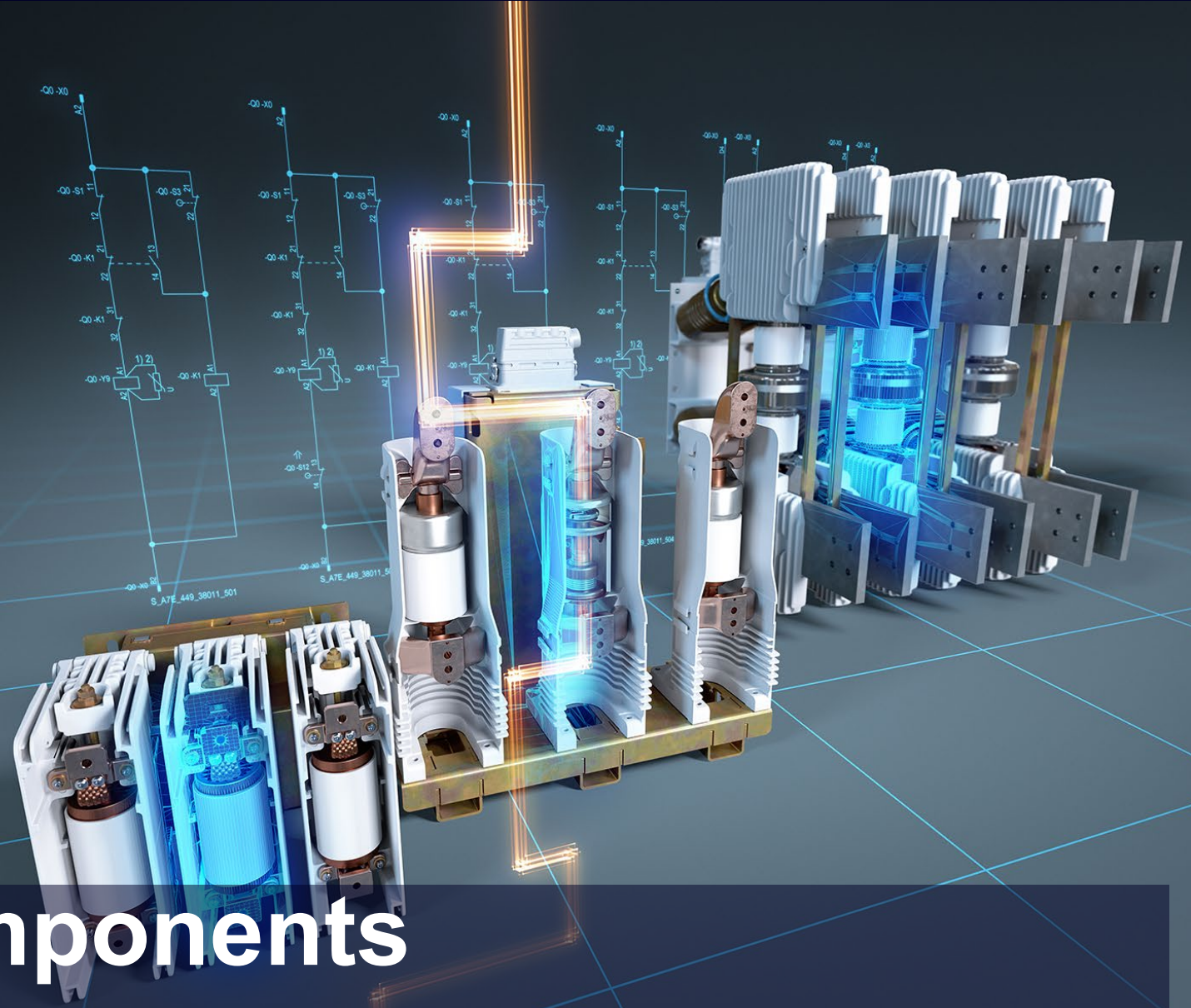

MV components application and engineering guide

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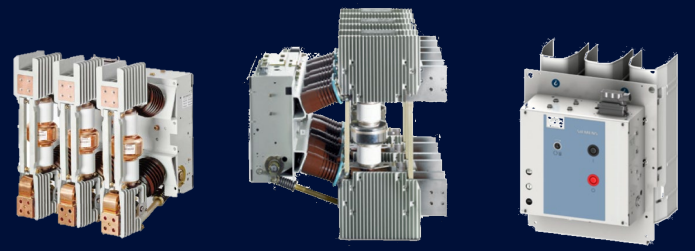
MEDIUM VOLTAGE COMPONENTS – PRODUCT PORTFOLIO INDOOR

Vacuum circuit-breakers for general applications

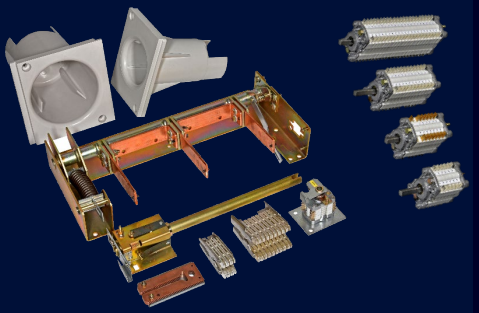
Vacuum circuit-breakers for special applications



Vacuum contactors

Vacuum interrupters

Auxiliary switches and accessories



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Rated Values
Influencing parameters on devices and switchgear

A number of parameters have to be considered for selecting the right product

Network specific values	Switching duty	Operating conditions
Voltage	Inductive circuits	Ambient conditions
Current	Capacitive circuits	External influences
Frequency	Adjustable circuits	Statutory requirements
Neutral point treatment		Frequency of operation

Load switching vs. Fault switching

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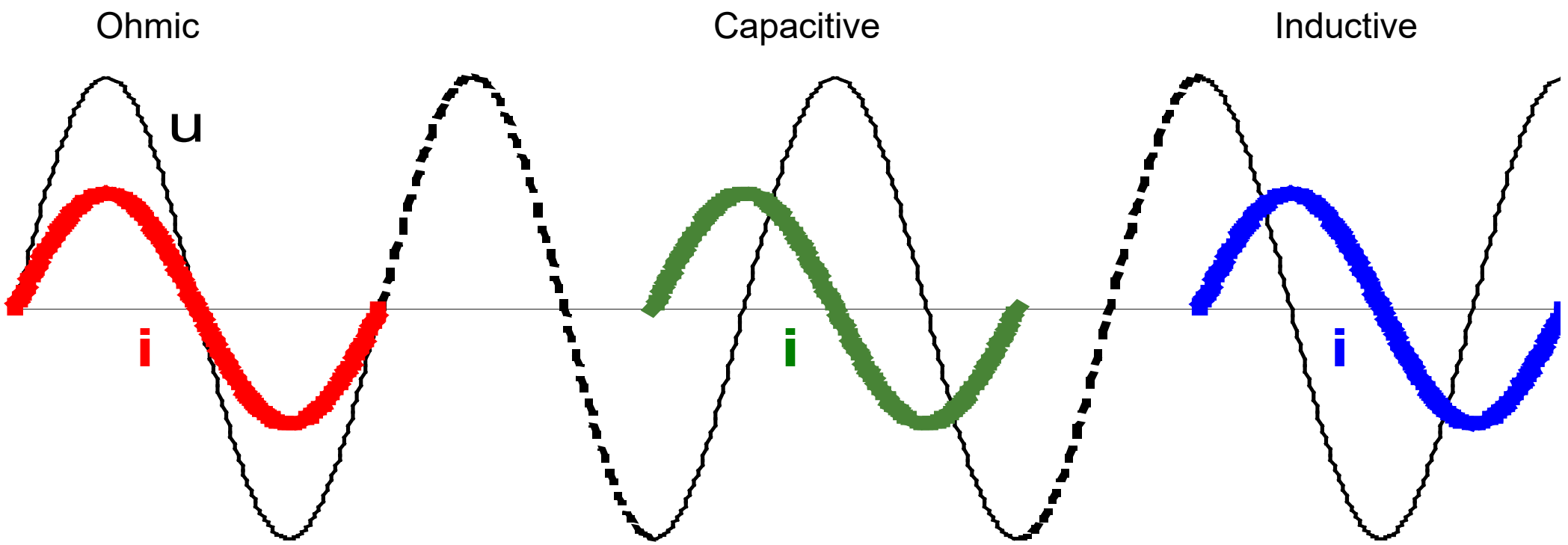
Medium-voltage switches are current-zero interrupters

