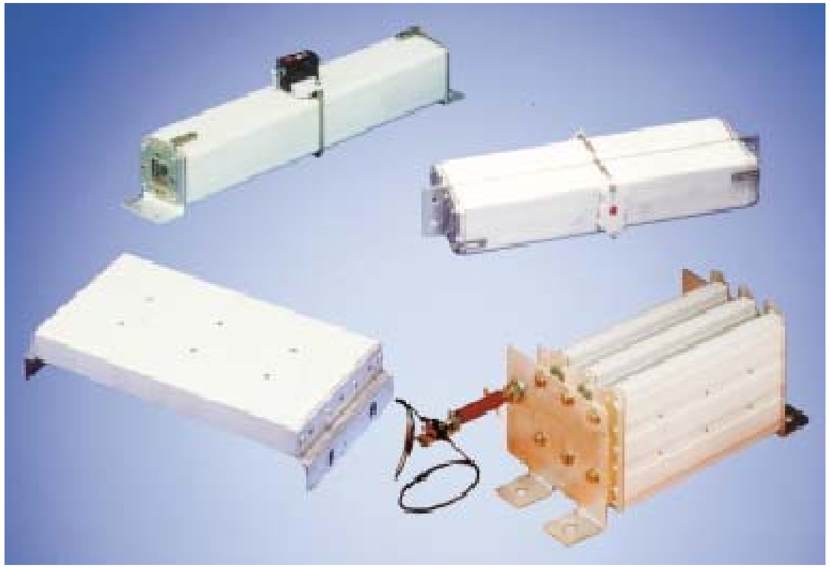
Semiconductors Fuses



Three families of power semiconductors

1

- Diode
- Thyristor
- Triac
- Bipolar transistor
- GTO
- IGCT…

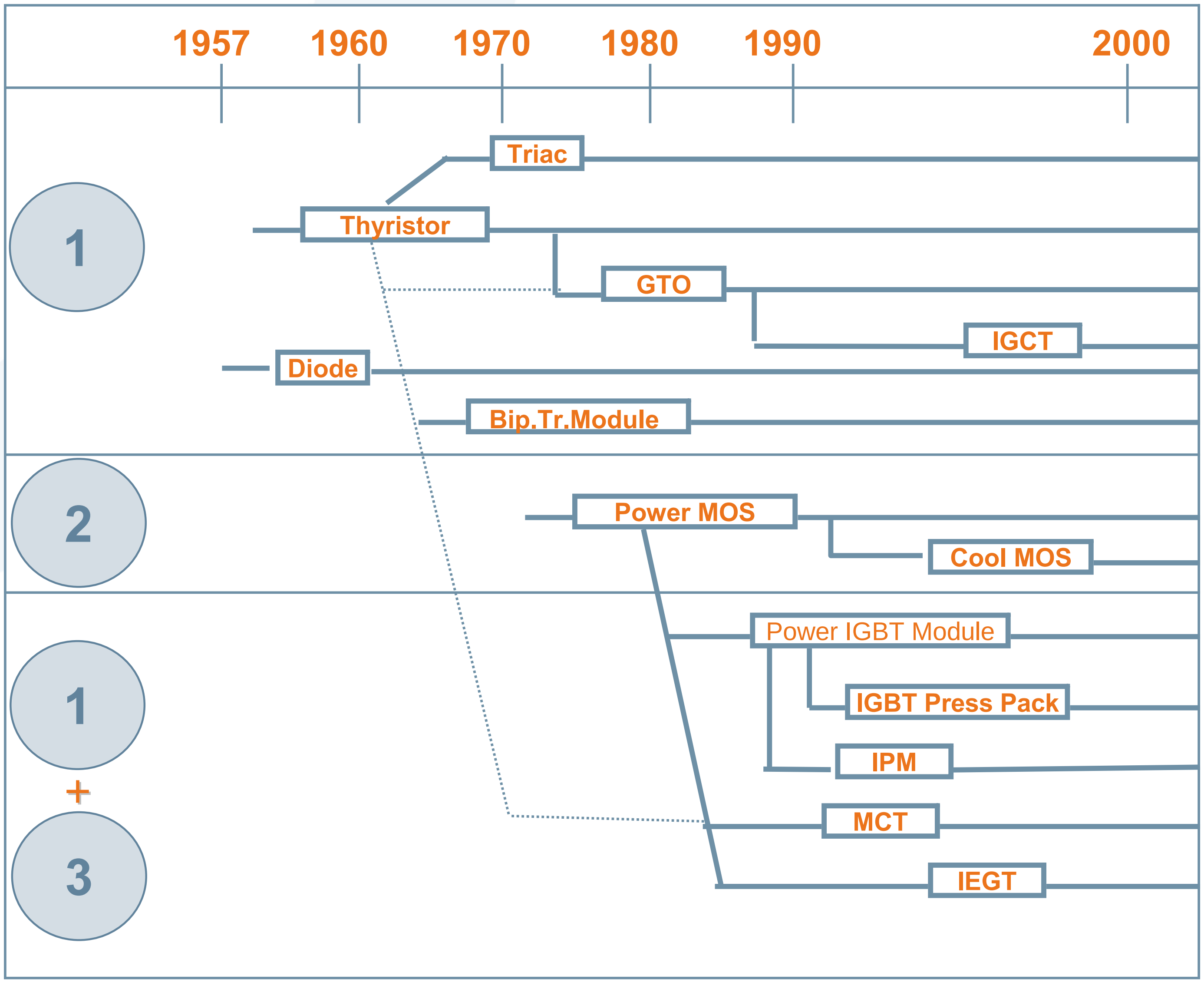
2

- MOS Power Transistor
- Cool MOS

3

- MCT
- IGBT
- IEGT…

History of power semiconductor



