Introduction to Protection by Fuses

Overcurrents

There are 2 types of overcurrents:

- Overload
- Short circuit

Overcurrents

Overload current

Overload current: less than 8 times or 10 times the rated current

Short-circuit current: typically more than 10 times the normal current of the system – up to 300 KA

Overcurrents

Common causes of overloads

Lack of maintenance
Dust/dirt build-up
foreign particles

Ageing of equipment
Worn parts
Insufficient lubrication

Thermal damage
Insulation degradation
component failures

Improper use
Insufficient capacity
excessive use

Power quality
Transients
Undervoltage
over voltage

Low-magnitude ground faults
Metallic particles
water damage

Overcurrents

Common causes of short-circuits

- **Foreign articles**: Bolts, screwdrivers, other conductive objects
- **Components failure**: Semiconductor breakdown
- **Voltage spikes**: Lightning switching surges
- **High magnitude ground faults**: Direct path to ground
- **External influences**: Floods fires vibrations

Overcurrents

Consequences of overcurrents

Injury
Loss of life, burns, flash blindness

Downtime
Thousands of dollars or euros per minute

Loss of Process control
Continuous process, steel in arc furnace, non-conforming parts

Mechanical effect
Equipment damage, destruction from Magnetic movement

Thermal effect
Equipment damage, destruction from energy arcs

Overcurrents

Impact of legal considerations

- Manufacturers are fully responsible for their components

- OEM's are fully responsible for their assemblies / equipment

- «Limited liability» is a thing of the past!

- Cost of settlements are growing astronomically! (personnel injury, equipment, downtime, mental anguish, punitive damages)

Fuse advantages

Safety

• The metallic element inside the fuse melts directly upon the fault current effect without any intermediate mechanism , sensors etc ….

• The arc extinction is totally enclosed: no emission of gas, flames, arcs or melted materials

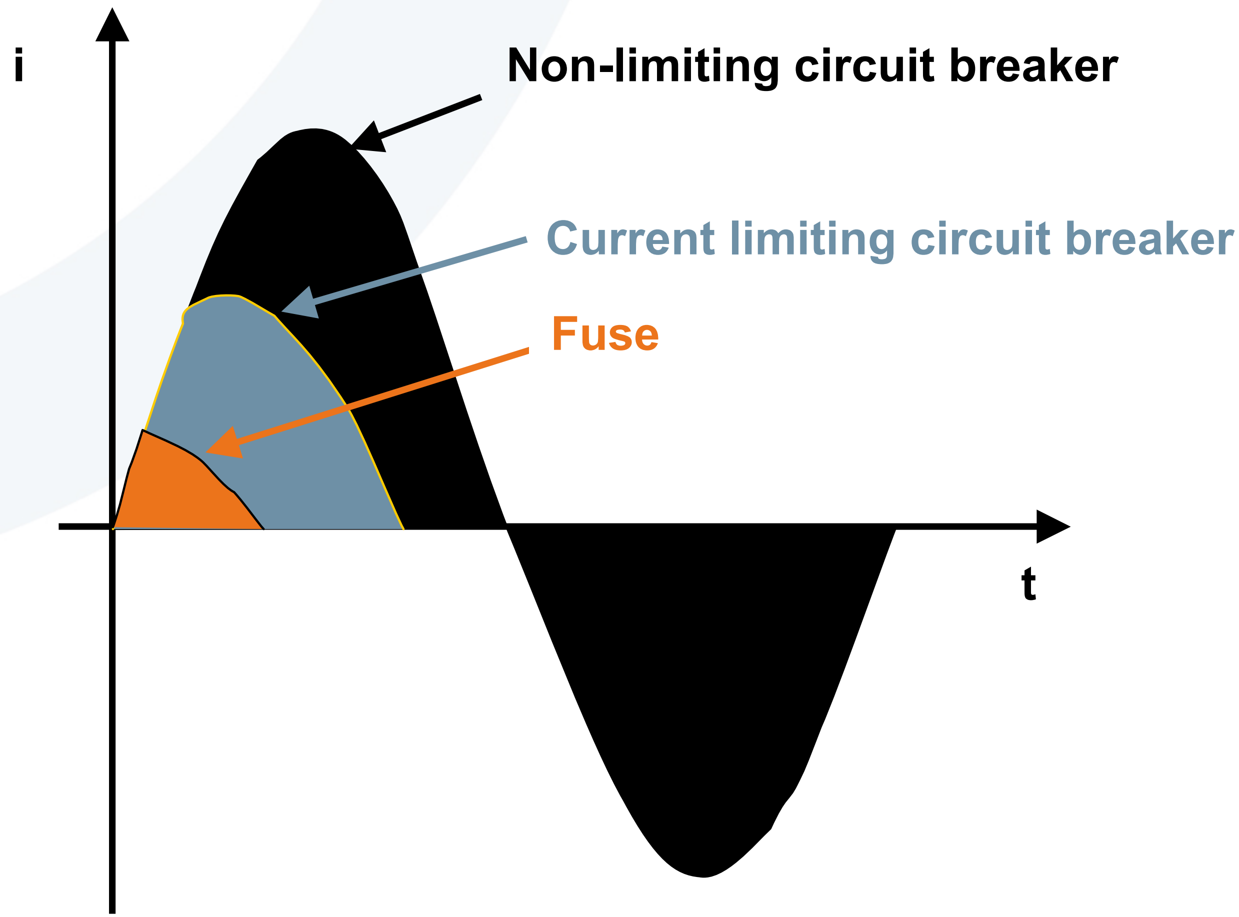
• The arc flash energy is drastically reduced when the peak current is limited by a fuse.

Maximized energy limitation =

Minimized damage & injury

Fuse advantages

Speed / Peak let through current
Comparison of protective devices



Fuse advantages

Breaking capacity: up to 100 000 A, 200 000 A and even 300 000 A.

Maintenance before a short-circuit: no maintenance.

Maintenance after a short-circuit: replace the blown fuse by a new one. quick and gives the insurance the equipments are still protected with exactly the same efficiency as before.

Fuse advantages

Selectivity (or discrimination)

Fuse = minimized circuit disruption, no black out.