Stationary phase angle between current and voltage



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Inductive circuits

- In inductive circuits the current lags behind the voltage, $\cos \varphi < 0.3$.
- When interrupting inductive currents the electromagnetic energy remains stored in the inductance.
- The stored energy discharges by means of high-frequency oscillations in the circuit which has been switched-off.
- When switching off the following effects can be observed:
  - **(DC offset) at s.c. current interruption**
  - **Current chopping**
  - **Multiple re-ignitions**

Source: Maschinenfabrik Reinhausen

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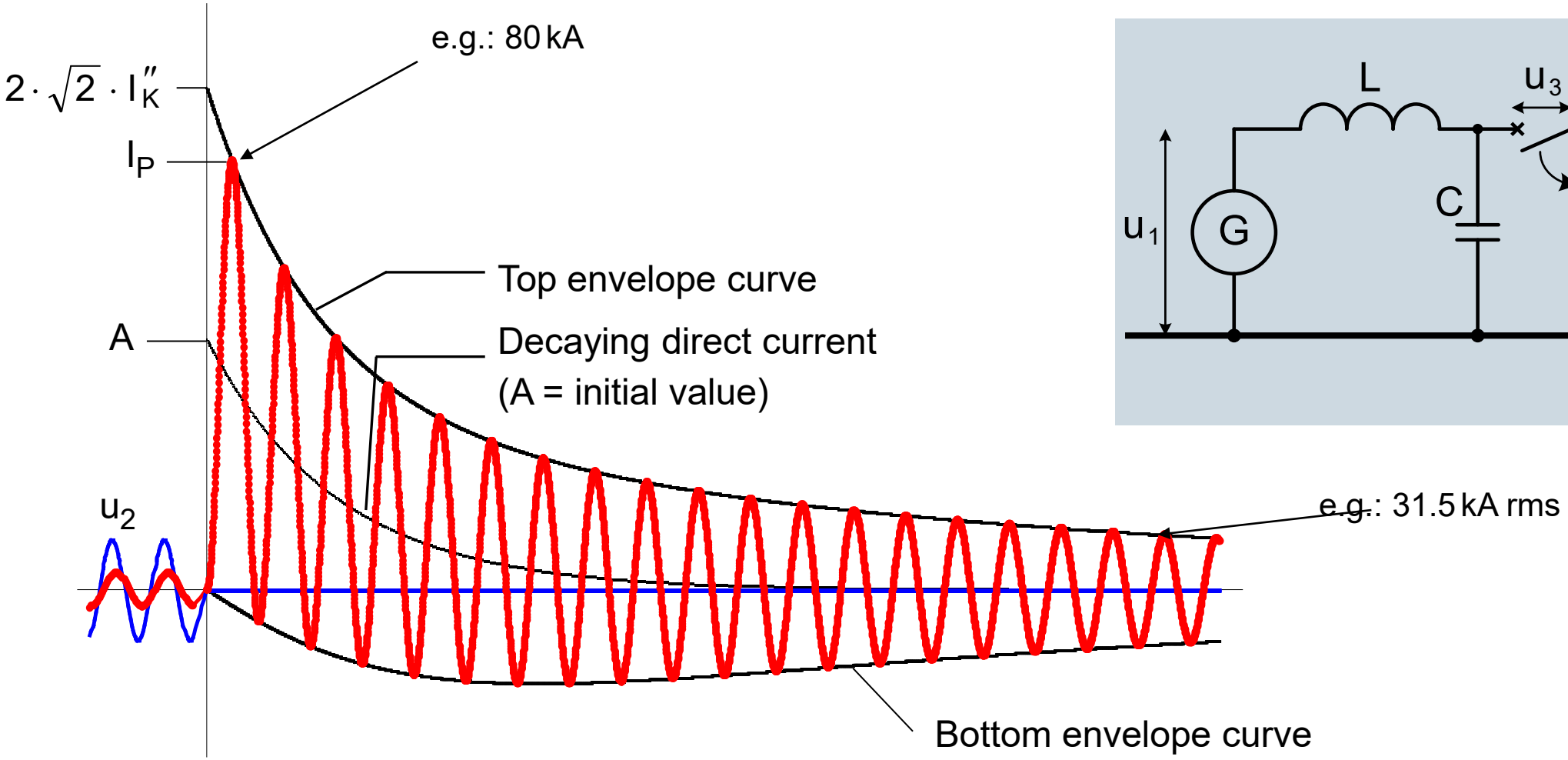
L1. Large inductive currents
Current and voltage in a short-circuit



