Module 6
Current-Sourced Converters

Content

- Current-sourced PWM rectifier
- Current-sourced PWM inverter
- Current-sourced vs voltage-sourced ac-ac frequency converter

Learning outcomes of the module

After the module, you will be able to:

- understand how current-sourced PWM rectifiers and inverters operate
- understand the difference between voltage- and current sourced converters

Current-type PWM rectifier

- Large smoothing inductance on the dc-side
  - Ideally perfect dc
  - Is an energy storage too
  - Requires continuous current path
- Dc-current is not changing polarity, dc-voltage can
  - Power can flow in both directions
- Very similar to line-commutated six-pulse thyristor bridge, except turn-on, turn-off devices (IGBT) and use of PWM instead of phase-shift modulation
- Converter has two changeover switches (SA, SB, SC) and (SA', SB' and SC')
  - each with three positions or poles
  - one of the poles has to be closed, otherwise there would not be a path for the load current io
  - 3*3 = 9 combinations for the conducting switches (see next slide)

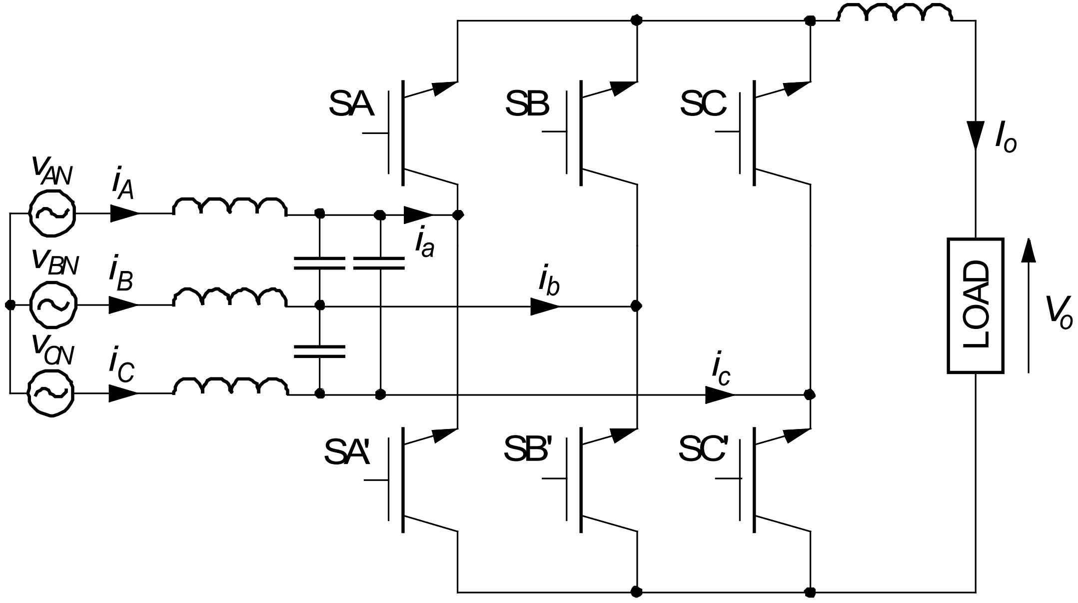


Fig. 4.45

Switching variables *a*, *b*, *c*, *a'*, *b'*, and *c'* of switches SA through SC' must satisfy the condition

$$a + b + c = a' + b' + c' = 1.$$

It can be seen that the above condition limits the number of allowable states of the rectifier to 9, namely:

state 1: *a* = *b'* = 1 (conducting switches: SA & SB'),

state 2: *a* = *c'* = 1 (conducting switches: SA & SC'),

state 3: *b* = *c'* = 1 (conducting switches: SB & SC'),

state 4: *b* = *a'* = 1 (conducting switches: SB & SA'),

state 5: *c* = *a'* = 1 (conducting switches: SC & SA'),

state 6: *c* = *b'* = 1 (conducting switches: SC & SB'),

state 7: *a* = *a'* = 1 (conducting switches: SA & SA'), switches in the same phase conduct

state 8: *b* = *b'* = 1 (conducting switches: SB & SB'), switches in the same phase conduct

state 9: *c* = *c'* = 1 (conducting switches: SC & SC'), switches in the same phase conduct