Future system growth

Low power consumption

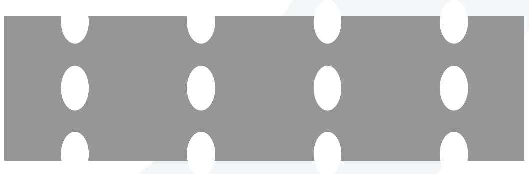
Fuse advantages

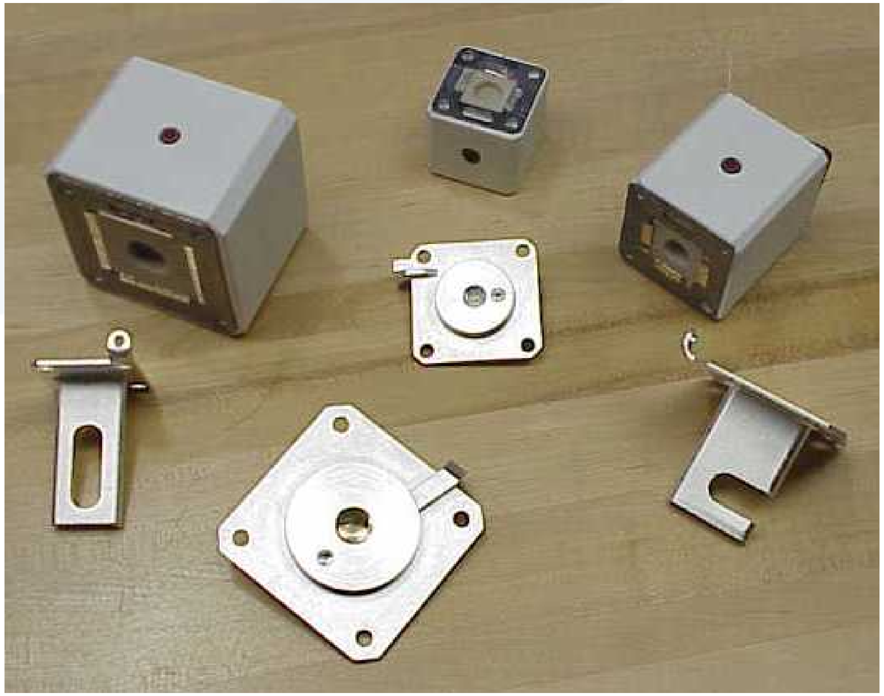
Reliability

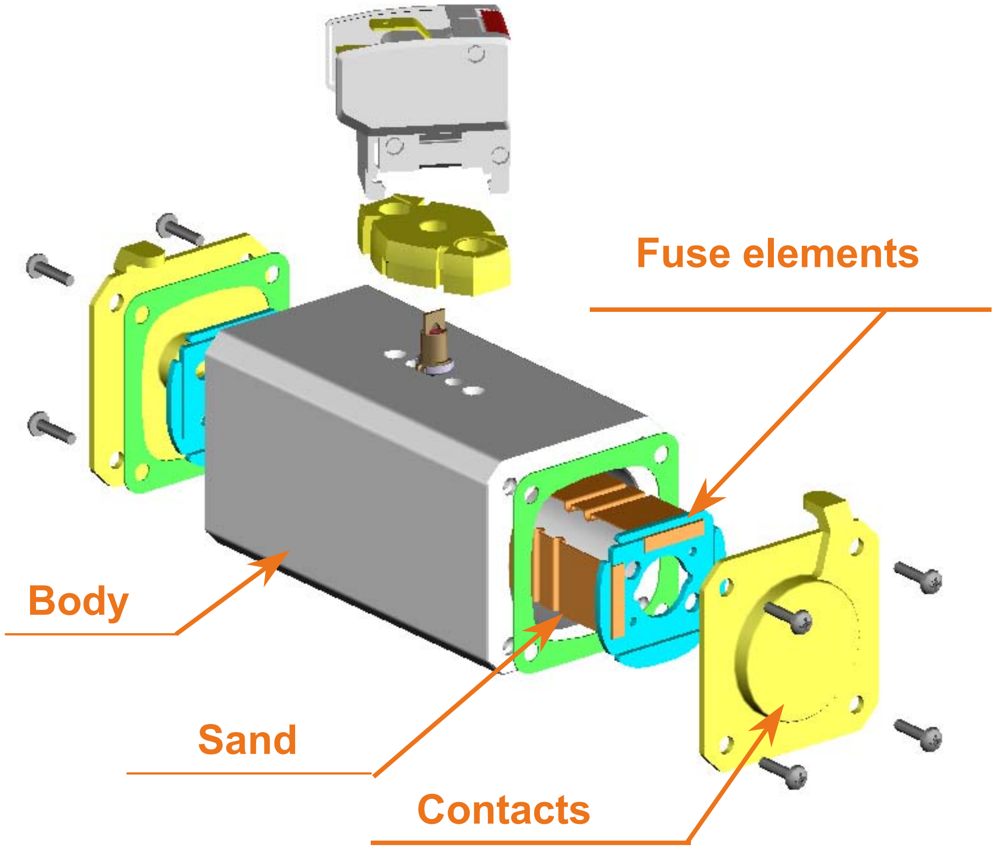
Universal

Price

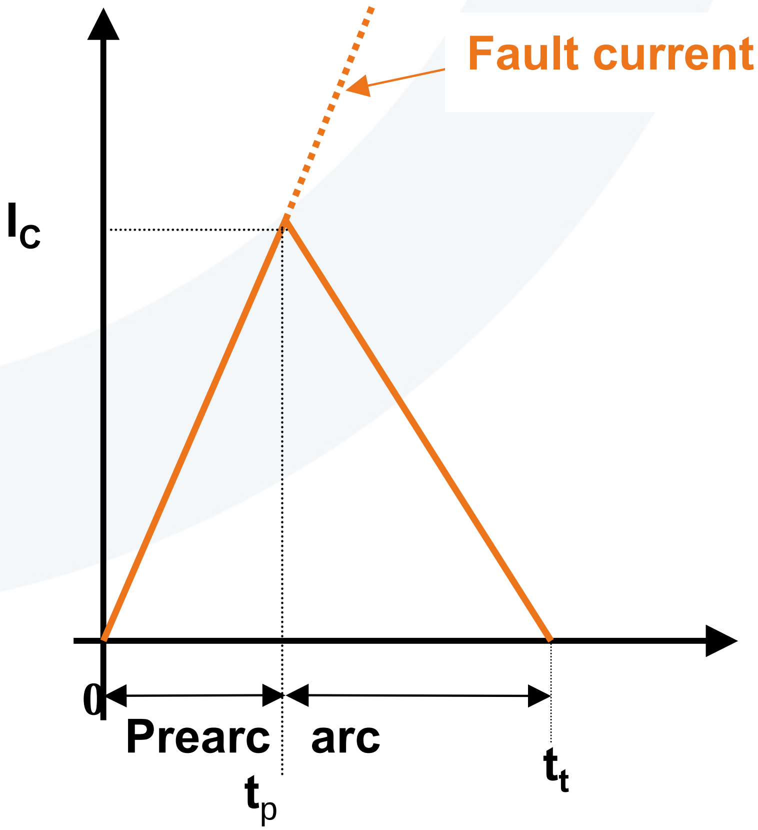
Construction of a fuse

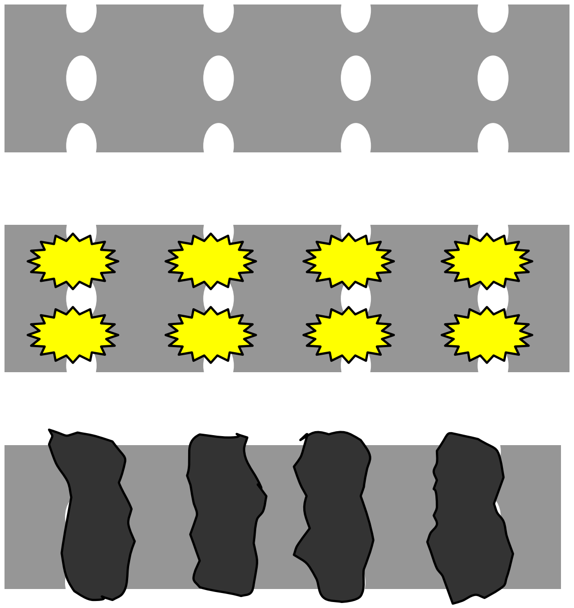




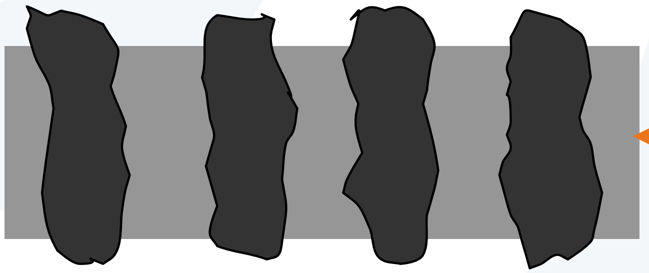


Interruption of short circuit currents



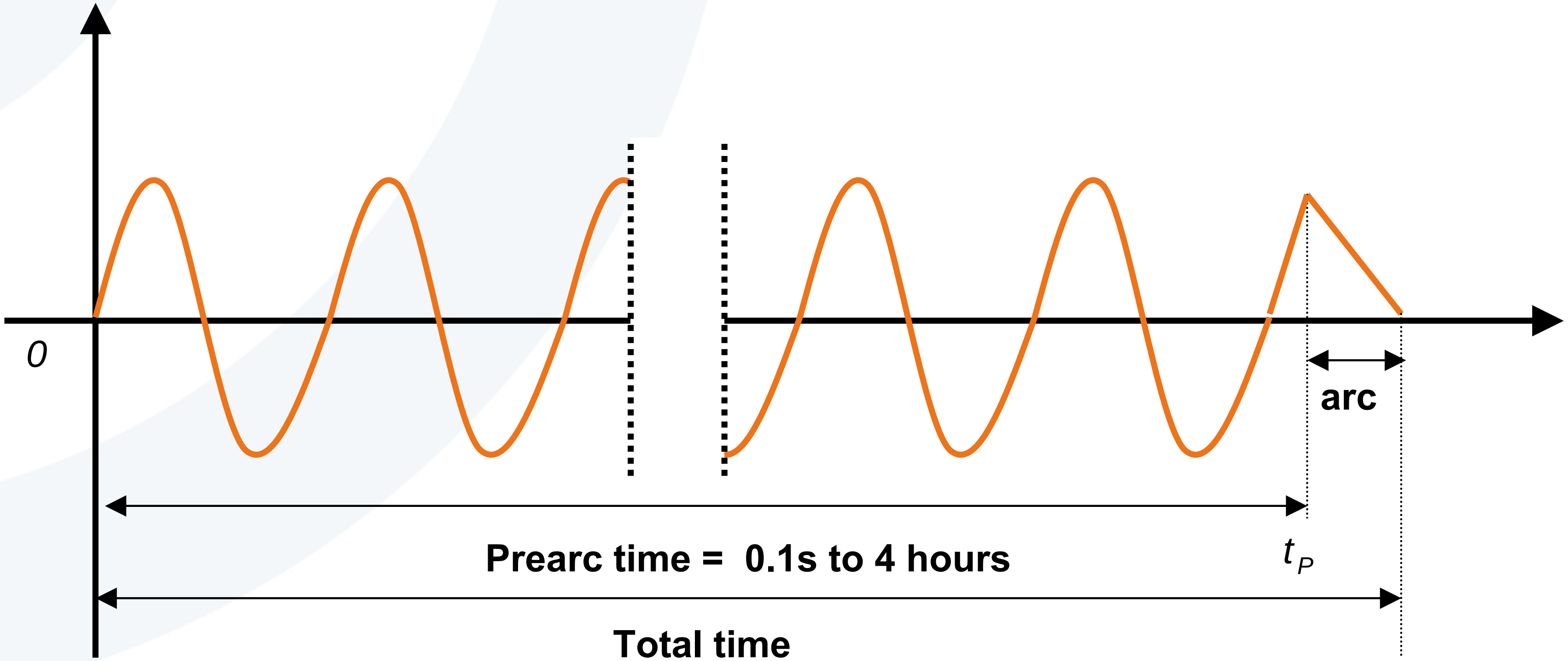


Interruption of short circuit currents



Melted sand = fulgurite
(glass-like substance)

Interruption of overloads



When the fuse is not designed to interrupt overloads damaged to the body may occur due to excessive temperatures reached inside the fuse before melting the fuse elements.