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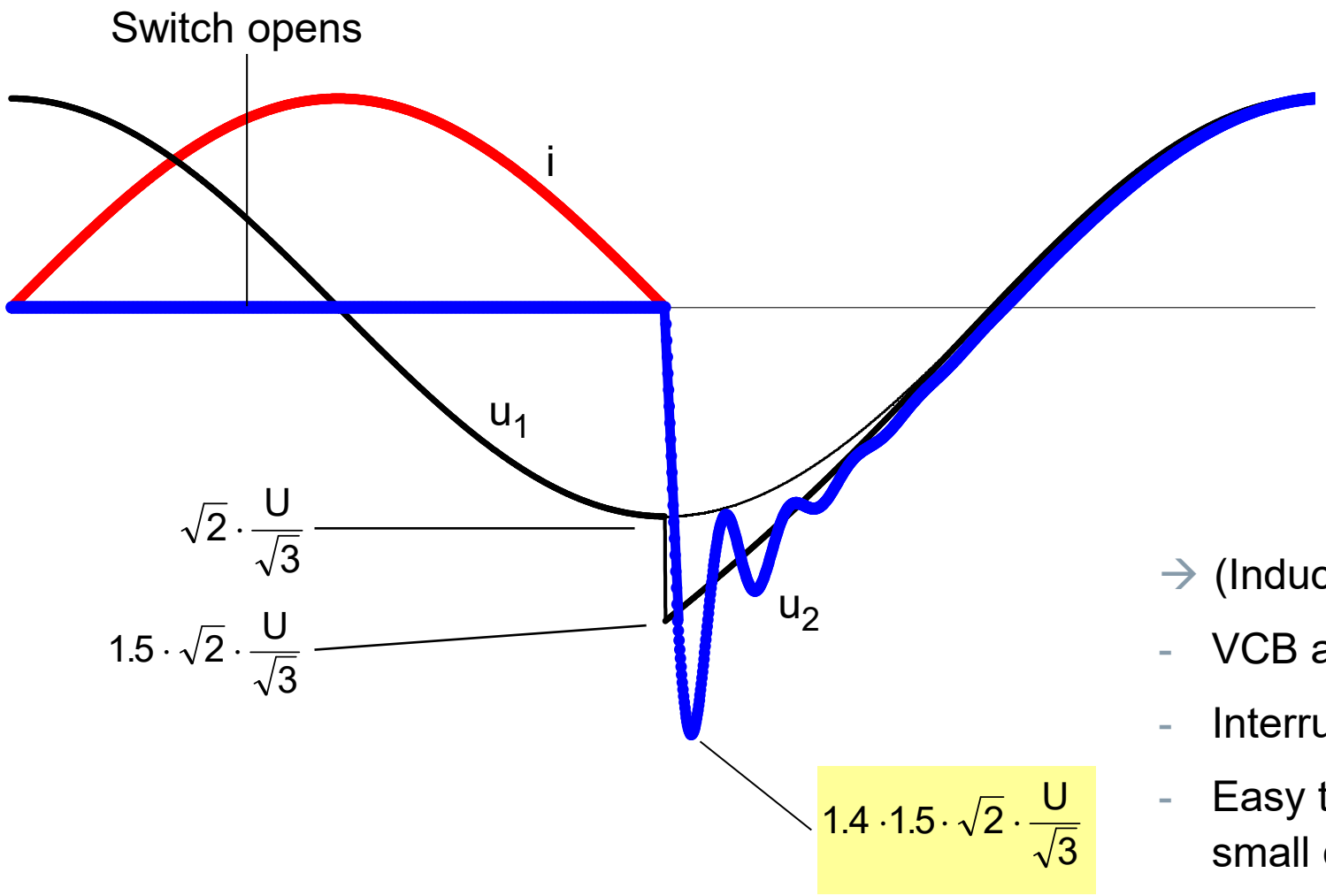
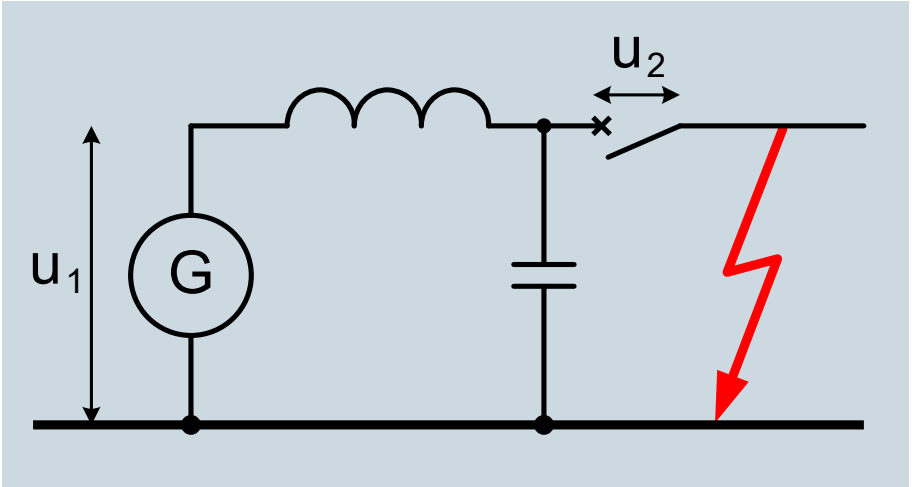
Transient recovery voltage (TRV) in the first pole to open / first pole to clear





→ (Inductive) s.c. currents are the major duty of CB

- VCB are designed for it
- Interrupt safely
- Easy to cope with other requirements in test e.g. small critical currents, RRRV, reclosing, etc.

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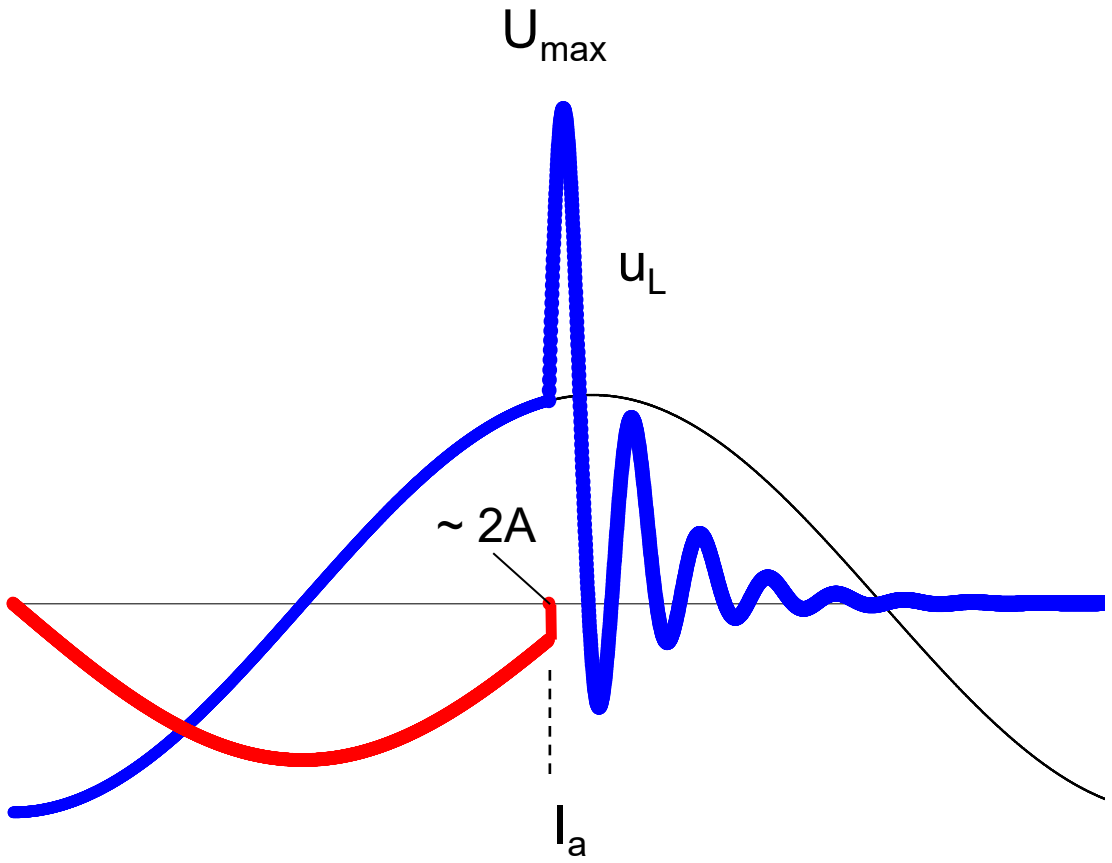
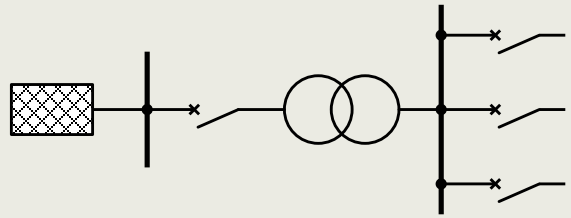
L2. Small inductive currents - chopping when breaking