Applications of power semiconductor

Power

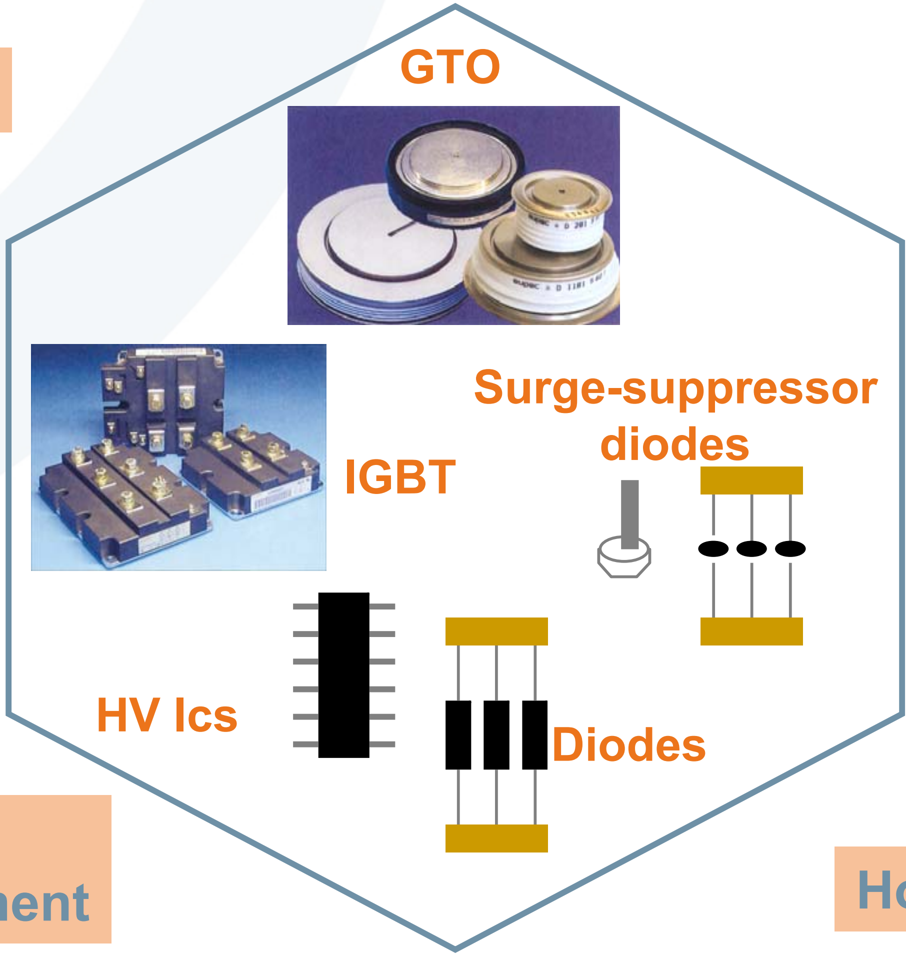
Transportation

Industry

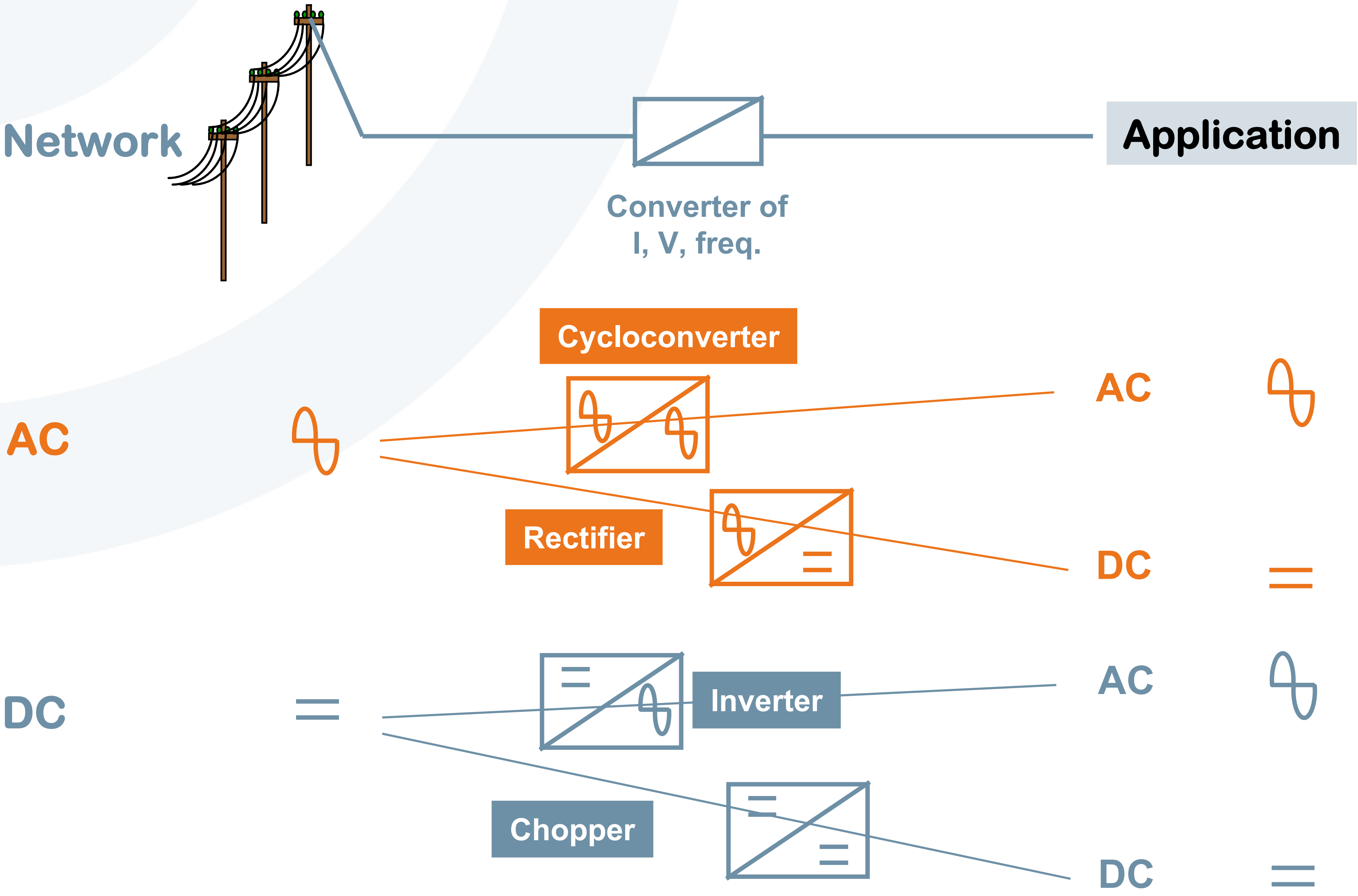
Automobiles

Telecom
Office equipment

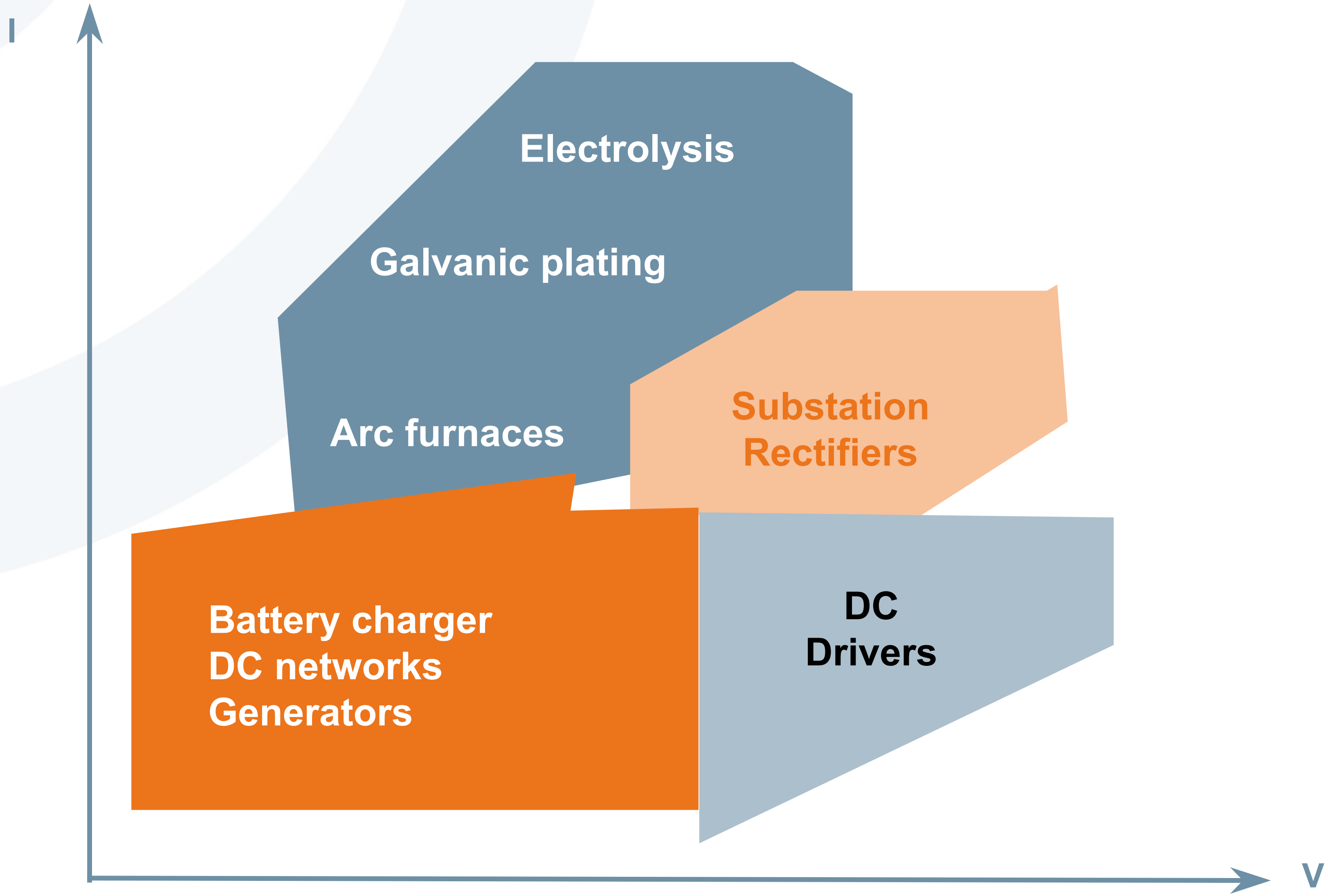
Home appliances



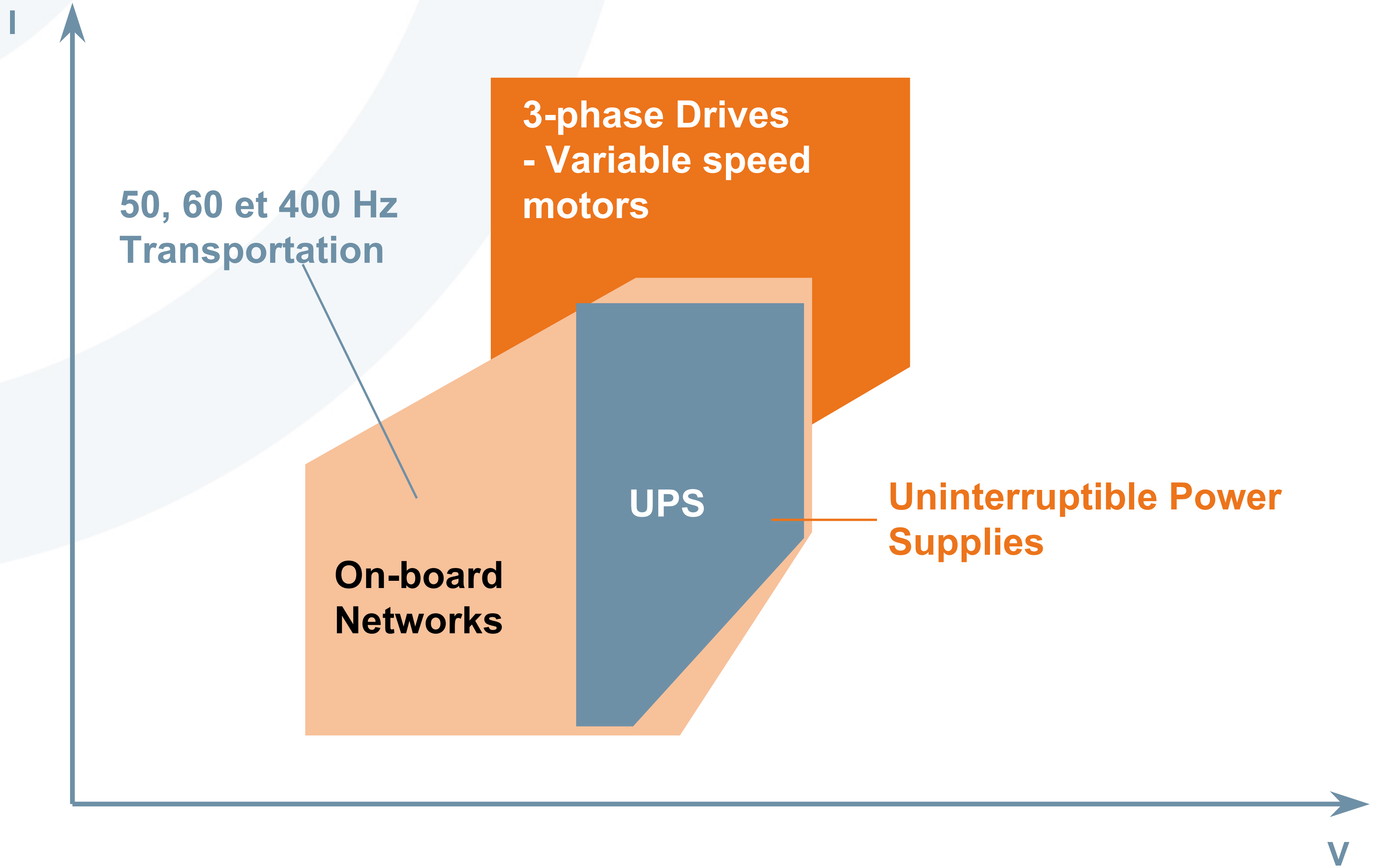