Interruption to IEC 60269 standard

General Rules

IEC 60269-1
Low voltage fuses
1000VAC & 1500VDC

IEC 60269-2
Systems for use by authorized persons (industrial application)

CEI 60269-2-1
Section I : NH system

Section II : BS88

Section III: 10x38,14x51,22x58

Section IV: BS88
Offset blades

Section V : UL 248
Class J & class L

Industrial usage
General cables and motors protection

IEC 60269-3
Systems for use by unskilled persons (household applications)

CEI 60269-3-1
Section I : D & D0 (Neozed®)
Section IIA : NF
6A 6,2 x 22,2 - 10A 8,4 x 22,2
16A 10,2 x 25,4 - 20A 8,4 x 31
25A 10,2 x 31 - 32A 10,2 x3 7,4

Section IIB : BS 1361
Section IIC : type C (Italy)

Section III : pin-type fuses
Section IV : fuses in plugs (BS 1362)

Domestic usage
As per type and country rules

IEC 60269-4
Systems for the protection of semiconductor devices

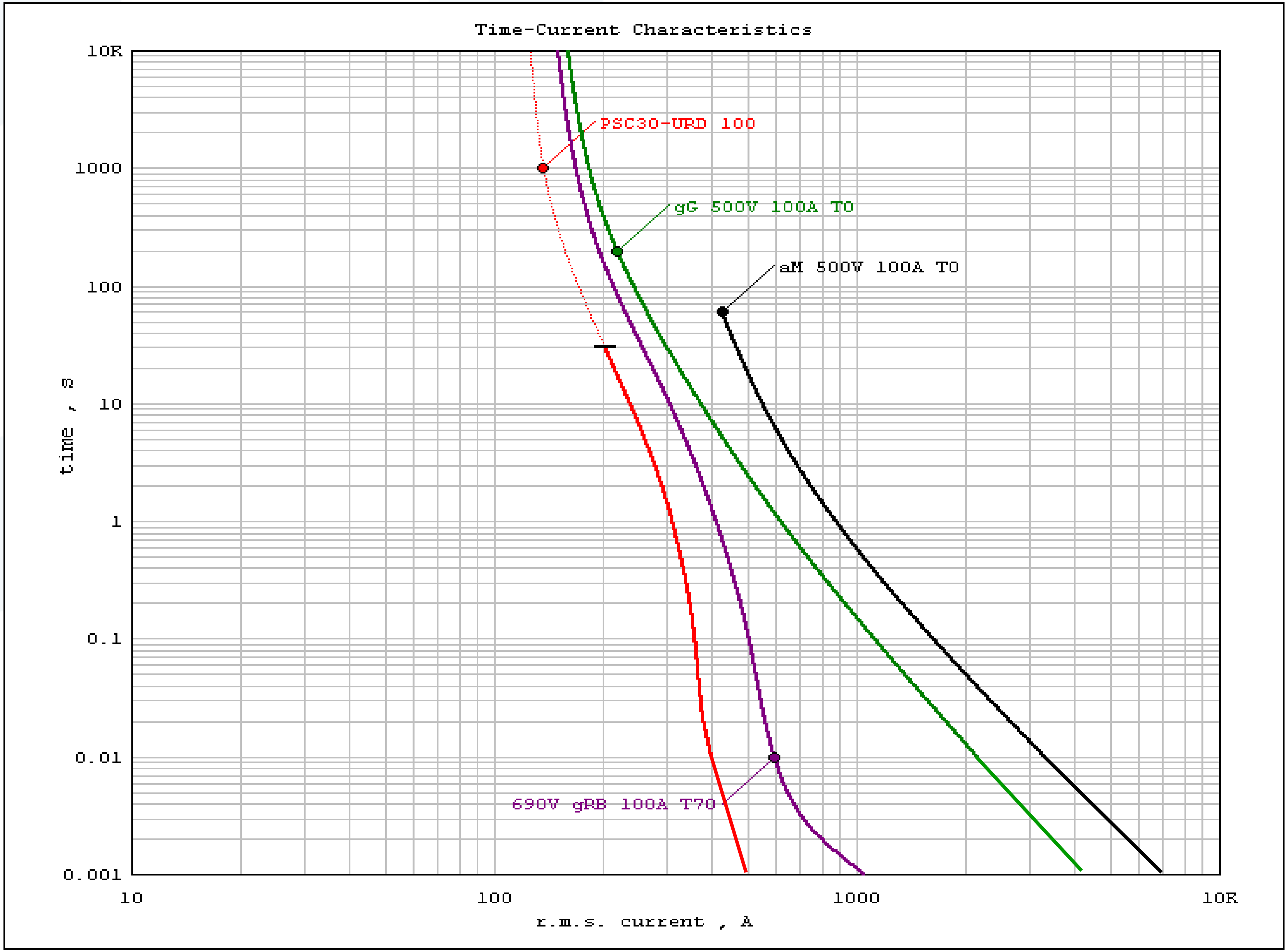
IEC 60269-4-1
Examples of types: BS88, USA, DIN etc…

Specific usage
Voltages can go above 1000VAC & 1500VDC

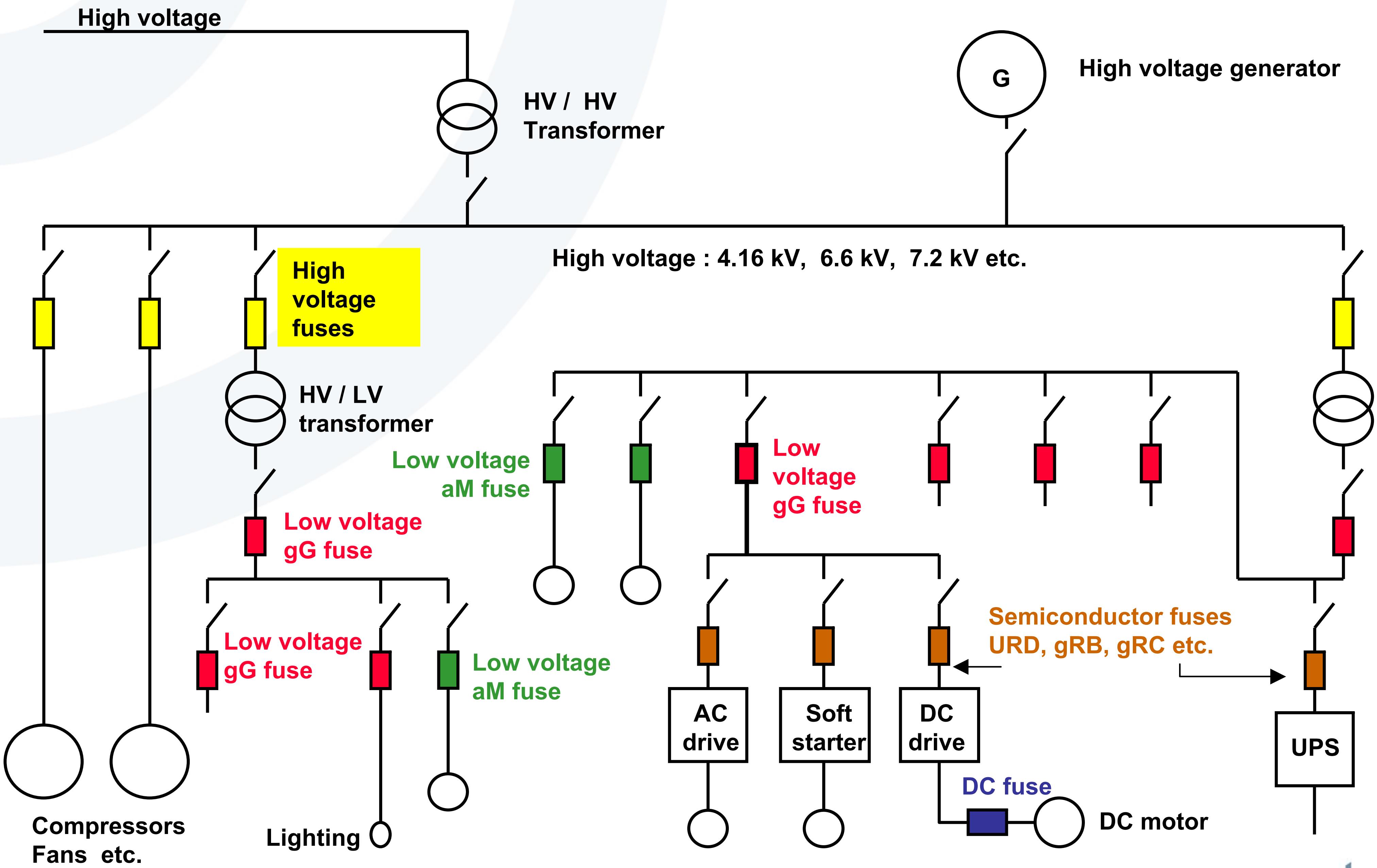
Interruption to IEC 60269 standard

Type	Applications	Breaking Range
aM	Short circuit protection of motor circuits	Partial range (back-up)
aR	Semiconductor protection	
gG	General purpose: mainly conductor protection	Full range
gM	Motor circuit protection	
gN	North American general purpose for conductor protection	
gD	North American general purpose time-delay	
gR, gS	Semiconductor protection	
gTr	Transformer protection	
gL, gF, gI, gII	Former type of fuses replaced by gG type	