e. g. switching off unloaded transformers

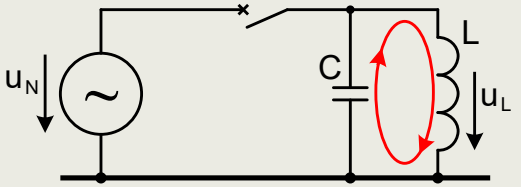


Single phase diagram

Single line diagram



Equivalent circuit-diagram



Formula for stored energy

$$\frac{1}{2} \cdot C \cdot u^2 = \frac{1}{2} \cdot L \cdot i^2$$

Maximum voltage at load

$$u_{max} \cong \sqrt{\frac{L}{C}} \cdot i_a$$

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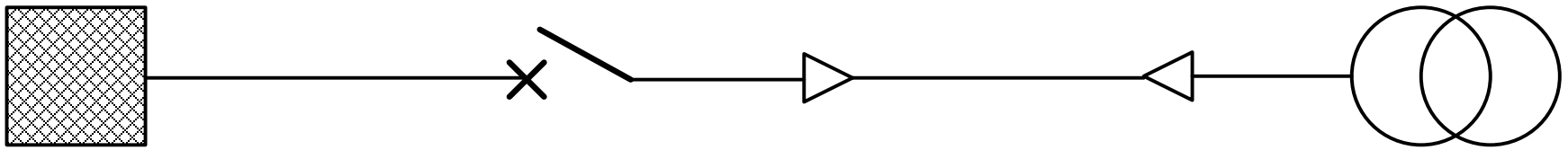
L2. Small inductive currents
Replication of real installation conditions

Representative applications of transformers in industry and distribution networks

- Typical distribution transformers (U_r, S_{rT}, u_k, vector group, oil and cast-resin insulation)
- Vacuum circuit-breakers
- Network voltage from 6 kV to 30 kV
- Cable lengths from 2.5 to 300 m



MV network
6 to 30 kV

Circuit-breaker

Cable
2,5 to 300 m

Transformer
100 kVA to 3140 kVA

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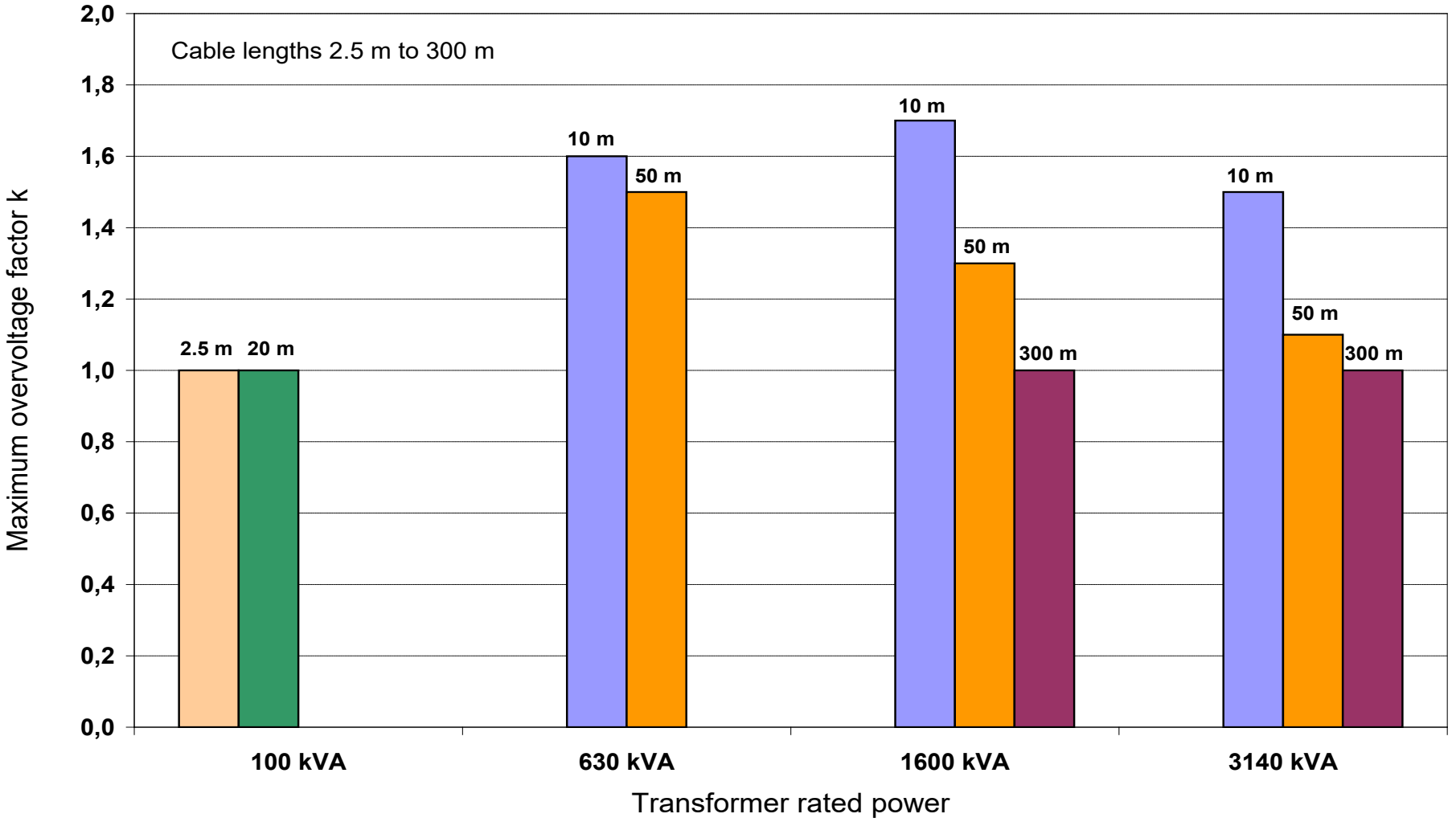
L2. Small inductive currents
Maximum overvoltage factors recorded