Applications of power semiconductor



Rectifier applications

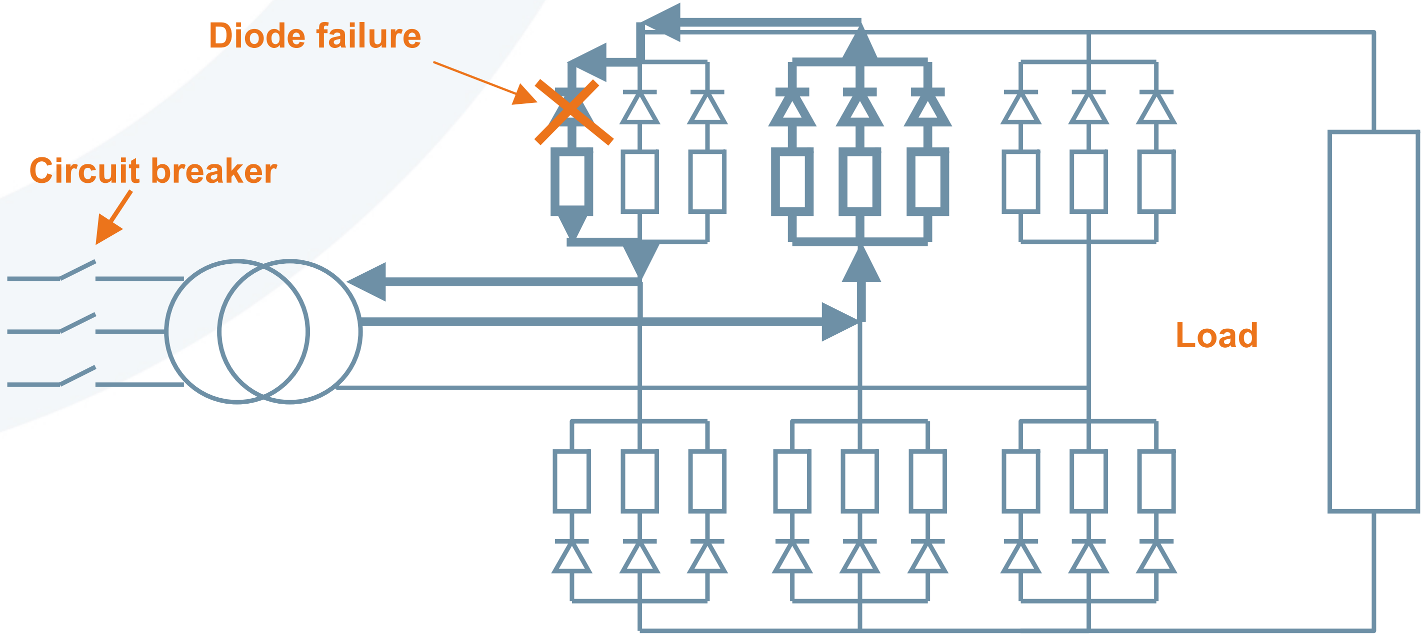


Inverter applications



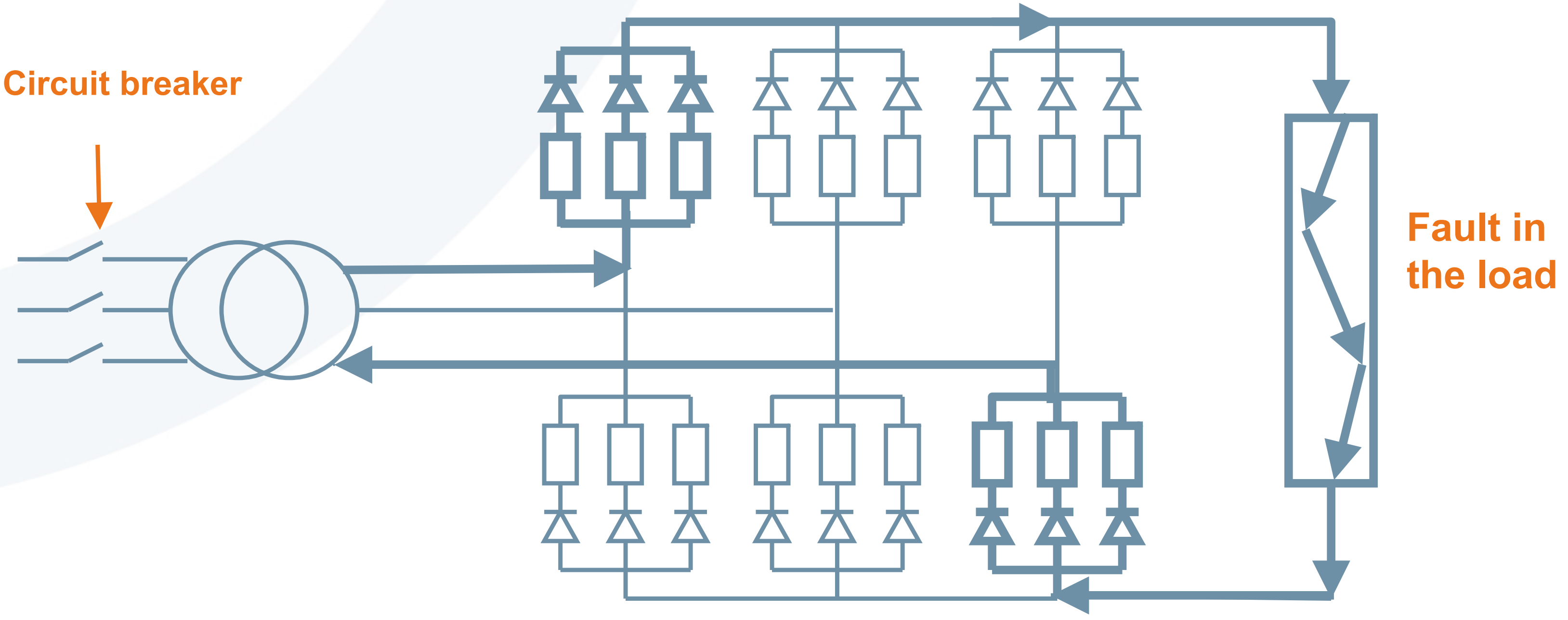
Two types of faults

Internal fault



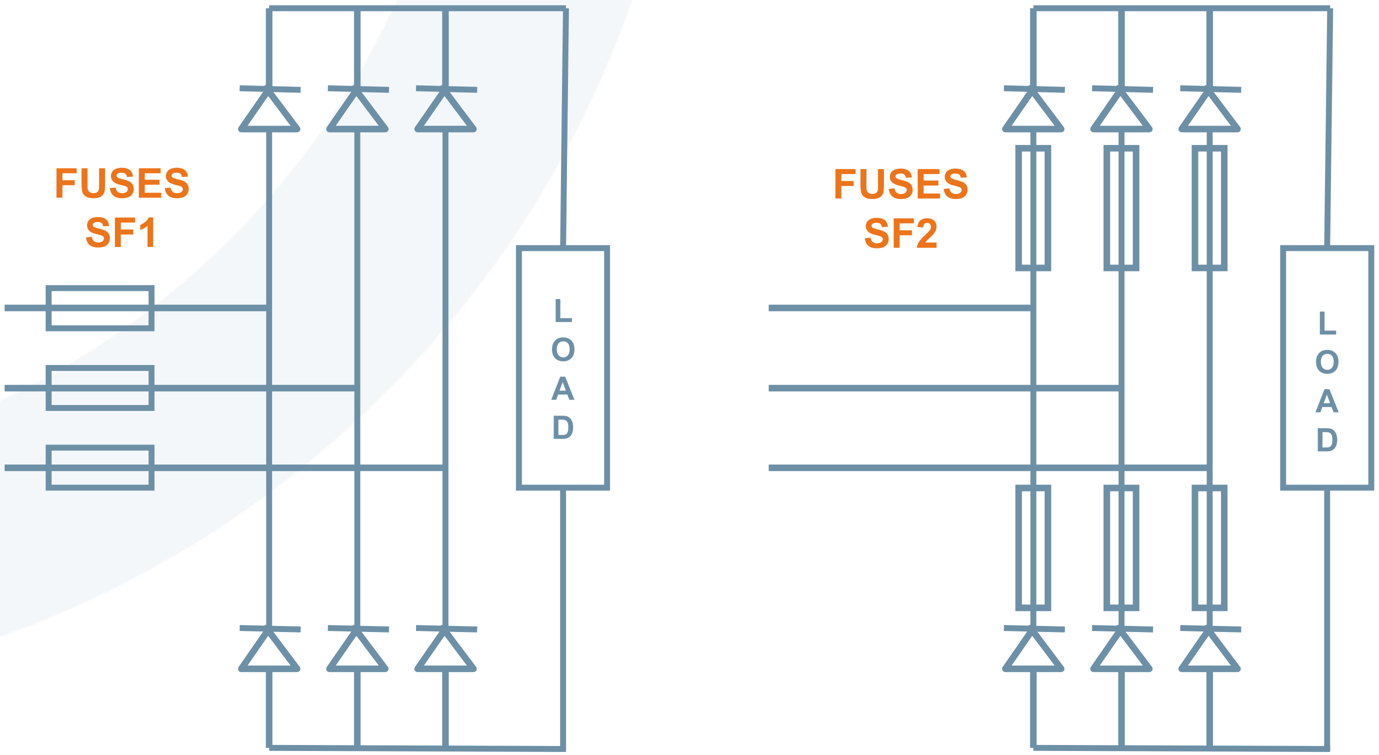
Two types of faults

External fault



Total protection