Typical IEC Curves



Typical layout of a large plant



Fuse voltage rating selection

$$U_{FUSE\ MAX} > V_{CIRCUIT\ MAX}$$

Fuse Type	Rated Voltage of the Fuse U_N (V)	Maximum operational voltage of the fuse $U_{FUSE\ MAX}$ (V)
gG, gM, aM, aR[1], gR[1], gS[1]	230	253
	400	440
	500	550
	690	725
gN, gD (American ranges)	600	600

[1] When protecting static current & voltage converters the rated voltage U_N of fuses for semiconductors often require:

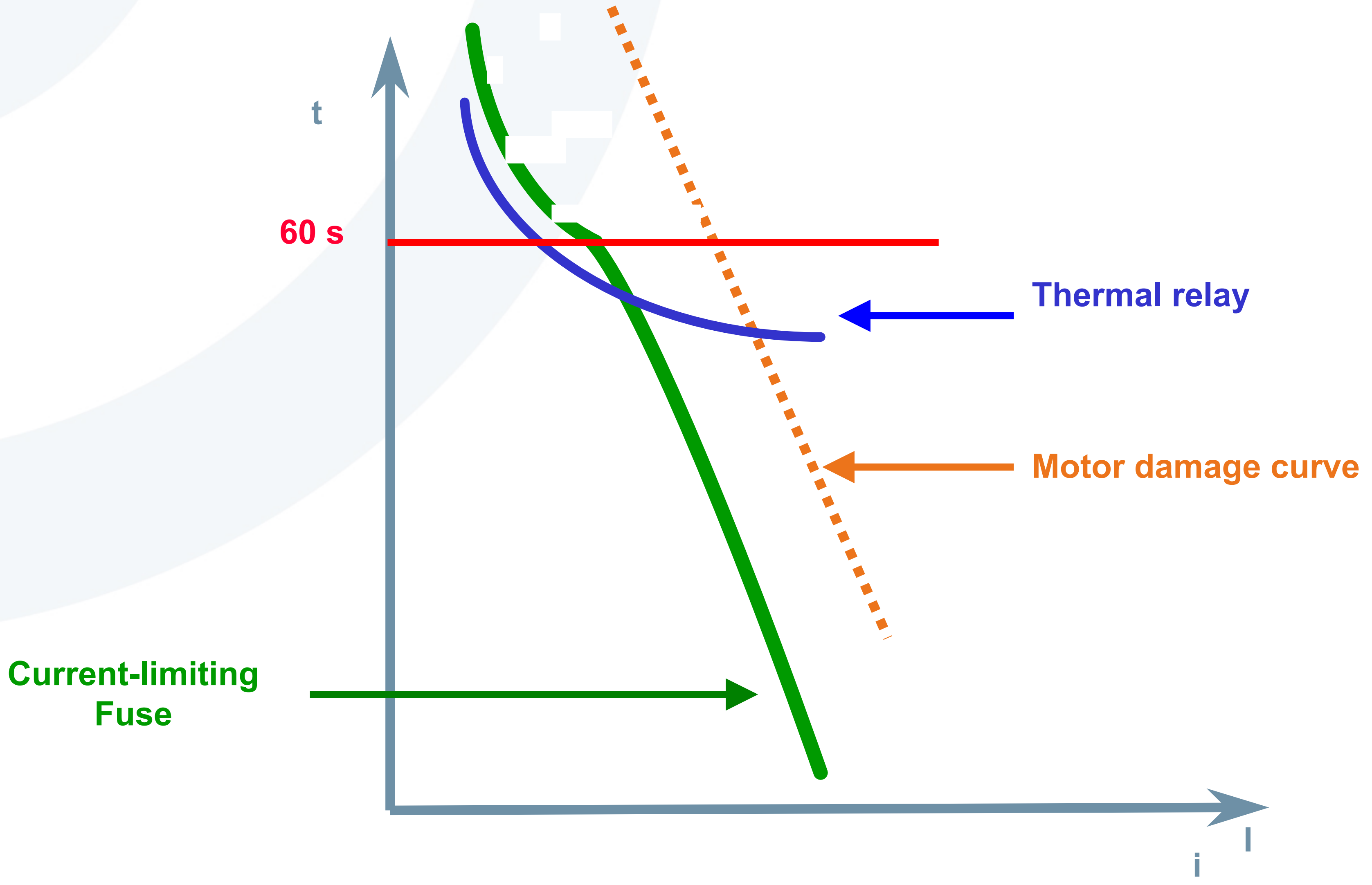
$$1.06\ U_N > V_{CIRCUIT\ MAX}$$

Cable protection

$$I_B \leq I_N \leq I_Z$$

$$I_F \leq 1.45 I_Z$$

Motor circuit protection



Motor circuit protection

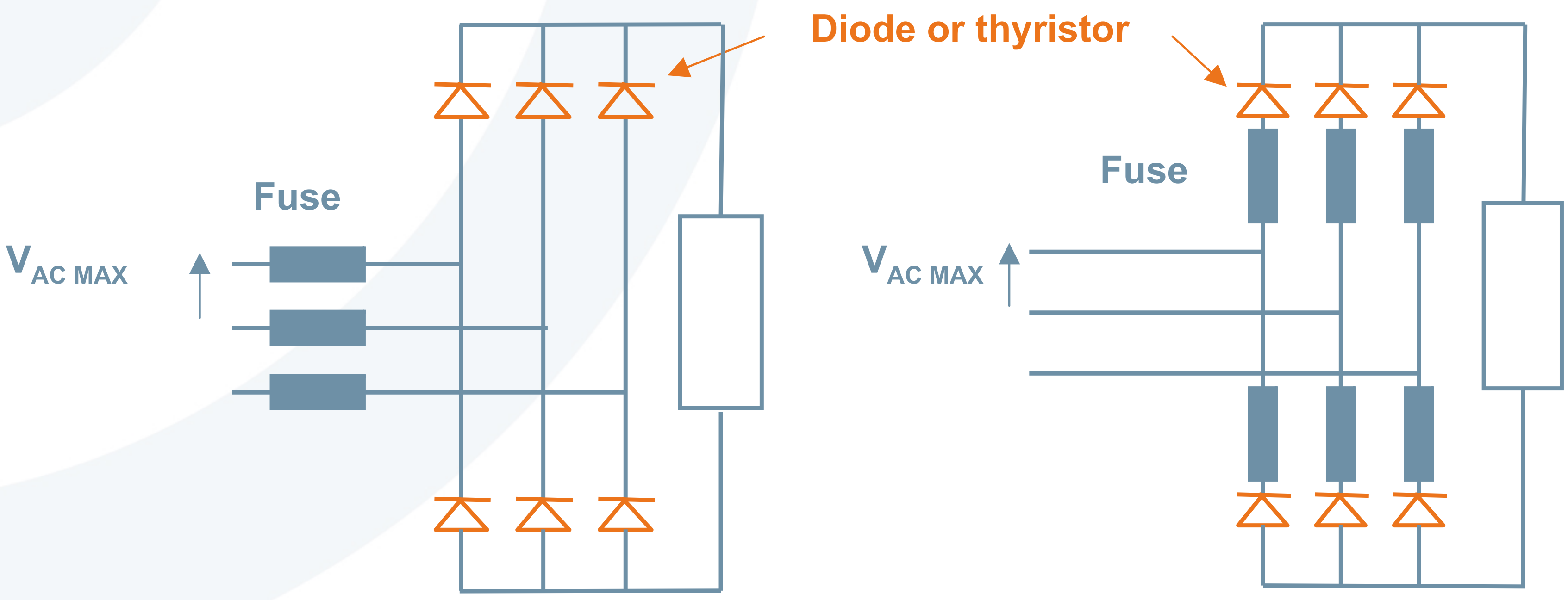
1500 RPM three phase asynchronous motor									Selected fuses: class, voltage, ranting and current rating																			
220 V			380 V			660 V			380 V		250 V à 500 V		400 V à 690 V		400 V à 690 V		400 V à 500 V		500 V à 690 V								440 V à 660 V	
									8 x 32		10 x 38		14 x 51		22 x 58		T 00		T 0		T 1		T 2		T 3			
kW	Ch	I_N (A)	kW	Ch	I_N (A)	kW	Ch	I_N (A)	gl	aM	gl	aM	gl	aM	gl	aM	gl	aM	gl	aM	gl	aM	gl	aM	gl	aM	gl	aM
						0,10	0,14	0,18					0,25		0,25													
0,05	0,068	0,39	0,10	0,135	0,30	0,20	0,27	0,35			1		1	0,5	1	0,5												
0,10	0,135	0,53	0,18	0,25	0,55	0,37	0,50	0,60	2	1	2	1	2	1	2	1												
0,18	0,25	0,94	0,37	0,5	1,1	0,55	0,75	1	4	2	4	2	4	2	42													
			0,55	0,75	1,6	1,1	1,5	1,5	4	2	4	2	4	2	4	2												
0,37	0,5	1,9	0,75	1	2	1,5	2	2	6	4	6	4	6	4	6	4												
0,55	0,75	2,8	1,1	1,5	2,6	2,2	3	2,9	8	4	8	4	8	4	8	4												
0,75	1	3,5	1,5	2	3,5	2,8	3,8	3,5	10	4	10	4	10	4	10	4												
1,1	1,5	4,4	2,2	3	5	4	4,5	4,8	12	6	12	6	12	6	12	6												
1,5	2	6	3	4	6,6	5	7,5	6,6	16	8	16	8	16	8	16	8	16											
2,2	3	8,7	4	5,5	8,5	7,5	10	8,8	20	10	20	10	20	10	20	10	20											
3	4	11,5	5,5	7,5	11,5	10	13,5	11,5			25	12	25	12	25	12	25	25										
4	5,5	14,5	7,5	10	15,5						32	16	32	16	32	16	32	16	32									
						15	20	17				20	40	20	40	20	40	20	40									
5,5	7,5	20	10	13,5	20	18,5	25	21				25	50	25	50	25	50	25	50	25	50							
7,5	10	27	15	20	30	26	35	29							50	32	50	32	50	32	50							
10	18,5	35	18,5	25	37	30	40	34							63	40	63	40	63	40	63							

