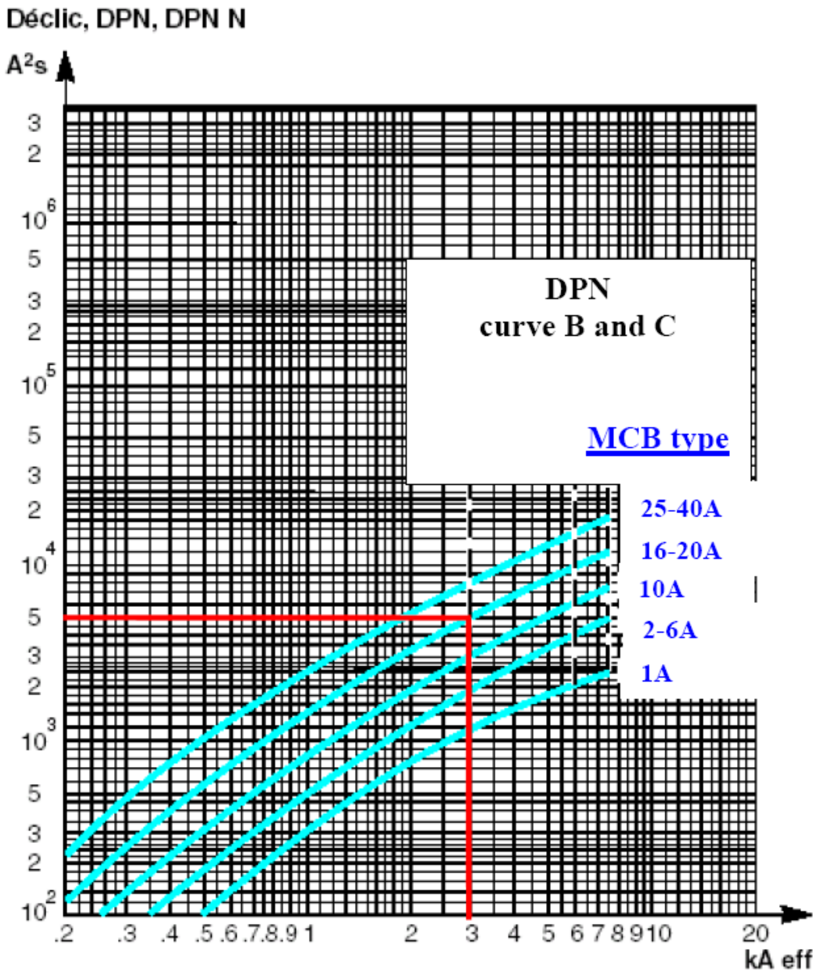
K curves is a good alternative to Z curves up to 63A

Other MCBs or curves types are possible.

ABB MOELLER Schneider



Example with a curve B and C from SCHNEIDER



You can see with a 16A MCB curve B or C and a 5000A2s SSR you can reach more than 3KA for short circuit prospective current.

By experience, generally the short circuit prospective current on a resistive load rarely exceeds 2kA.

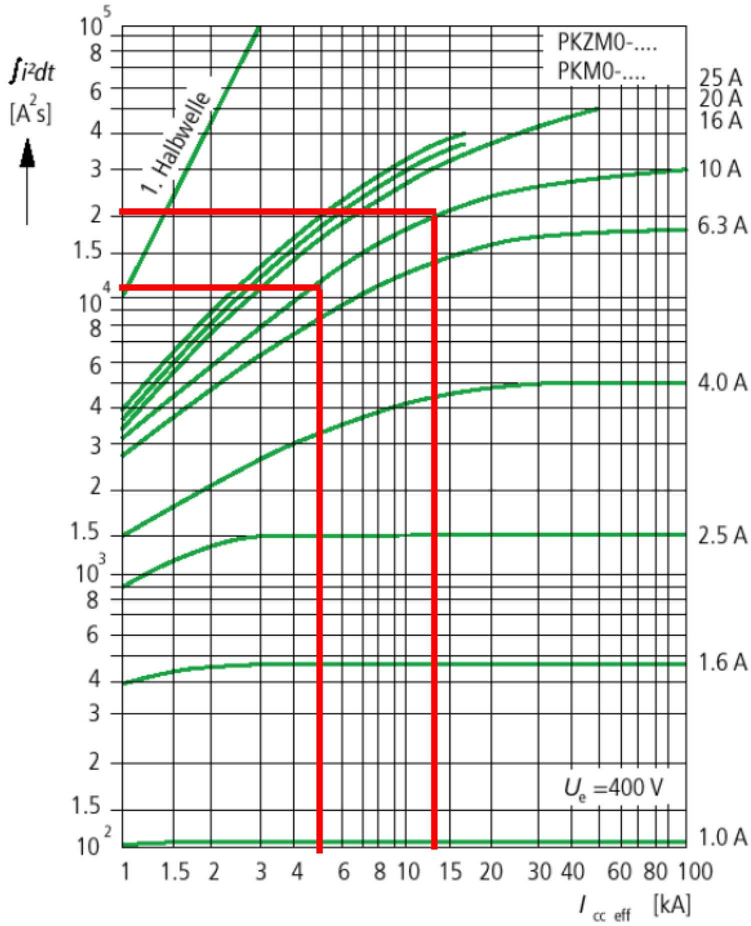
AC-53 Applications (Motors applications)

For motors applications, the more popular is now to use **MOTOR PROTECTIVE CIRCUIT- BREAKERS**
These devices : **Motor-protective circuit-breakers are built for coordination type "1" and coordination type "2"**

Example : PKZM0 from MOELLER

In case of Coordination type 2, we have to choose the right model in terms of Breaker with the right thermal current.