Fuses must interrupt internal and external faults

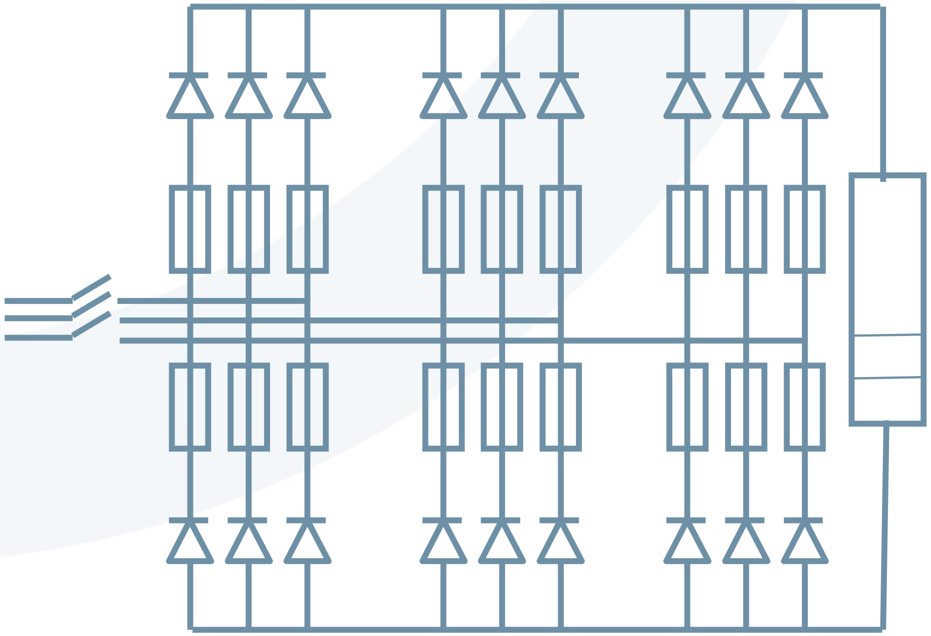


Choice of the fuses location: two possibilities

$$I^2t_{fuse} < I^2t_{junction}$$

Internal protection

Fuses must interrupt internal faults



The fuse must be mounted in the arms of the converter.