MERSEN

Power electronic protection

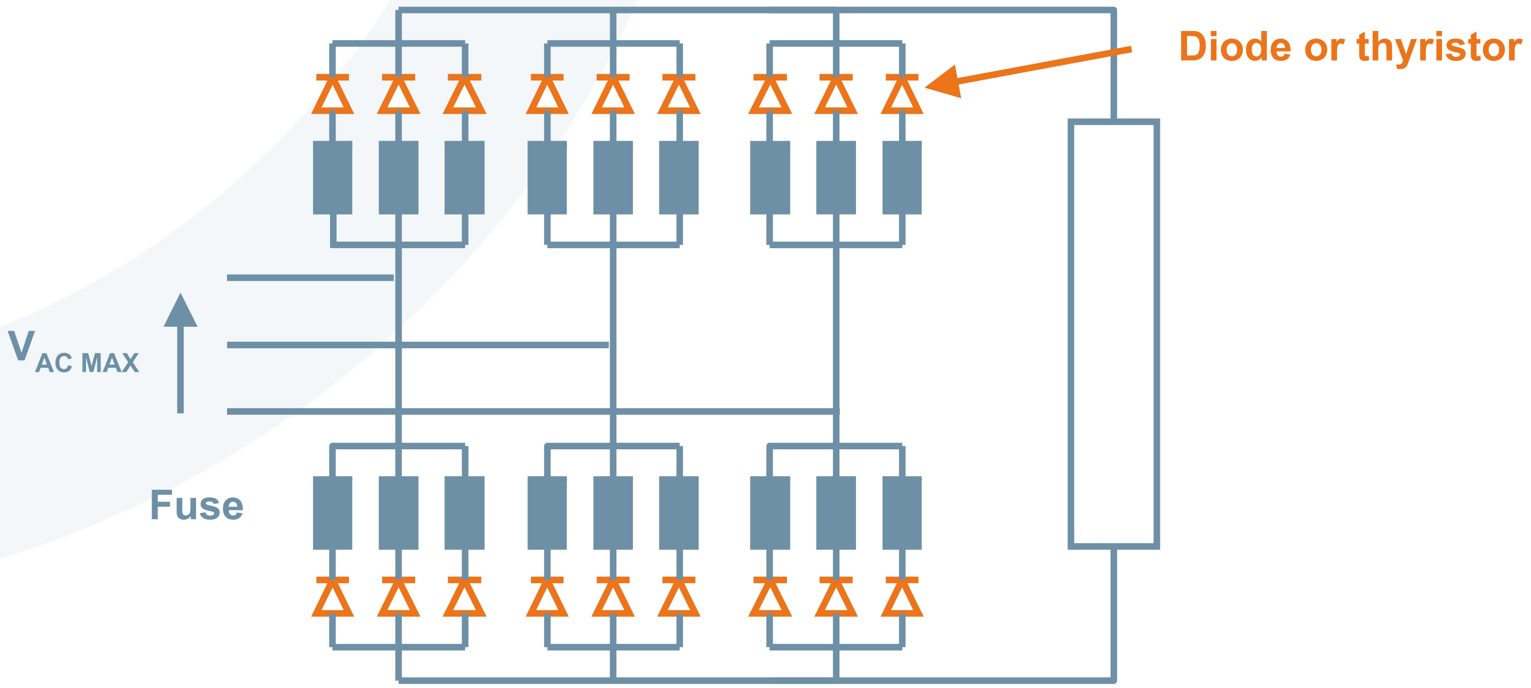
Fuse parameters	Requirements
Voltage rating	$V_{FUSE} > V_{LINE\ TO\ LINE}$ and $V_{FUSE} > V_{FAULT}$ In regenerative DC drives V_{FAULT} is higher than $V_{LINE\ TO\ LINE}$ Faults are not always with an AC voltage (inverters & regenerative DC drives)
Current rating	$I_{FUSE} > I_{RMS}$ The calculation of the current rating of the fuse must use corrective coefficients taking into account the effect of : • ambient temperature inside the cubicle • cooling • size of cables or copper bars connected to the fuse • variations of the current (reduce the fuse life time) Coordination with a circuit breaker requires a suitable melting curve at 15 ms Such coordination may require a fuse rating higher than the rating calculated from the RMS value of the current.
Total I^2t	Fuse total I^2t < I^2t of the semiconductor junction or Fuse total I^2t < I^2t of the semiconductor case rupture
Breaking capacity	Fuse Breaking Capacity > largest RMS value of the short circuit current I_{FAULT}
Minimum interrupting capacity	Fuse minimum interrupting capacity > minimum fault current or coordination with another protection system must be checked
Arc voltage	Fuse Peak Arc voltage < Reverse Voltage of the semiconductor

Three phase bridge with 1 semiconductor per arm



Fuse voltage rating U_N	
IEC 60269	For most ratings: $V_{AC\ MAX} \leq 1.06\ U_N$ For some ratings: $V_{AC\ MAX} \leq 1.10\ U_N$ For some 690V fuses: $V_{AC\ MAX} \leq 1.05\ U_N$
UL 248	$V_{AC\ MAX} \leq U_N$