E.g. in state 1, currents i_A, i_B, and i_C equal I_o, - I_o, and 0, respectively. Thus, the space vector of input currents in this state is

$$\vec{\mathcal{F}}_s = \mathcal{F}_{as} + \mathcal{F}_{bs}\mathrm{e}^{\mathrm{j}120^{\mathrm{o}}} + \mathcal{F}_{cs}\mathrm{e}^{\mathrm{j}240^{\mathrm{o}}}$$

$$\overrightarrow{I_1} = \frac{3}{2}I_o - j\frac{\sqrt{3}}{2}I_o.$$

Current vectors associated with the remaining states can be determined similarly. States 7, 8, and 9 produce zero vectors of input currents:

$$\vec{I}_7 = \vec{I}_8 = \vec{I}_9 = 0.$$

Reference current vector in the vector space of input currents of a current-type PWM rectifier

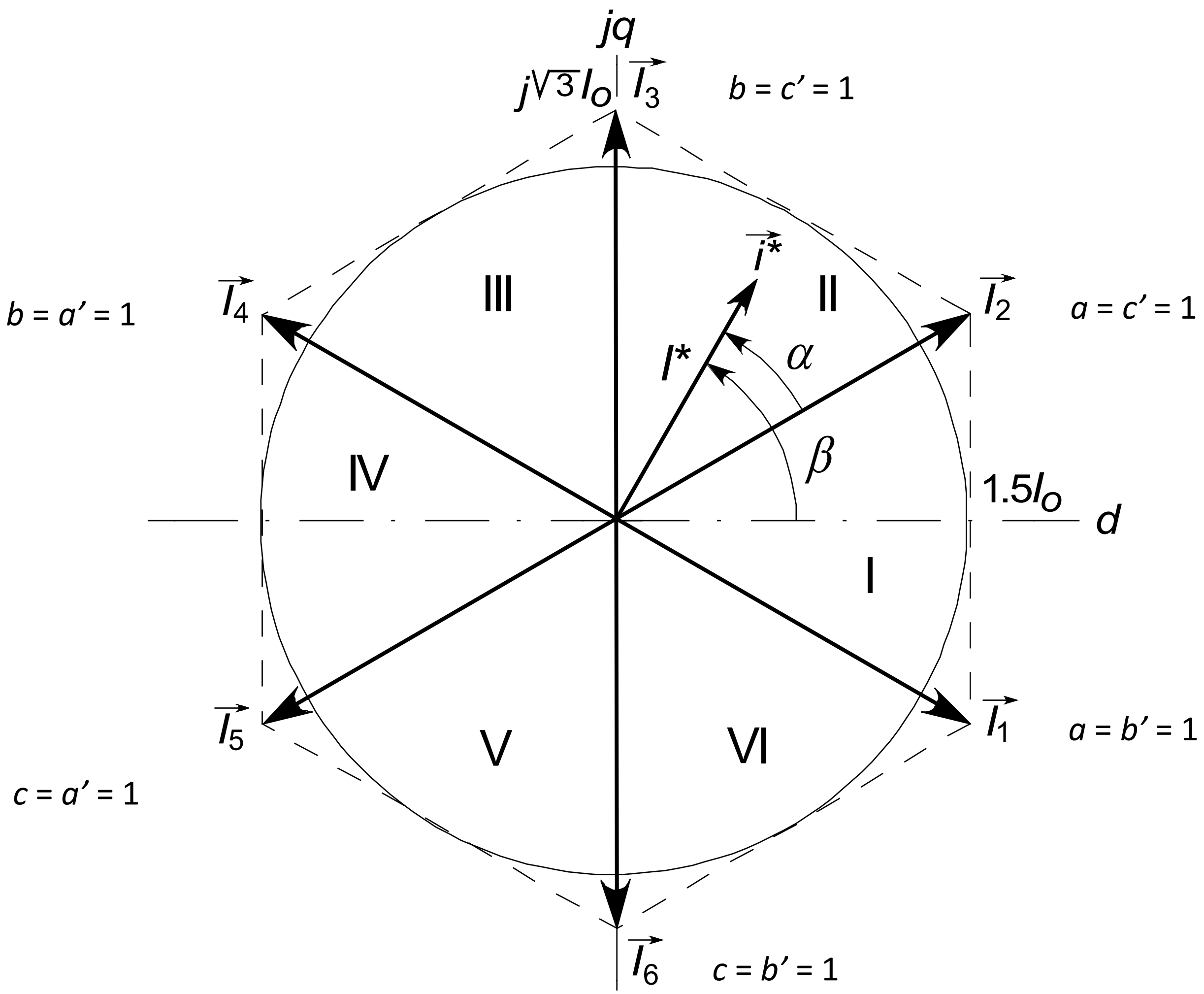


Fig. 4.46

Control scheme of a current-type PWM rectifier

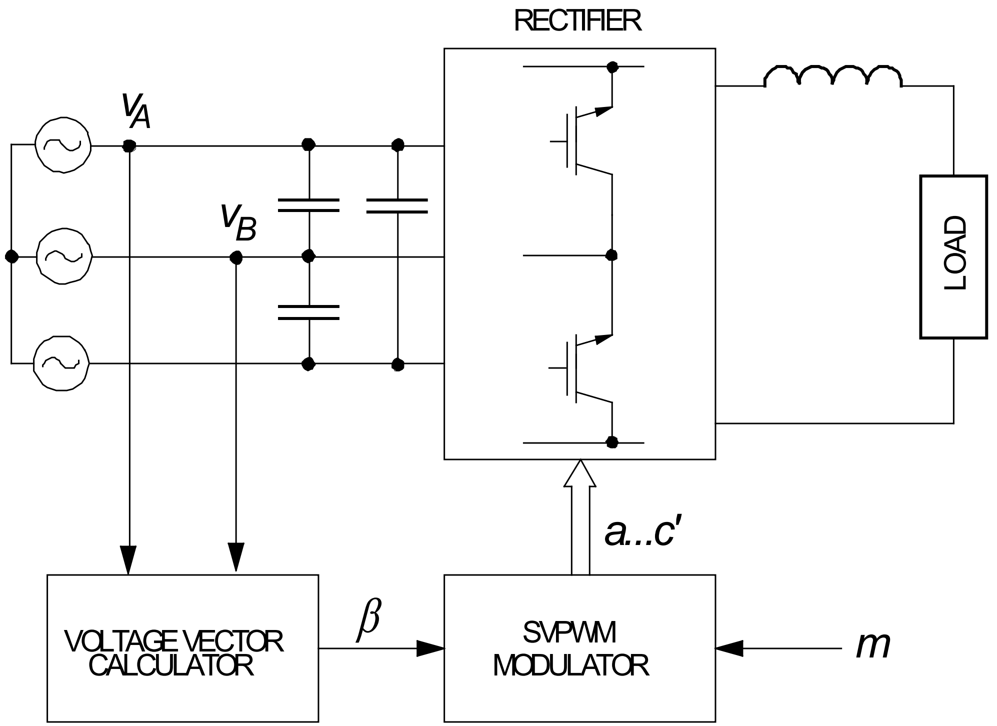


Fig. 4.48

Waveforms of output voltage and current in a current-type PWM rectifier: (a) m = 0.75, (b) m = 0.35 (fsw/fo = 24, RLE load)