Fuses must safety interrupt faults produced by a semiconductor failure.

$$I^2t_{fuse} < I^2t_{case}$$

Selection criteria of a semiconductor fuse

Voltage Rating	$V_{Fuse} \geq V_{fault}$
Current Rating	$I_{Fuse} > I_{RMS}$
Total clearing I^2t	$I^2t_{total} < I^2t_{semiconductor}$ (Junction or case)
Interrupting Rating	$IR_{Fuse} > I_{fault}$
Arc Voltage	$V_{fuse\ arc} < V_{semiconductor}$

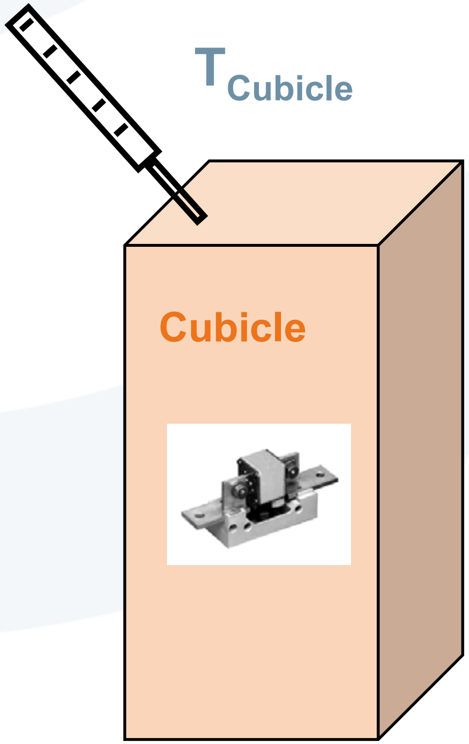
Selection of fuse voltage rating (U_N)

Rectifier	$U_N \geq V_{RESEAU}$
PWN inverter	No formula because the fuse must interrupt a capacitor discharge. A specific application leaflet with special appropriated curves must be used.
Soft starters	$U_N \geq V_{RESEAU}$
Regenerative DC drive	$U_N \geq V_{RESEAU} + \frac{V_{CONTINU}}{\sqrt{2}}$

The fuse current rating selection requises corrective coefficients

Parameters	IEC 60269 test conditions	Working conditions inside equipments
Ambient temperature	30°C max.	40°C to 60°C dans la plupart des cas
Cable & bus bar dimensions	1m long on each side of the fuse cables up to 400A 240mm² copper cable for 400A 60 mm² copper bars for 1000A (see table in annexe 1 for all ratings)	Lenght shorter than 1m, one end can be connected to a hot component or to a water cooled heat sink. In most applications the current density in the cables or bus bars is higher. The material is cooper or aluminium.
Cooling	Natural	Natural or forced air cooling or water cooling
Load current	Continuous or stable	Variable with overloads in most cases
Frequency	50 or 60 hertz	0 to 20 kilohertz

Corrective coefficient for ambient temperature θ_a



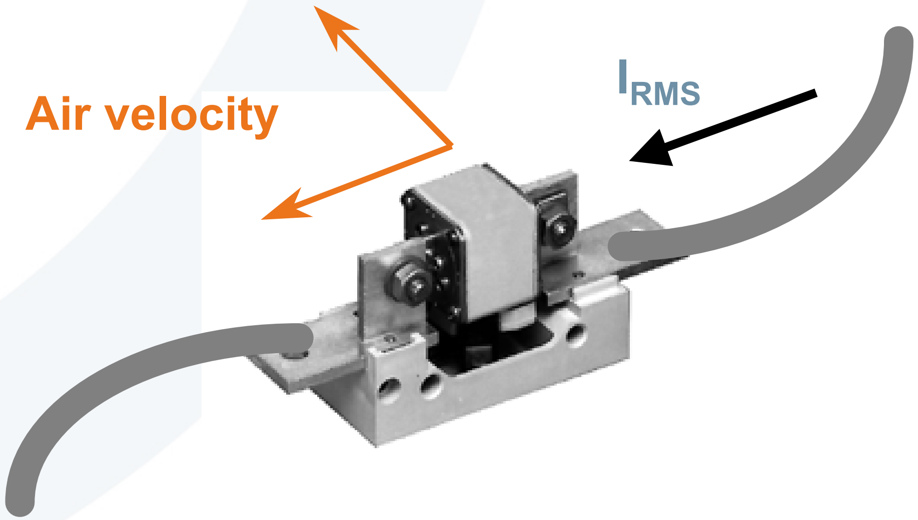
Corrective Coefficients

- a = ambient
- A'_2 = duty cycle
- B_1 = air flow
- B'_2 = thermal
- C_1 = connections
- Cf_3 = overload
- C_{PE} = proximity effect

$$A_1 = \sqrt{\frac{a - \theta_a}{a - 30}}$$

$$I_N = \frac{I_{RMS}}{A_1}$$

Corrective coefficient for air flow



$$B_V = 1 + 0{,}05 * V$$

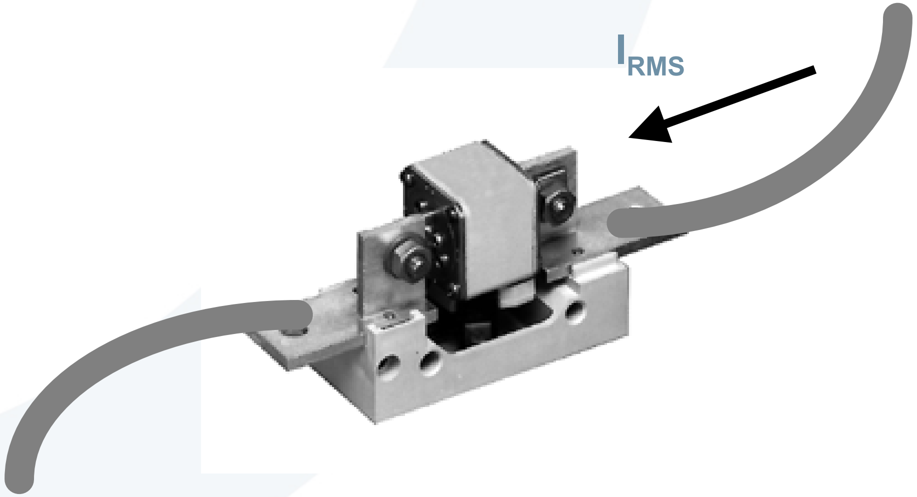
$$V \leq 5\ m / s$$

$$I_N = \frac{I_{RMS}}{A_1 * B_V}$$

Corrective Coefficients

a = ambient
A'_2 = duty cycle
B_1 = air flow
B'_2 = thermal
C_1 = connections
Cf_3 = overload
C_{PE} = proximity effect

Corrective coefficient for connections

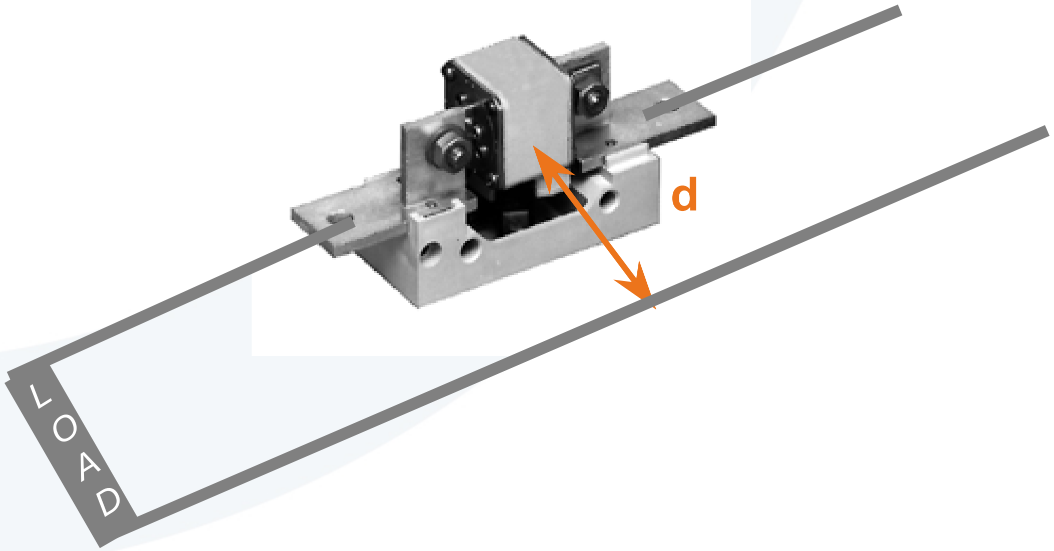


$$I_N = \frac{I_{RMS}}{A_1 * B_V * C_1}$$

Corrective Coefficients

a = ambient
A'_2 = duty cycle
B_1 = air flow
B'_2 = thermal
C_1 = connections
Cf_3 = overload
C_{PE} = proximity effect