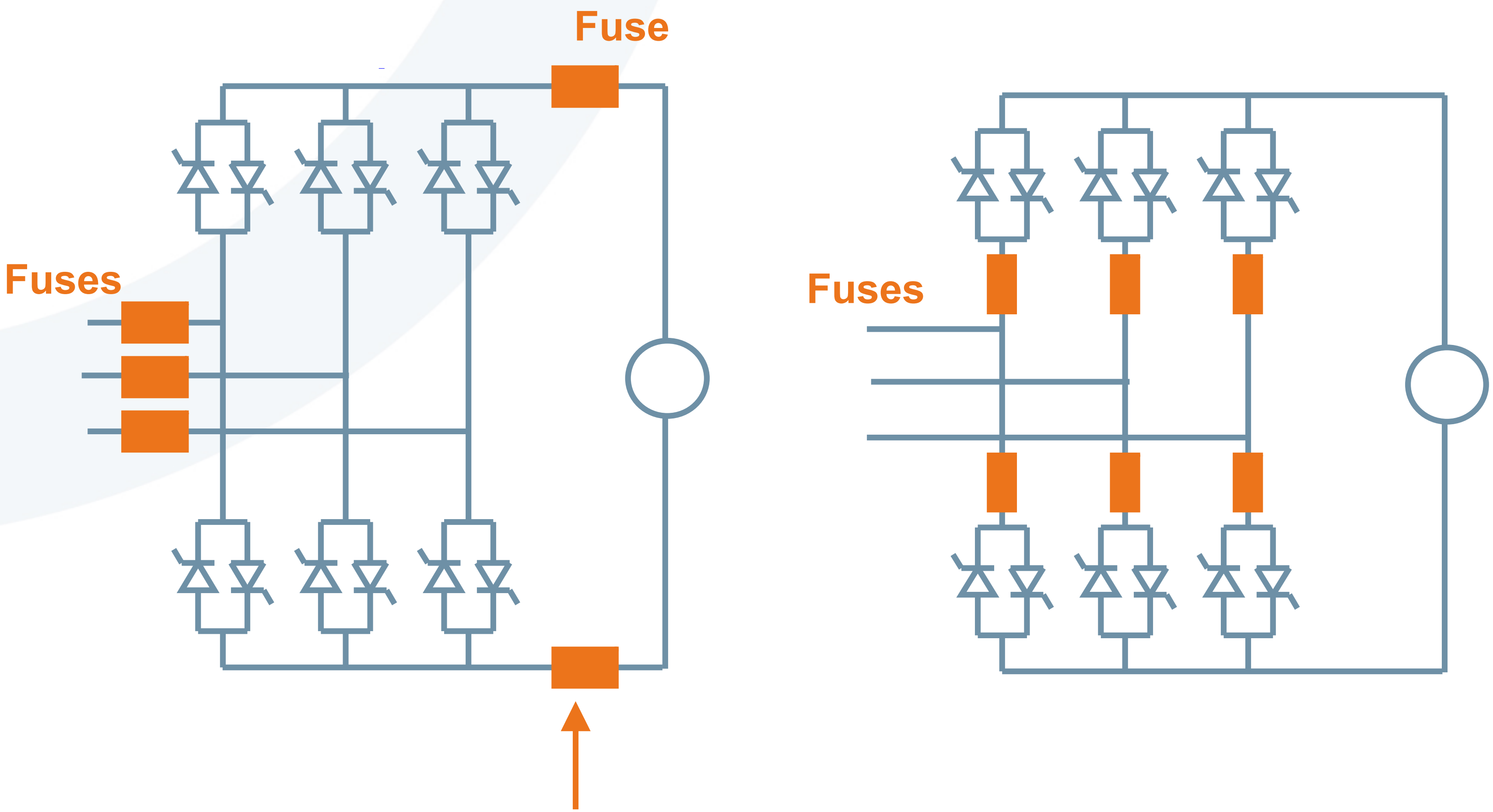
Three phase bridge with several semiconductor per arm