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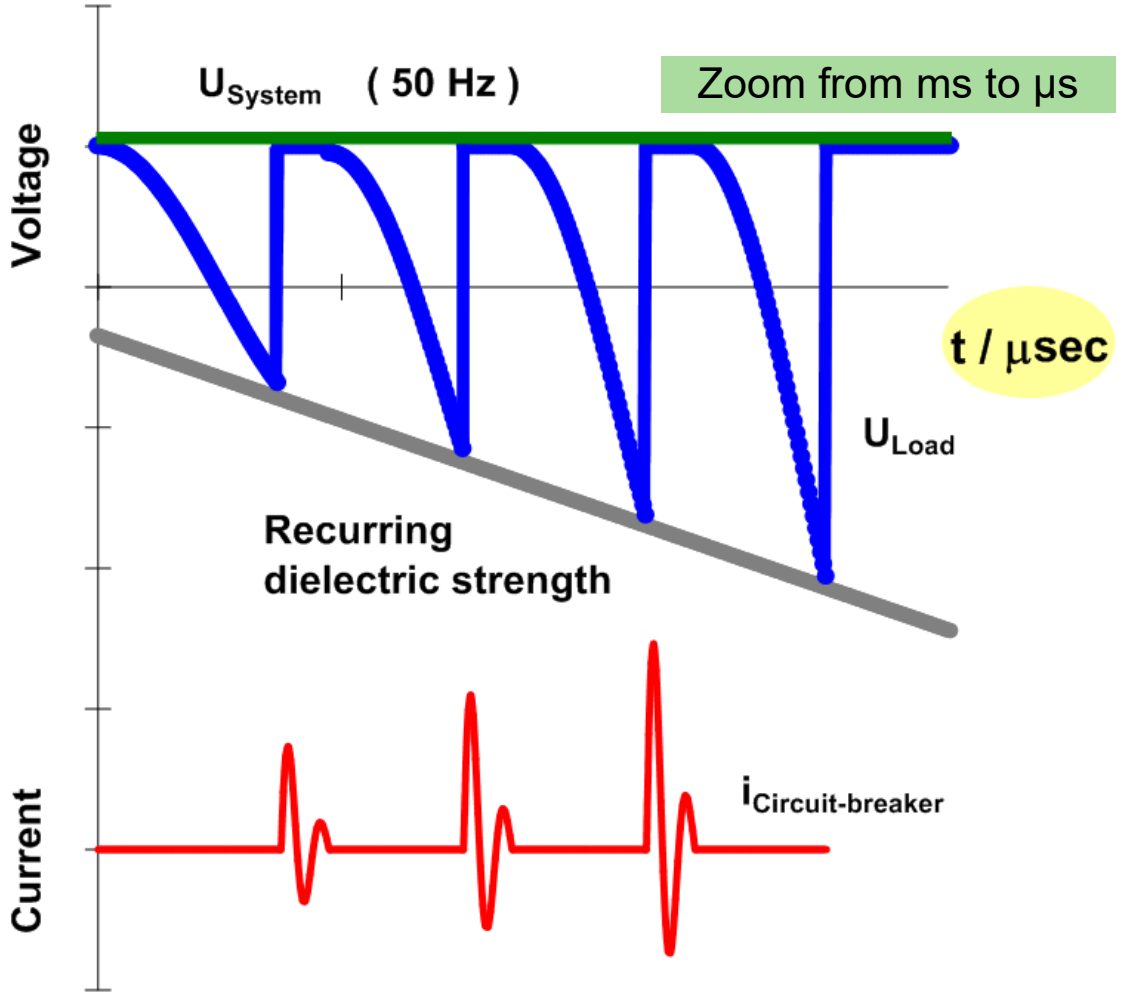
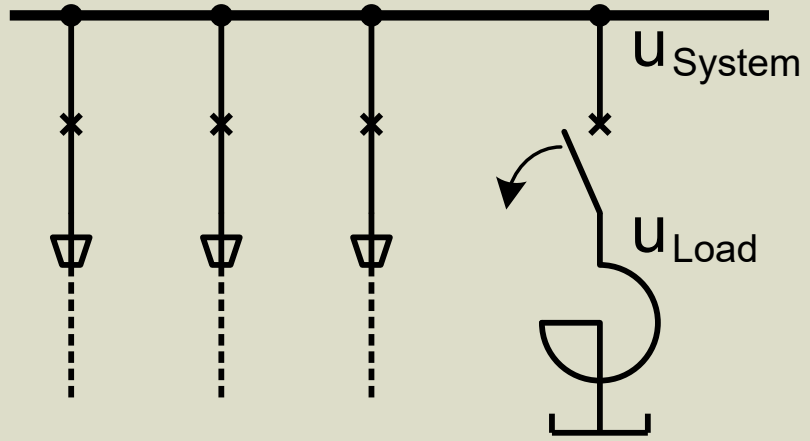
L3. Multiple re-ignitions – Principle



Preconditions for multiple re-ignitions:

- Breaking an inductive current
- Contact separation < 0.5 ms prior to current zero



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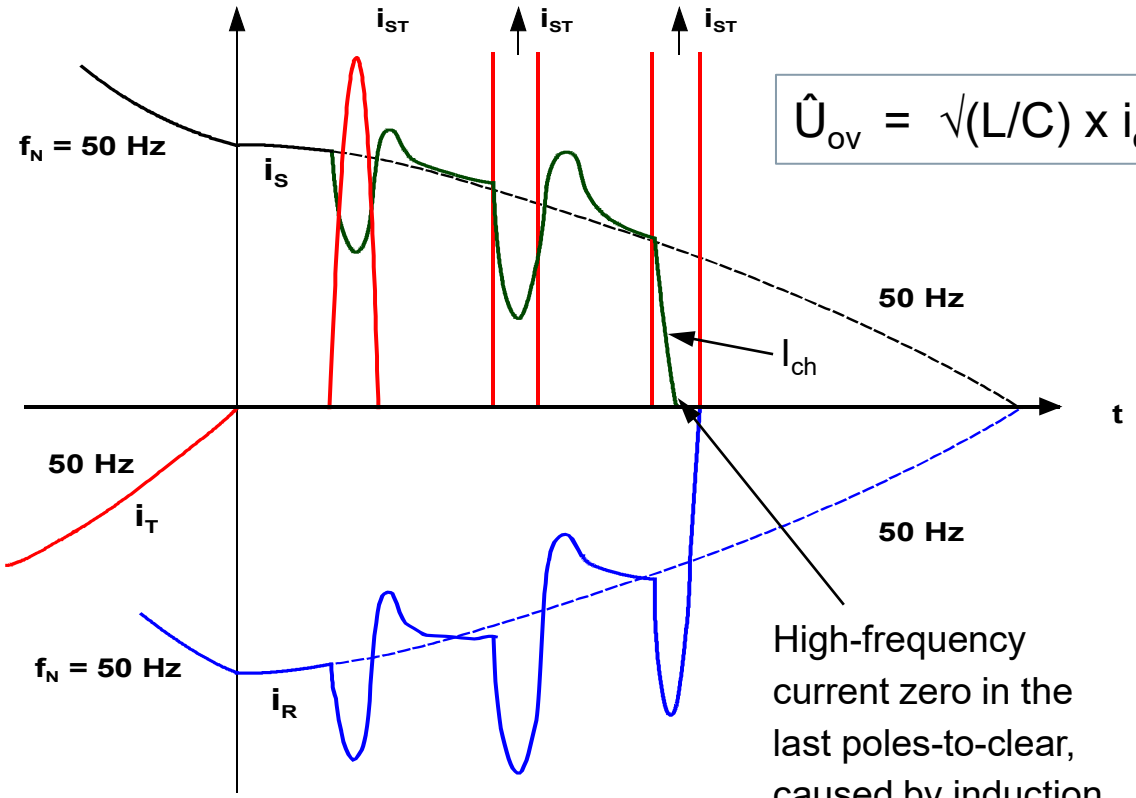
Induced (virtual) current chopping due to multiple reignitions

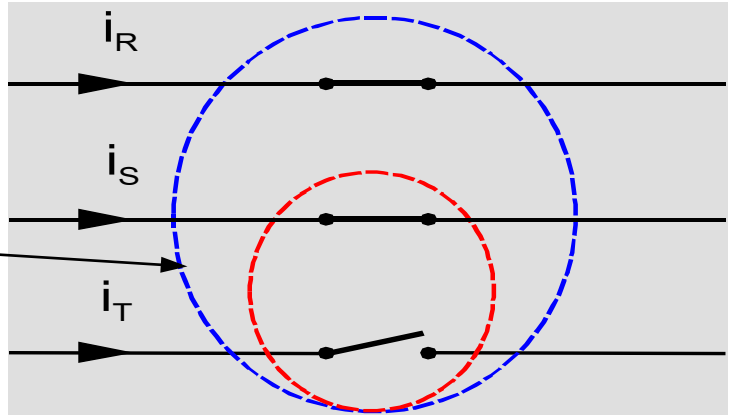
Can cause overvoltages !