Corrective coefficient for proximity effect



Corrective Coefficients

- a = ambient
- A_2 = duty cycle
- B_1 = air flow
- B_2 = thermal
- C_1 = connections
- Cf_3 = overload
- C_{PE} = proximity effect

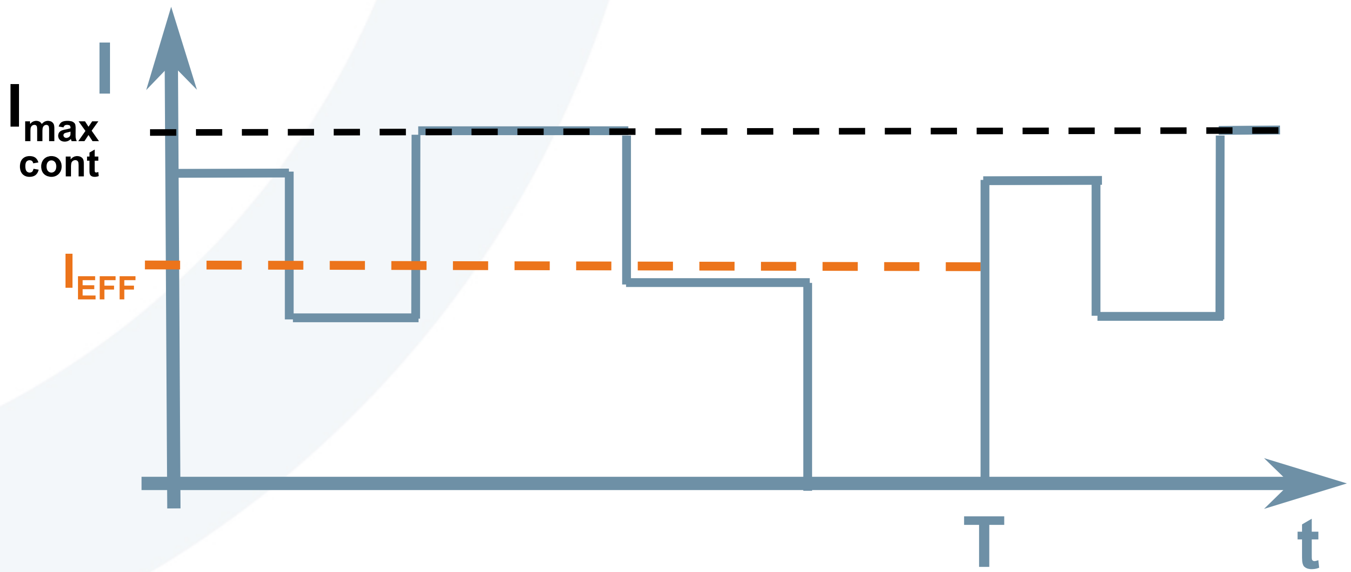
For frequency > 100 Hz for most fuses

C_{PE} = 0.9 at 1000 Hz

C_{PE} = 0.8 at 5000 Hz

$$I_N = \frac{I_{RMS}}{A_1 * B_V * C_1 * C_{PE}}$$

Corrective coefficient for duty cycle



Corrective Coefficients

a = ambient
A'$_2$ = duty cycle
B$_1$ = air flow
B'$_2$ = thermal
C$_1$ = connections
Cf$_3$= overload
C$_{PE}$= proximity effect

$$I_N = \frac{I_{RMS}}{A_1 * B_V * C_1 * C_{PE} * A'_2}$$

Corrective coefficient for repetitive overloads

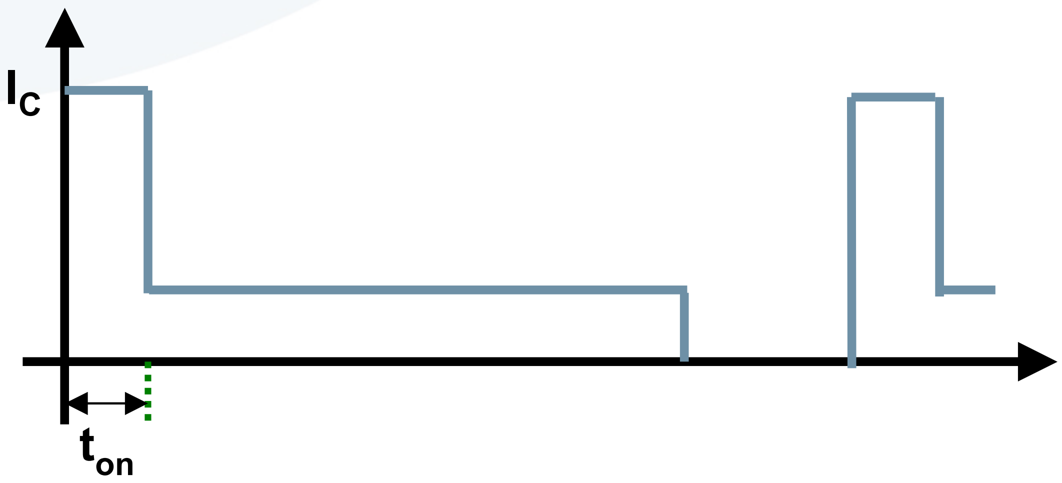
Corrective Coefficients

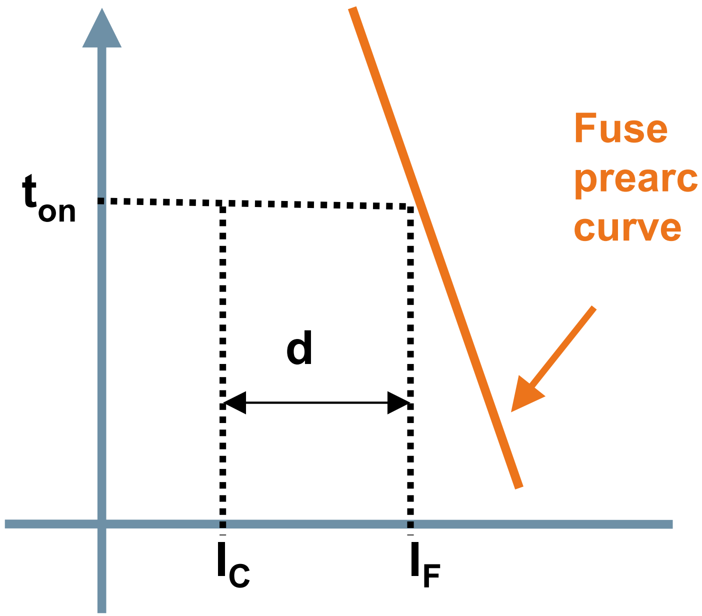
a = ambient
A'_2 = duty cycle
B_1 = air flow
B'_2 = thermal
C_1 = connections
Cf_3 = overload
C_{PE} = proximity effect

To withstand about 100 000 overloads the fuse must comply with the following conditions :