You have to check the curve I2t according to Prospective current



Example:
Motor 4 kW on 400VAC. IAC-53 = 8.5A Starting current Id = 8x In = 68A use with a PKZM0 - 10A.
According to this starting current, we have to choose a 95A SSR with an I2t value of 11250A^2s.
With this protection, you can reach more than 5kA for Iq.
By experience, generally the short circuit prospective current on a motor load rarely exceeds 2kA.
So SVT868 relays with I2t >11250A^2s is a good choice.
If necessary you can use SVT869 with I2t >20000A^2s, that means a protection up to 12kA

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Examples of tests made in ABB LABORATORY with S280Z

celduc has been the first manufacturer to introduce High I2t Solid State Relays.
celduc has a large experience with protection by Miniature Circuit-breakers.
First tests have been made in 1995 in ABB laboratory in Italy (below ABB certificate of test)

ABB Elettrocondutture SpA

ABB

Laboratorio

resoconto di prova

Data 17/5/95

Firma [signature]

LSP 1441

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Tabella n.6 - Compendio delle prove

Tipologia del relè statico		Limiti del coordinamento	
		Z 16	Z 50
Zero cross 70 A	75A model with 5000A2s	* 5000 A	3000
Random 70 A	125A model with 20000A2s	5000 A	3000 A
Zero cross 110 A		* 7000 A	4000 A

* Non è stata eseguita la verifica di questo punto per mancanza di relè statici Zero cross 70 A ; il limite non dovrebbe essere molto diverso dai valori sottostanti.

The values on Table N°6 are the ones accepted according to the test results carried out by ELC Test lab and CELDUC Test lab.
As a consequence the same values for coordination information can be published officially by marketing - sales requests.

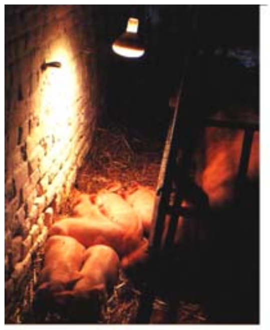
Guy Poncet

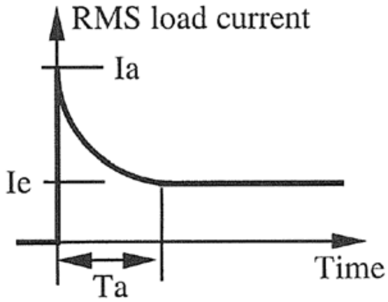
[signature] 21/6/95

Thanks to High performances Power thyristors (TMS^2 technology) and the long collaboration with thyristors dices manufacturers, celduc has got Solid State relays with the highest I^2t values of the market (> 20000A^2s for 125A SSRs)

IV- Other Applications (Heating applications with INFRARED Lamps)

Protection coordination type 2





Examples of choice (These values take the lifetime of the fuse into account)

SSR Nominal current	I2t of SSR (A2s)	Long Ia Lamp Ia= 5xIe Ta = 100ms		Short Ia Lamp Ia= 10xIe Ta = 10ms		MCB (breaker) solution
12A	72	Ie max = 3.5A	gRC12 14 x51	Ie max = 2A	gRC12 14 x51	No solution
25A	312	Ie max = 10A	gRC25 14 x51	Ie max = 8A	gRC25 14 x51	No solution
35A	800	Ie max = 14A	gRC32 14 x51	Ie max = 12A	gRC32 14 x51	No solution
50A	1500	Ie max = 20A	gRC50 22 x58	Ie max = 18A	gRC50 22 x58	No solution
75A	5000	Ie max = 30A	gRC63 22 x58	Ie max = 28A	gRC63 22 x58	S280K40
95A	11250	Ie max = 35A	gRC80 22 x58	Ie max = 32A	gRC80 22 x58	S280K50
125A	20000	Ie max = 50A	URD135 22x58	Ie max = 45 A	URD135 22x58	S280K63

VI-What we have to do after a short circuit.

During a short circuit, you can have some damages on the installation.

In first check where the short circuit has been done.

After reparation and wirings verification, we advice to test the Solid State relay.
Even with a correct protection, the number of short-circuit for a power semi-conductor is limited.
Some short circuits can limit the life-time of the components, so generally the number of possible short-circuit in the life of a power semi-conductor is maximum 10 times.