$$\hat{U}_{ov} = \sqrt{(L/C)} \times i_{ch}$$

High-frequency current zero in the last poles-to-clear, caused by induction

- Preconditions to trigger higher surges:
  - contact opening < 0.5 ms prior to current zero
  - inductive current between 20 A to 600 A
- 600 A: limit of virtual current chopping
- >600 A: no virtual current chopping observed
- < 20 A: iron losses damp TRV
- Type and degree of overvoltage depend on network inductances, capacitances



Recommendation for overvoltage protection
→ Refer to application guide HG11.13

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Capacitive circuits

- In capacitive circuits the current leads the voltage.
- When interrupting capacitive currents, the capacitance remains charged and keeps the voltage for a certain time.
- A differential voltage between network and capacitor will set up across the switching contacts, which can reach values twice the network voltage.
- When paralleling capacitor banks, very high inrush currents can occur.
- When switching the following transient effects have to be considered:
  - **High recovery voltage**,
  - **Inrush current during switching on**
  - **Voltage increase when switching off filters**

Source: Maschinenfabrik Reinhausen

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Capacitive circuits normal operation

For class C2, all circuit breakers comply with the following values acc. to IEC 62271-100.

	Line	Cable	Capacitors	Back-to-back capacitor bank	
Rated voltage	Rated line-charging breaking current	Rated cable-charging breaking current	Rated single-capacitor-bank breaking current	Rated back-to-back-capacitor-bank breaking current	Frequency of the inrush making current
U_r	I_l	I_c	I_{sb}	I_{bb}	f_{bi}
kV, r.m.s.	A, r.m.s.	A, r.m.s.	A, r.m.s.	A, r.m.s.	Hz
7.2	10	10	400	400	4250
12	10	25	400	400	4250
17.5	10	31.5	400	400	4250
24	10	31.5	400	400	4250

Rated back-to-back-capacitor-bank inrush making current – see chapter 3: Technical data

Capacitive current limit for Siemens VCB: 70 % of rated current

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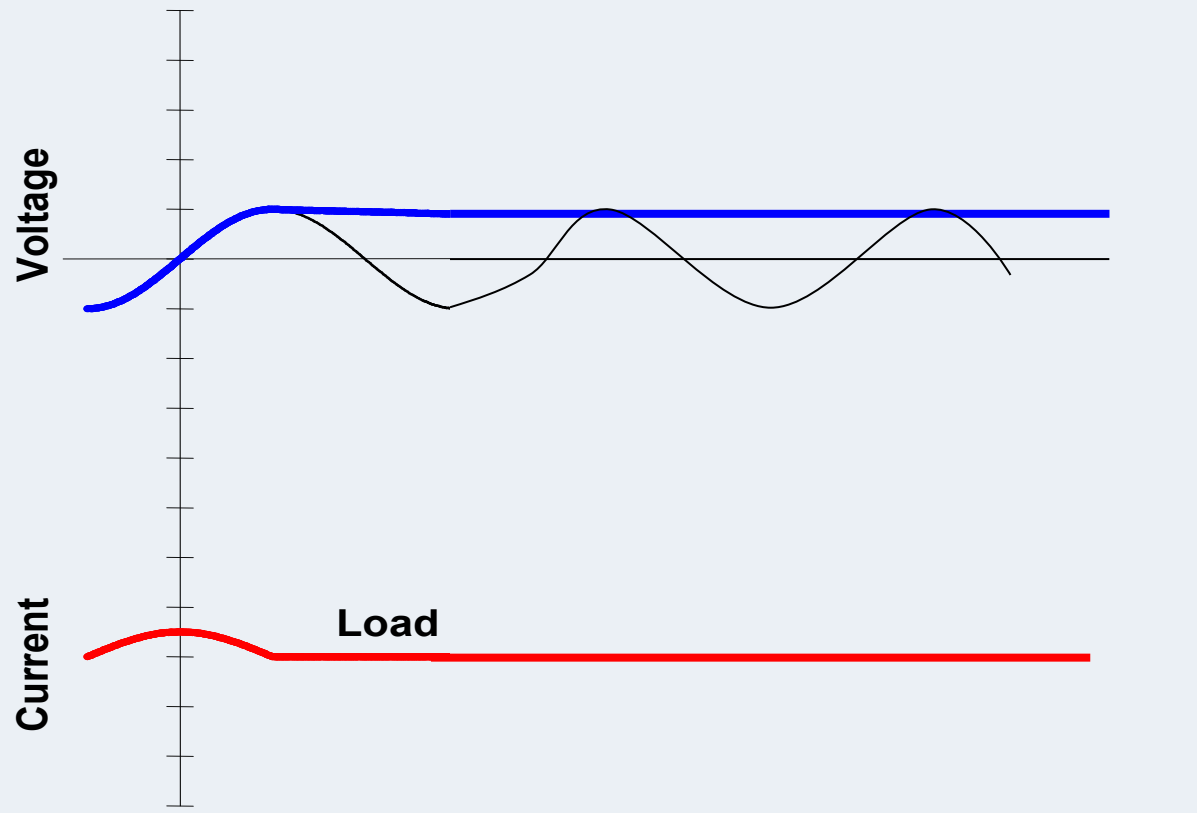
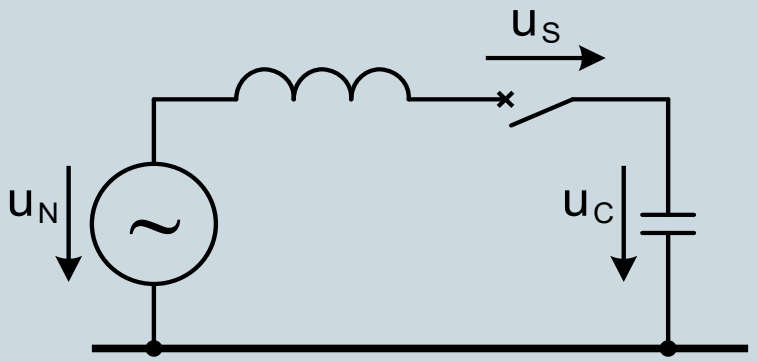
C1. Contact system is able to withstand the recovery voltage





u_N = System voltage
u_C = Load side
u_S = Voltage over the switch
i_C = Load current

The voltage difference across the contacts is twice the peak value of operational voltage.