- $I_F = 3\ I_C$ with PSC square fuses
- $I_F = 3{,}5\ I_C$ with aM fuses or ferrule UR- & gR-

$$I_F \geq \frac{I_C}{B'_2}$$





Corrective coefficient for non-recurrent overloads

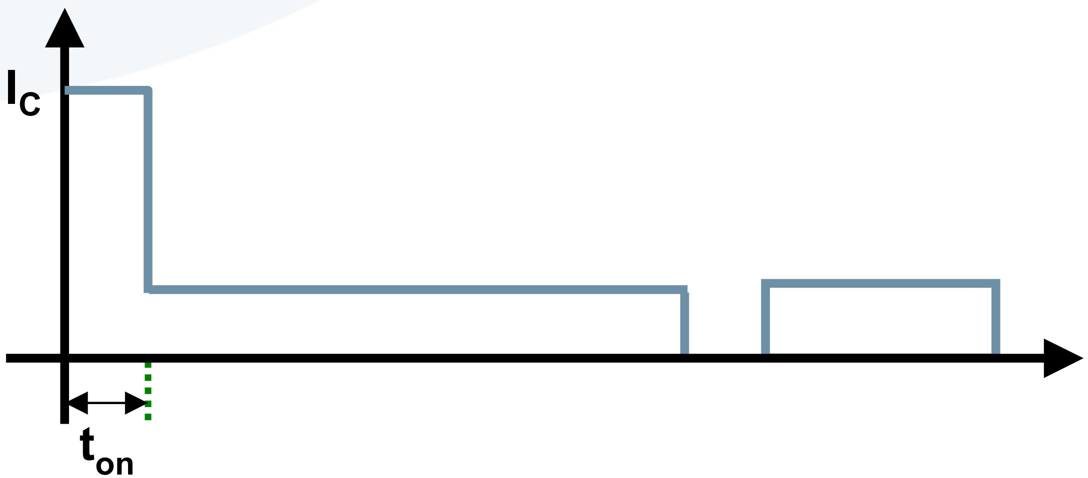
Corrective Coefficients

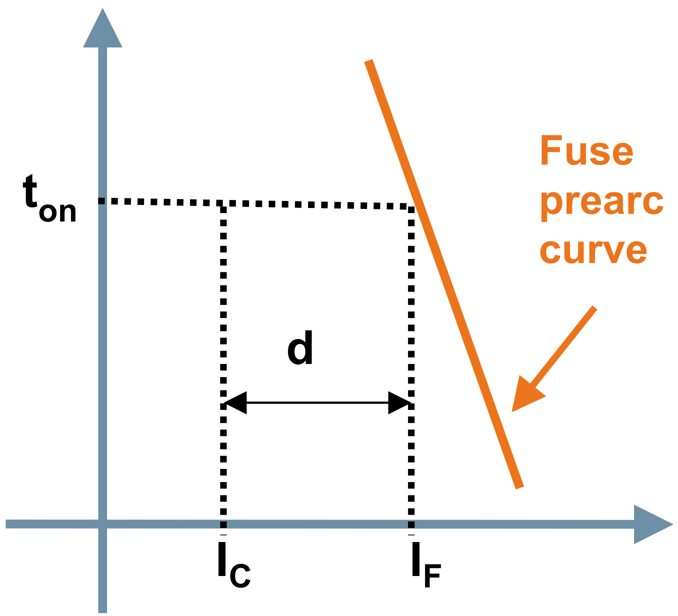
a = ambient
A'_2 = duty cycle
B_1 = air flow
B'_2 = thermal
C_1 = connections
Cf'_3= overload
C_{PE}= proximity effect