Regenerative DC drive

Fuse voltage rating U_N

$U_N = K_{AC} V_{AC\ MAX}$ with $1.25V \leq K_{AC} \leq 1.70$

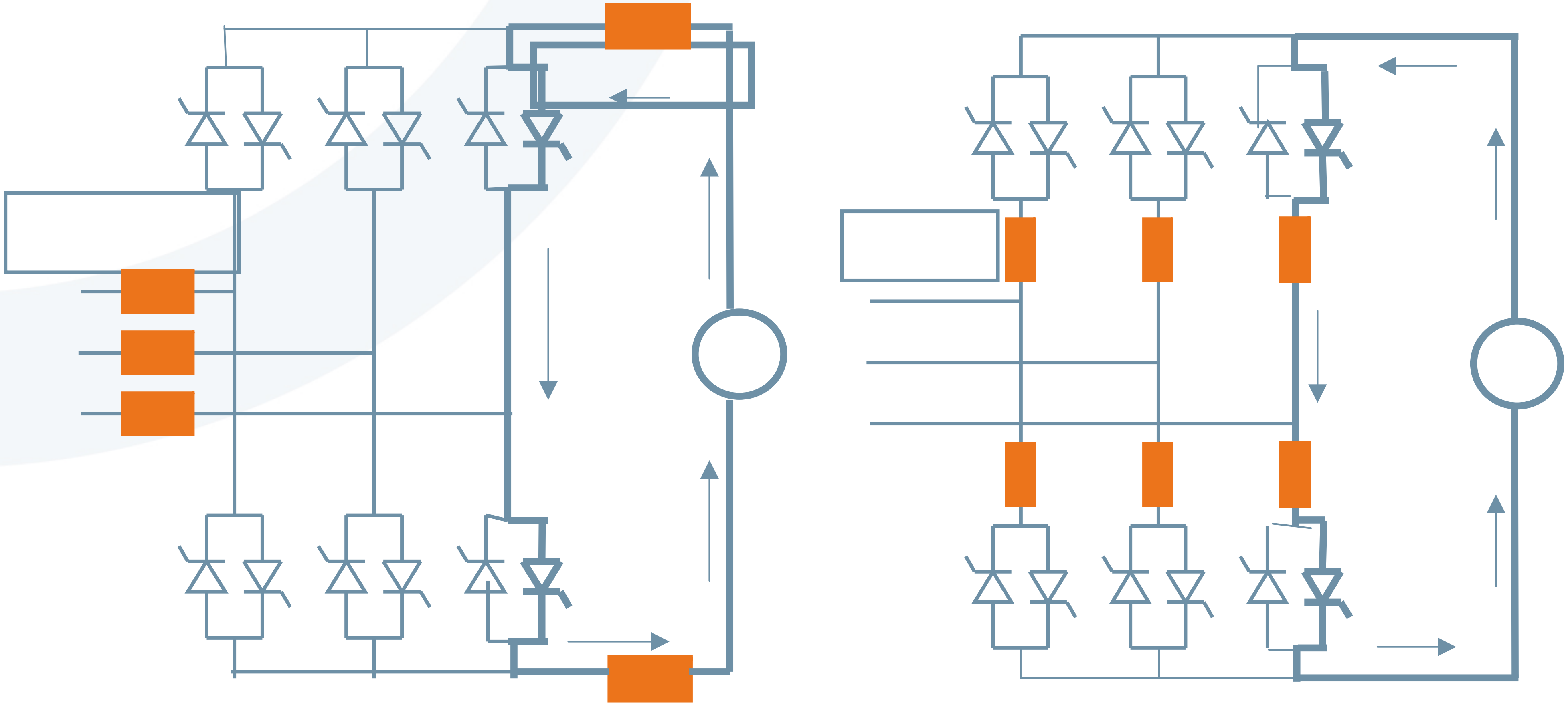


Necessary because of the DC shoot through fault

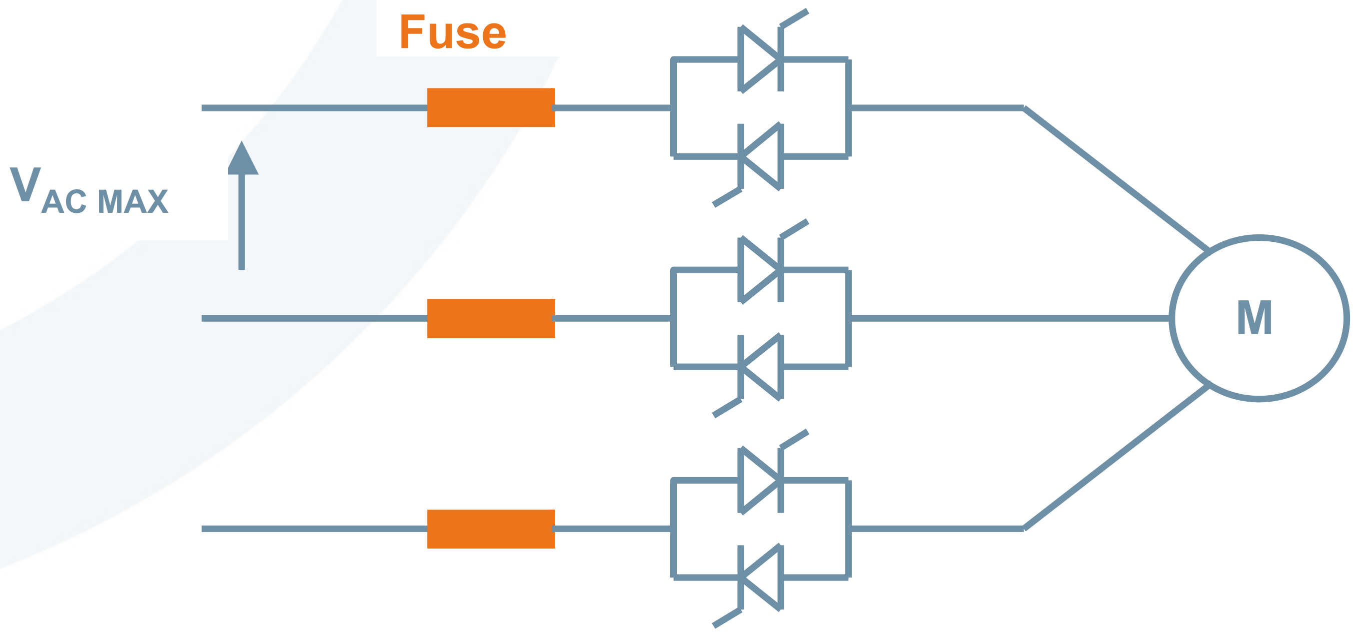
See next slide

Regenerative DC drive

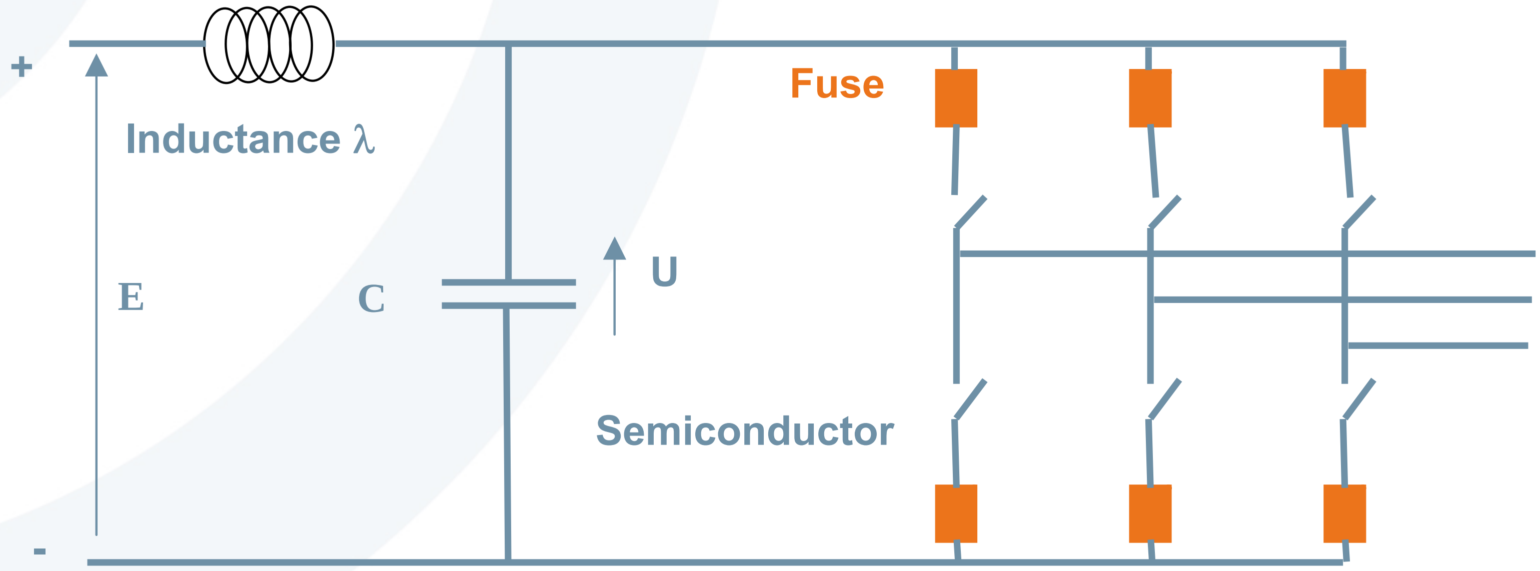
DC shoot throught fault

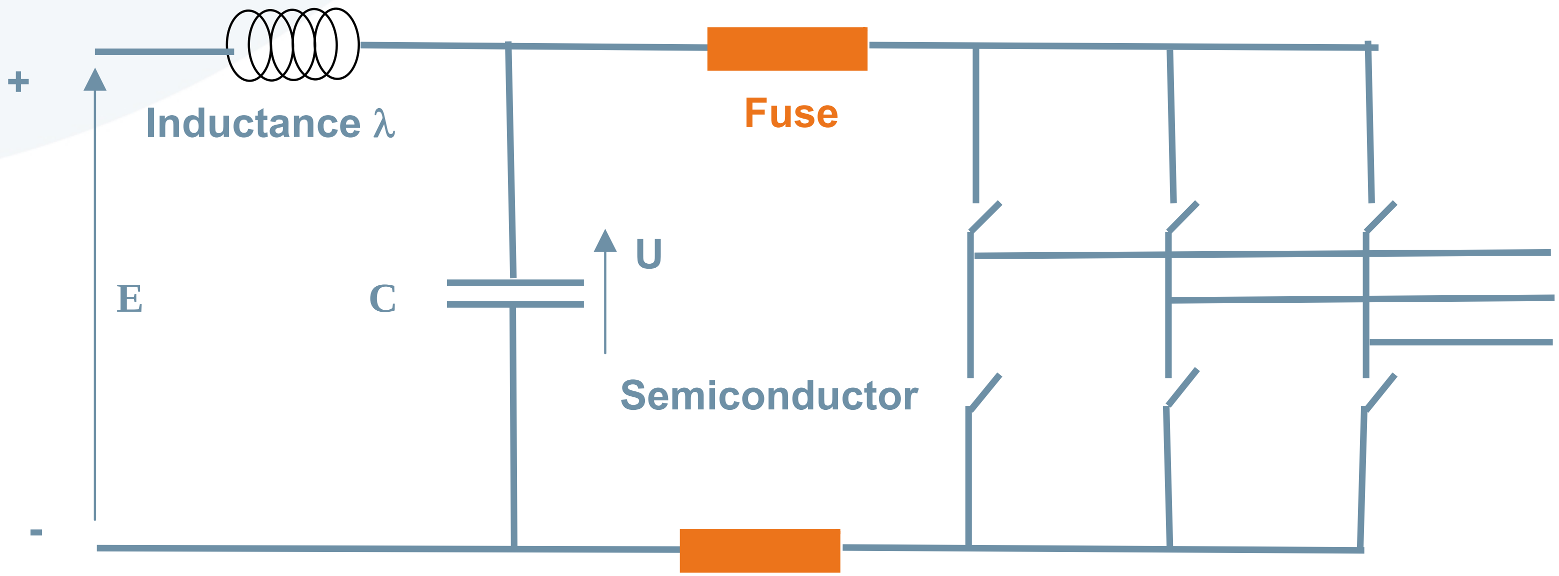


Soft starters & static switches

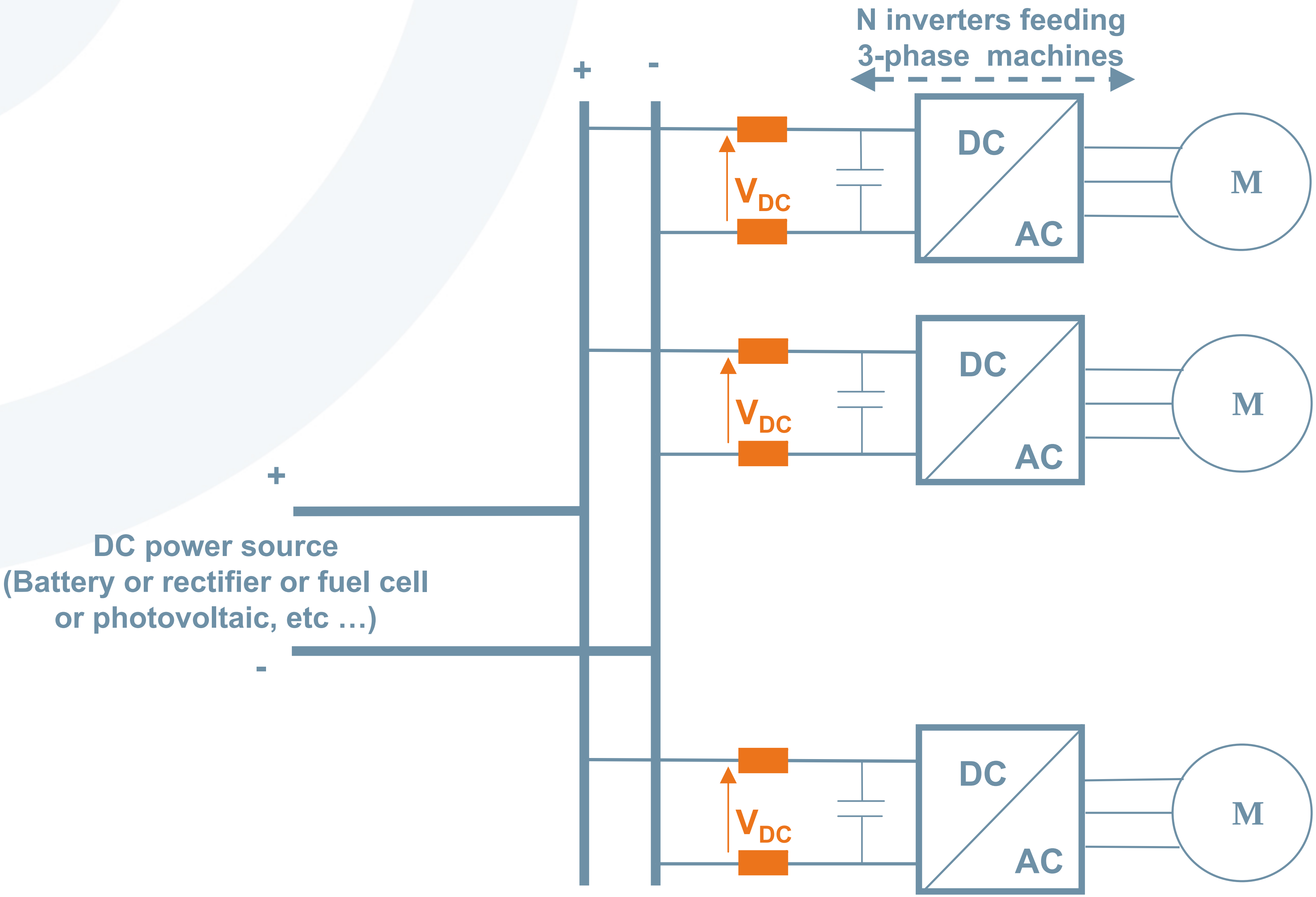


Inverters


+
Inductance λ
Fuse
E
C
U
Semiconductor
-

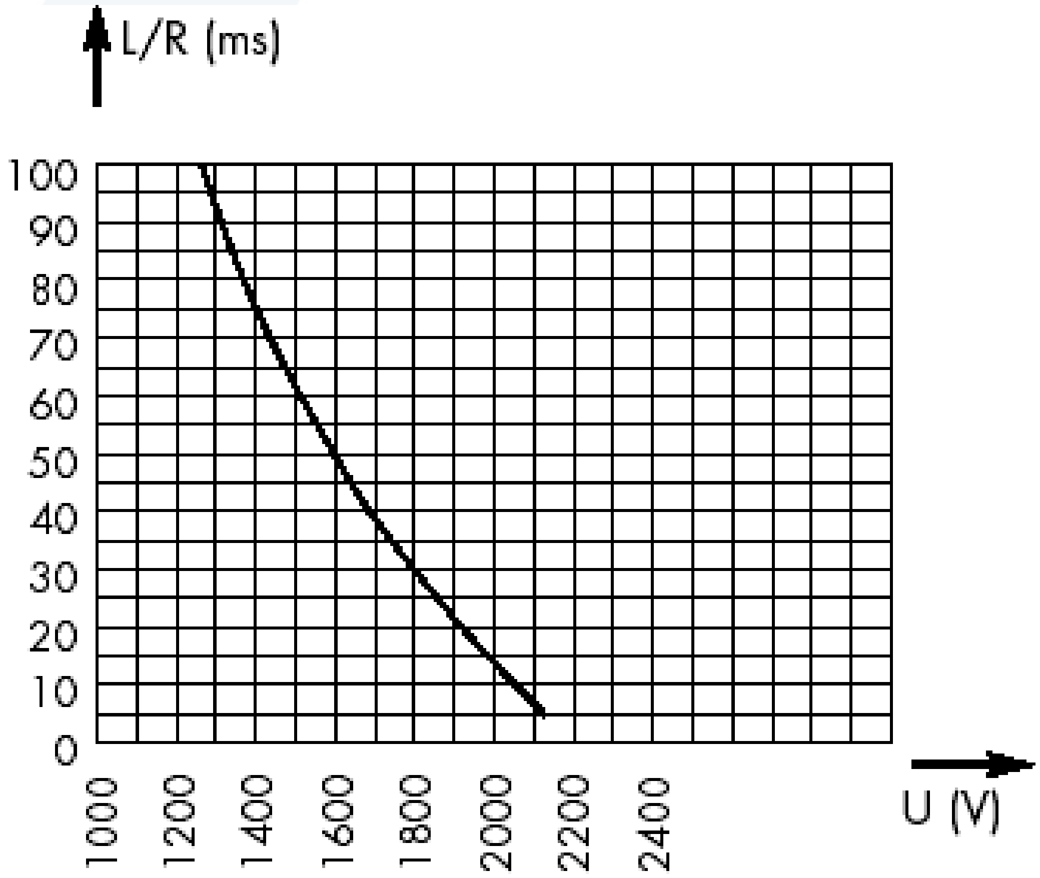

+
Inductance λ
Fuse
E
C
U
Semiconductor
-

Multi-inverters system



DC capacities of fuses

L/R = f(U) of 2000 V DC SRD fuses

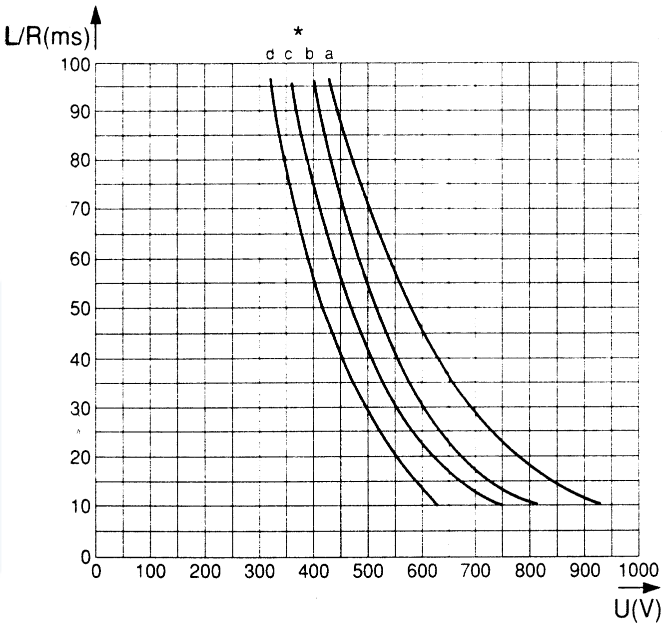


Typical values of L/R

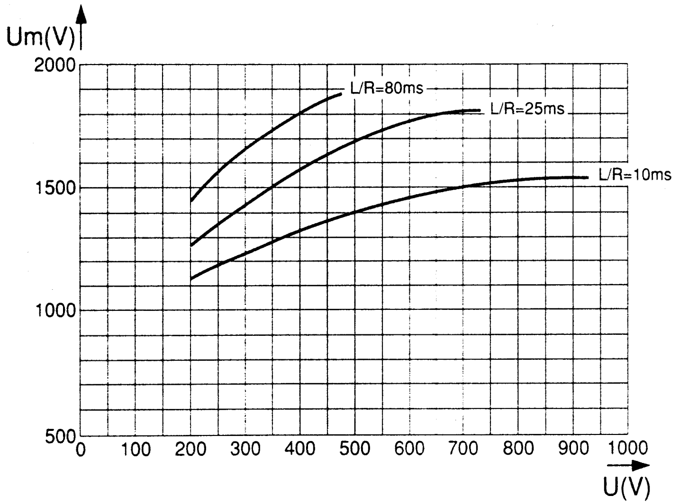
Equipement	L/R in ms
Capacitor bank	< 1
Battery	< 10
main DC bus bar fed by a three phase bridge	< 25
DC motor armature	20 - 60
DC traction systems	40 - 100
DC motor field circuit *	1000

Example of DC capabilities for an AC rated fuse range

L / R = f(U)



Value of Ipm (minimum interrupting capacity)



Um = f(U)