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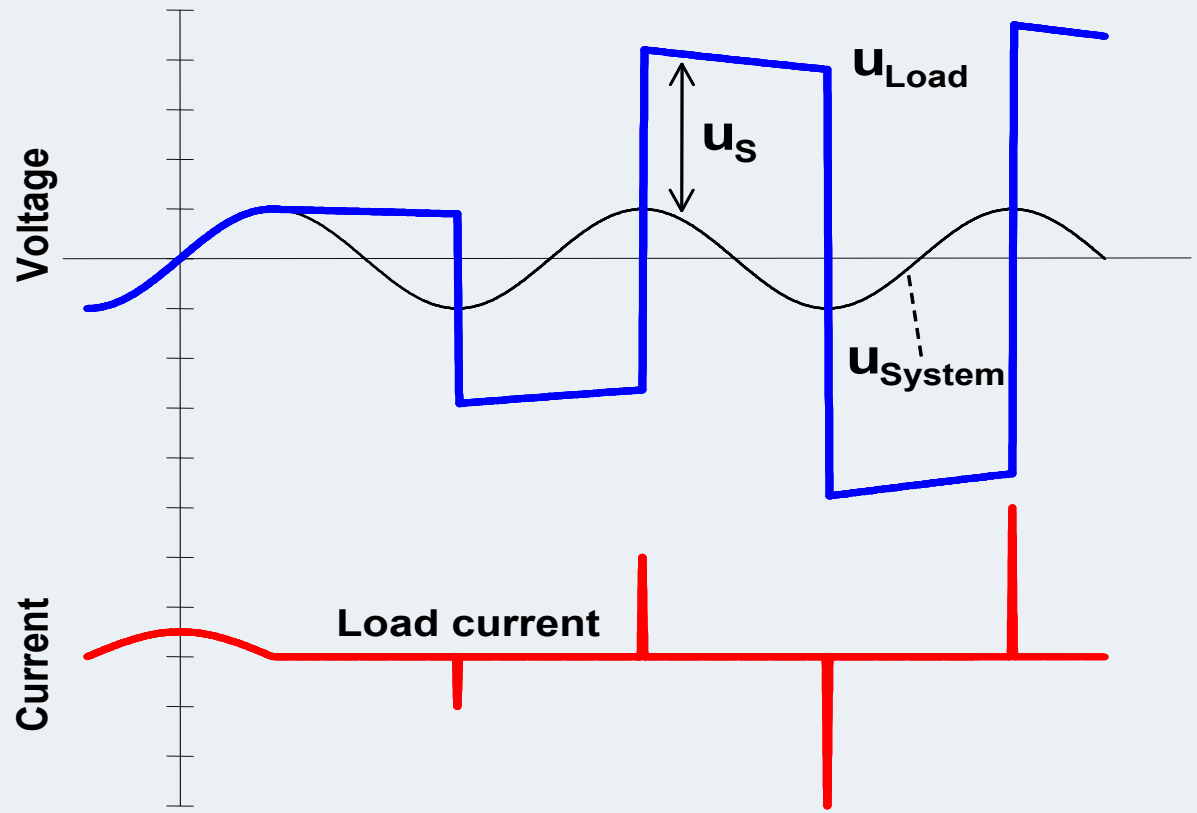
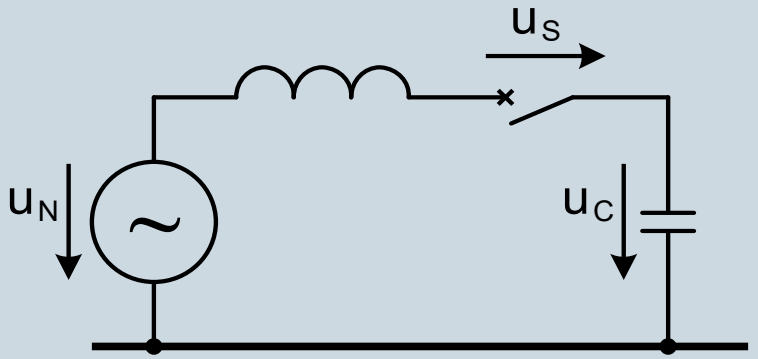
C1. Contact system is not able to withstand the recovery voltage – Re-striking with capacitive current





u_N = System voltage
u_C = Load side
u_S = Voltage over the switch
i_C = Load current

In case of re-striking the voltage escalates to very high values leading to failing of the breaker.
Breakers for capacitive switching must be re-strike-free. **Class C2 required**

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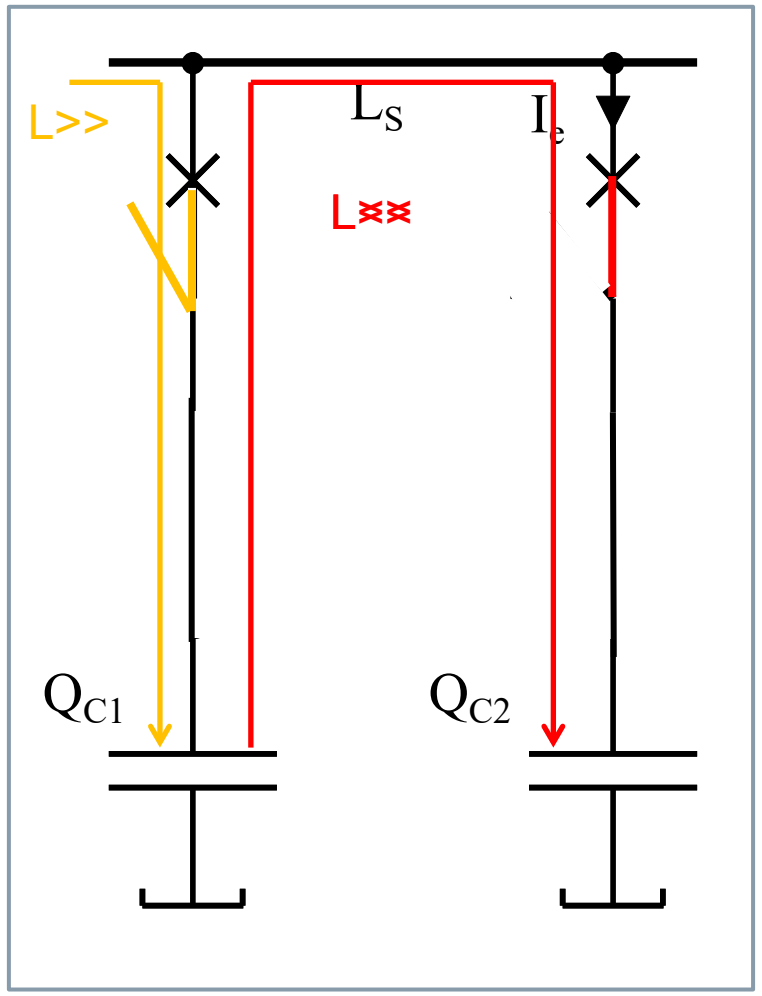
C2. Paralleling of capacitor banks



Switching on one capacitor:

- Inrush current will be limited by network inductance (L>>)

Switching on a second capacitor (paralleling):

- Inrush current will be limited by busbar inductance only (L<<)
- Limitation of current by additional coil in series (L>>)

I_e	Inrush current
L_1, L_2	Inductances
L_s	Inductance of bus-bar
Q_{c1}, Q_{c2}	Power of capacitors