$$I_F \geq \frac{I_C}{Cf'_3} \qquad Cf'_3 = 0{,}75$$

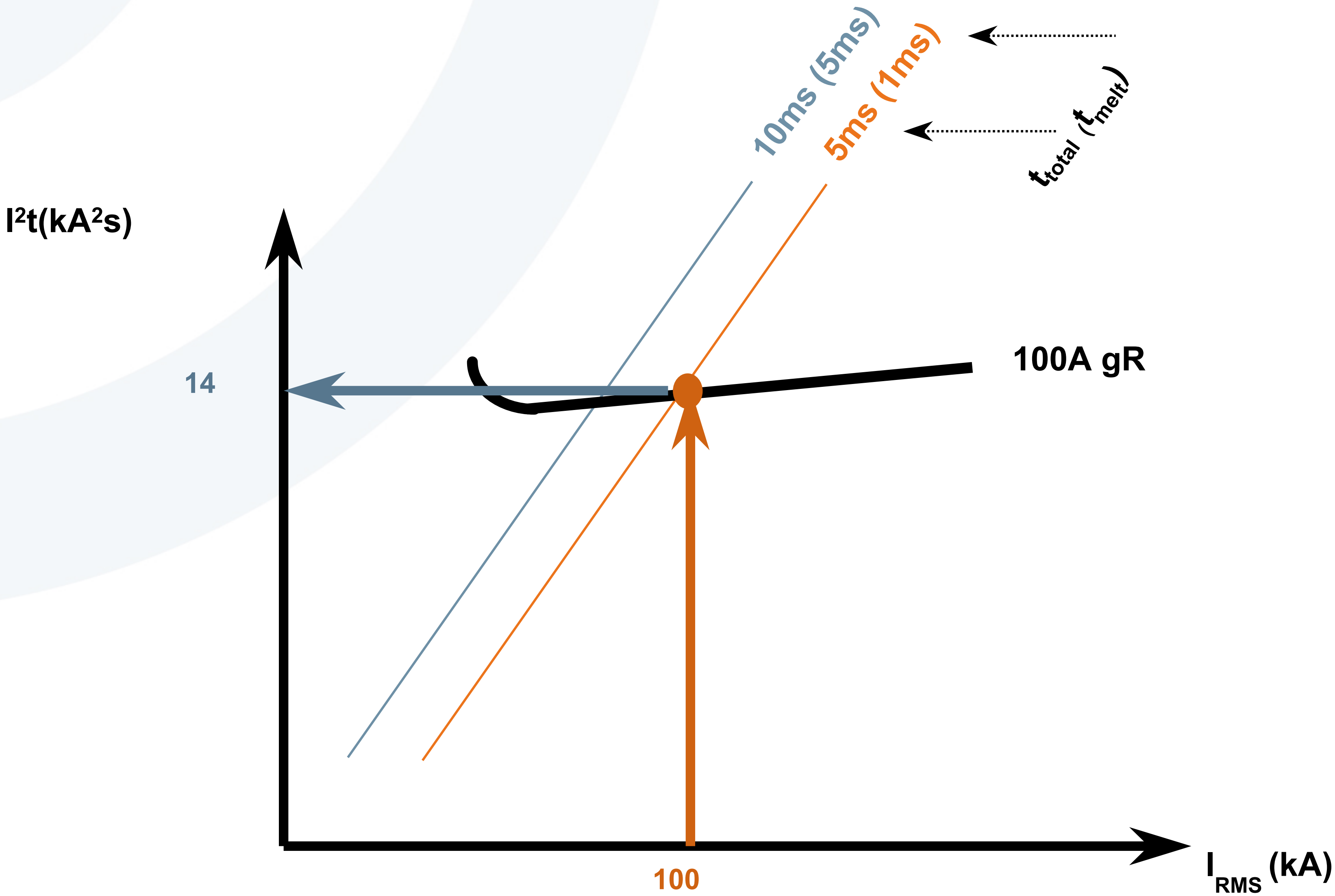
$I_F = 1{,}33\ I_C$

To withstand about 100 à 150 overloads





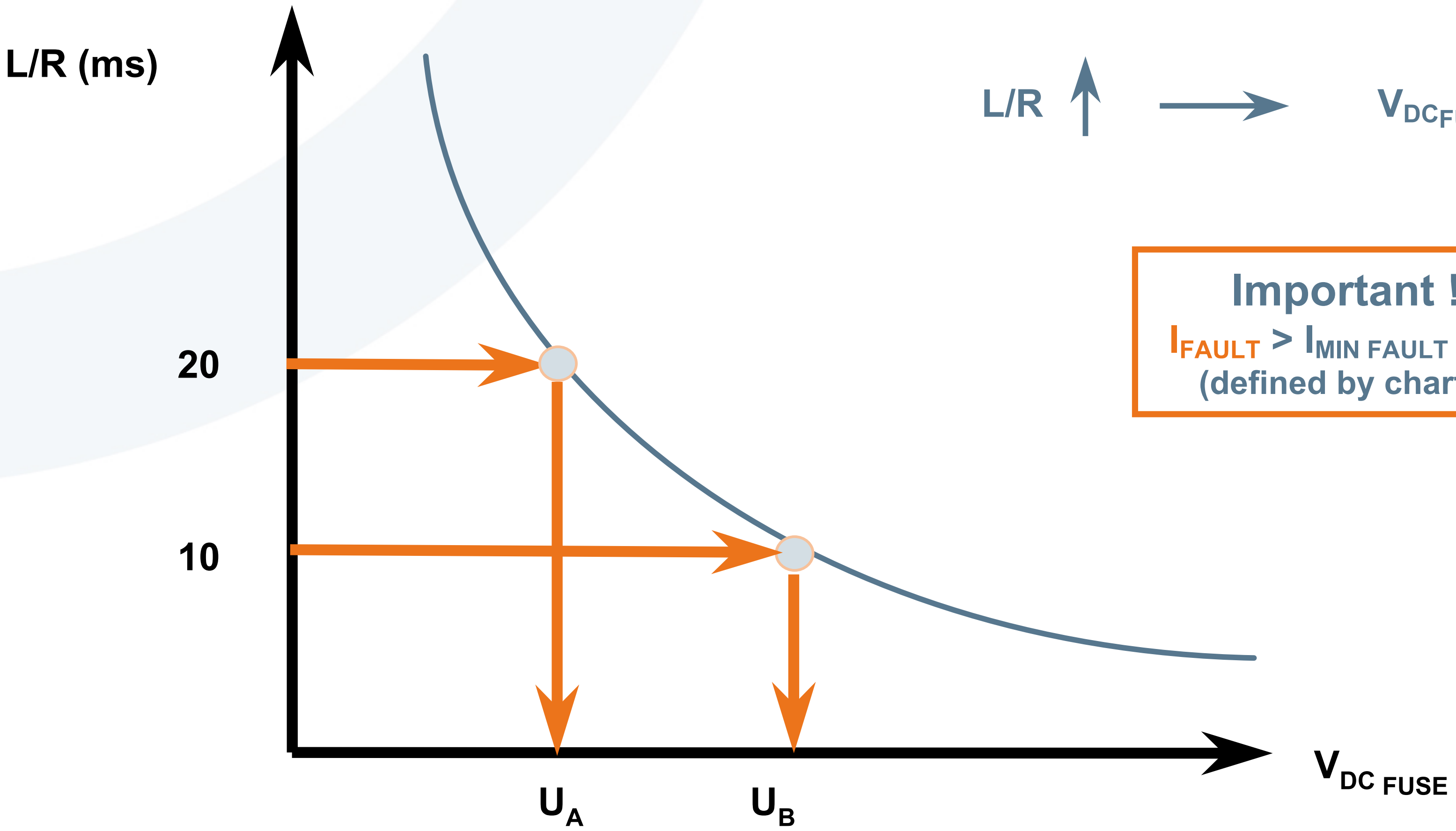
I^2t characteristics



DC fuse voltage rating based on system time constant (L/R)

U_A @ 20ms < U_B @ 10ms

L/R ↑ → V_{DCFUSE} ↓

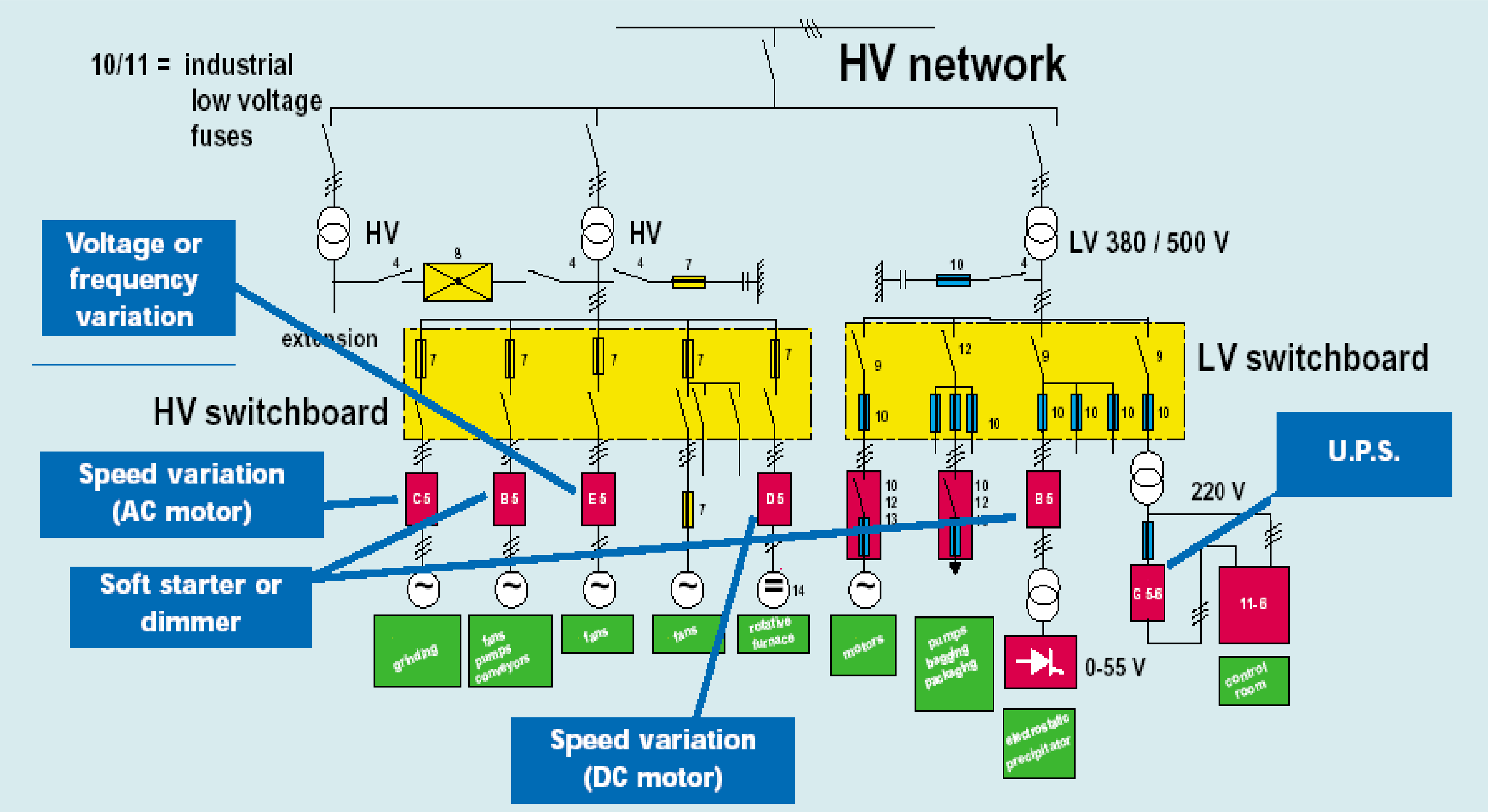


Important !

$I_{FAULT} > I_{MIN\ FAULT\ LEVEL}$

(defined by charts)

Example of a large plant (cement, steel mill…)

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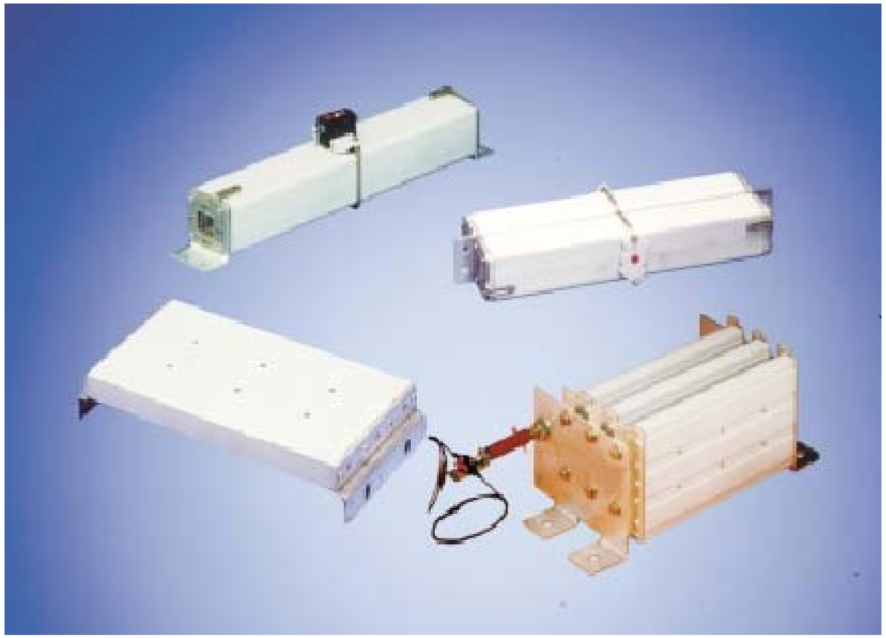

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