	70 * Ipm (A)	71 * Ipm (A)	72 * Ipm (A)	73 * Ipm (A)	2x72 * Ipm (A)	2x73 * Ipm (A)
63	a 270					
80	a 400					
100	a 520					
125	a 700					
160	a 950	a 950				
200	a 1300	a 1300				
250	a 1800	a 1800				
280	b 2200	a 2000	a 1800			
315	b 2600	a 2300	a 2200	a 2000		
350	c 3000	a 2700	a 2600	a 2400		
400		b 3500	a 3200	a 3000		
450		b 4000	a 3800	a 3500		
500		c 4800	a 4600	a 3900		
550		c 5200	b 5000	a 4400		
630		c 6400	b 6200	a 5300	a 4400	
700			c 6800	a 6000	a 5200	
800			c 8000	b 8000	a 6400	a 6000
900				b 9000	a 7600	a 7000
1000				c 11000	a 9200	a 7800
1100				c 12000	b 10000	a 8800
1250				c 13500	b 12400	a 10600
1400				c 15000	c 13600	a 12000
1600					c 16000	b 16000
1800						b 18000
2000						c 22000
2200						c 24000
2500						d 27000
2800						d 30000

Fuse definition under DC conditions

Voltage

Time constant L/R

Fault current magnitudes

Conclusion: simply perfect !

F — **F**ull overcurrent protection, **F**idelity of operation

U — **U**niversal use of T-D fuse (ideal all-purpose fuse)

S — **S**electivity, **S**implicity, **S**afety

E — **E**conomical, **E**nergy-limiting, **E**asy-to-use, **E**xcellent protection