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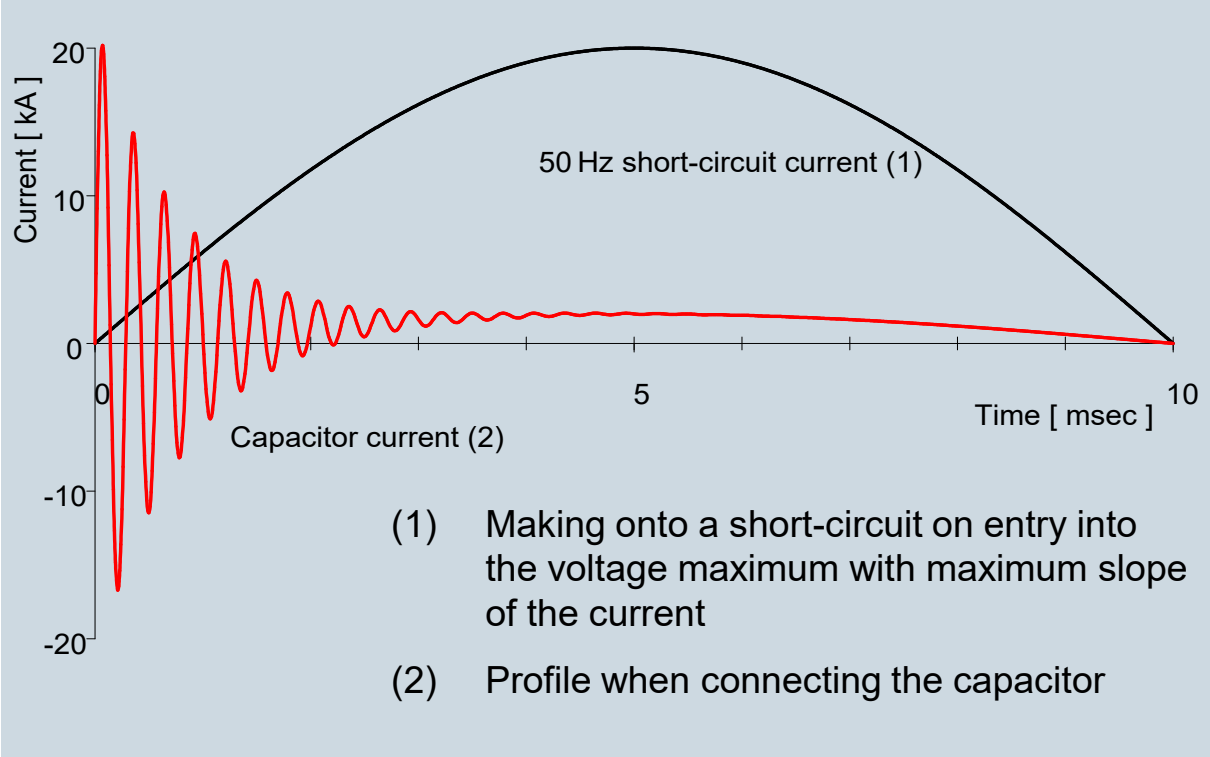
Paralleling of capacitor banks

Capacitor banks

- Current: up to 100 · I_{rC} (capacitor) permitted
- High amplitude and rate-of-rise of making current
- Very high load on the contact pieces
  - Plate contacts $\hat{i}_e$ = 10 kA
  - Requirement to IEC $\hat{i}_e$ = 20 kA at 4250 Hz

Switching devices must be able to open the partially welded contacts.

- This behaviour is influenced by
  - contact material
  - operating force
  - Quality of VI



(1) Making onto a short-circuit on entry into the voltage maximum with maximum slope of the current

(2) Profile when connecting the capacitor

→ Back-to-back capability is a rating has to be type tested

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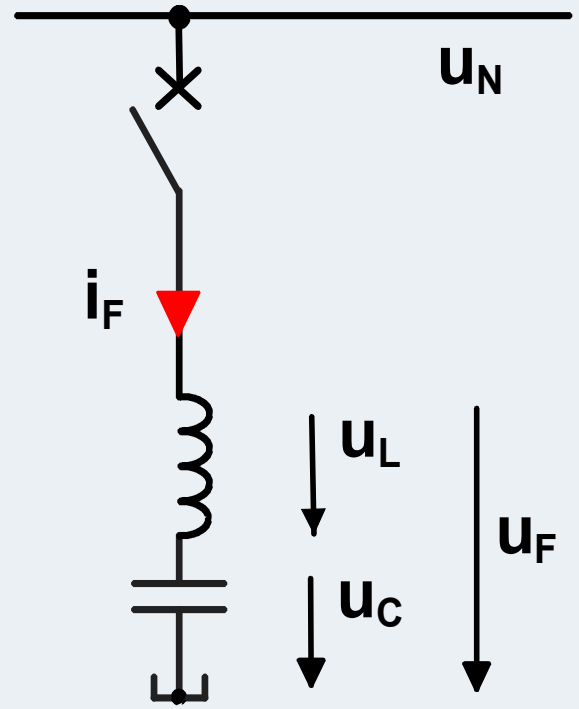
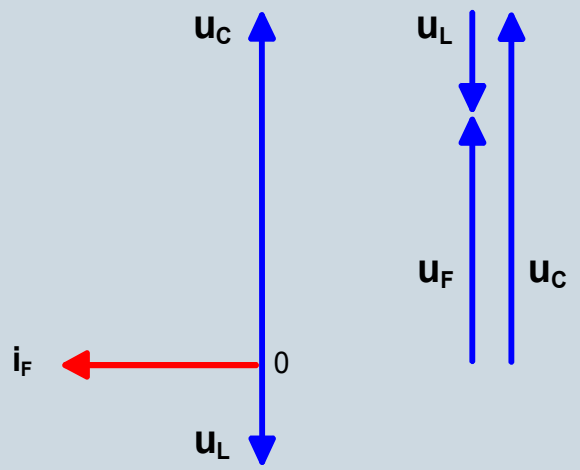
C3. Voltages in a filter circuit





U_N	System voltage
U_F	Voltage at Filter
U_L	Voltage at reactor
U_C	Voltage at capacitor
I_F	Current through filter
n	Harmonic number

Closed condition:

- Filter and system voltage are identical

Opened condition:

- Filter voltage is equal to capacitor voltage
- Voltage can be calculated by means of harmonic number

$$U_C = U_{N\max} \cdot \frac{n^2}{n^2 - 1}$$

Filter voltage can be higher than system voltage on the bus-bar side

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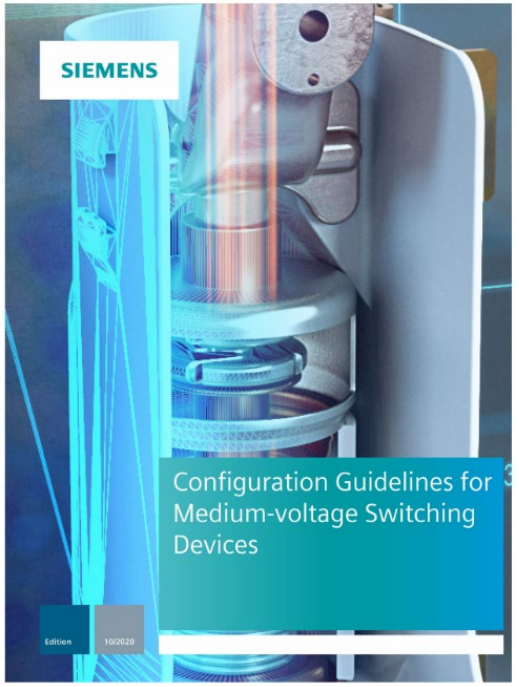
Engineering guide
Application guide for VCB and VC

- Physical / electrical background of applications
- Normal & fault operation
- Limits of application
- Protection measures, e.g. overvoltage protection by surge arresters, RC elements or design



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