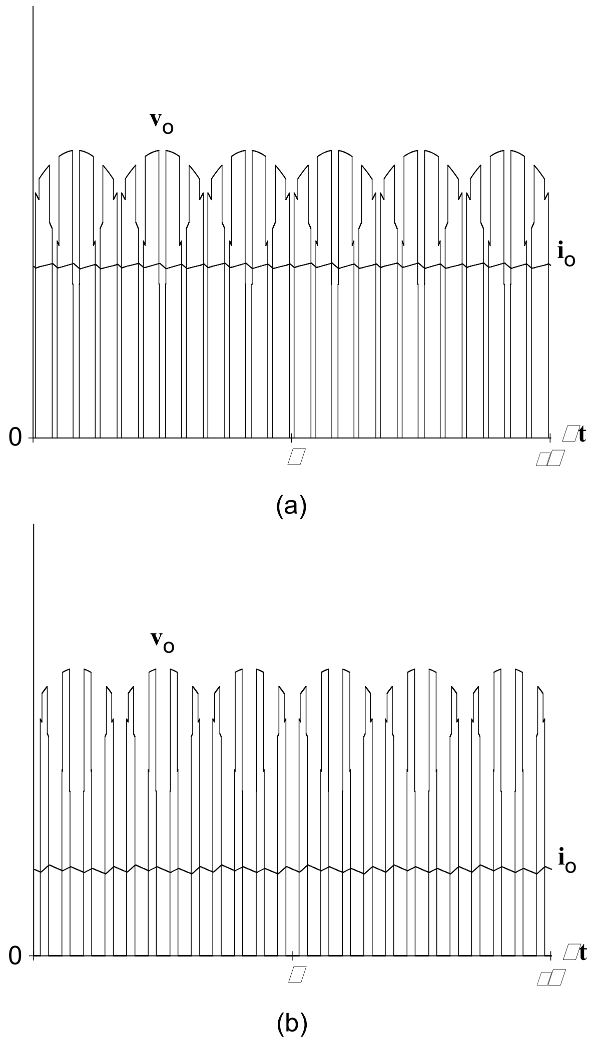


Fig. 4.49

Waveforms of the input current and its fundamental in a current-type PWM rectifier: (a) *m* = 0.75, (b) *m* = 0.35 (fsw/fo = 24, RLE load)

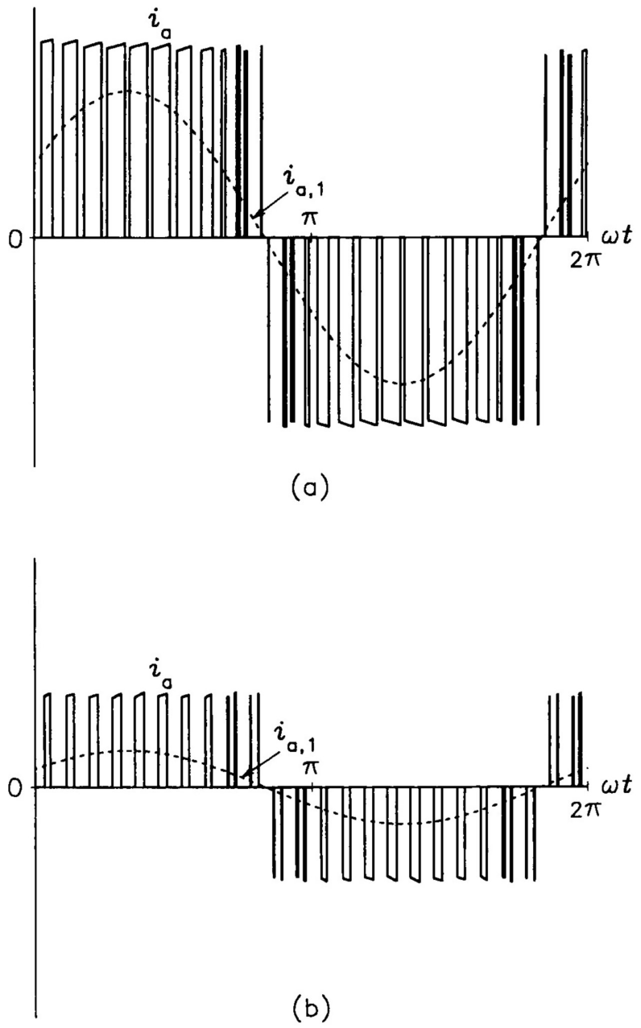


Fig. 4.50

Waveforms of (a) output voltage and current,
(b) input current and its fundamental
in a current-type PWM rectifier in the **inverter mode**

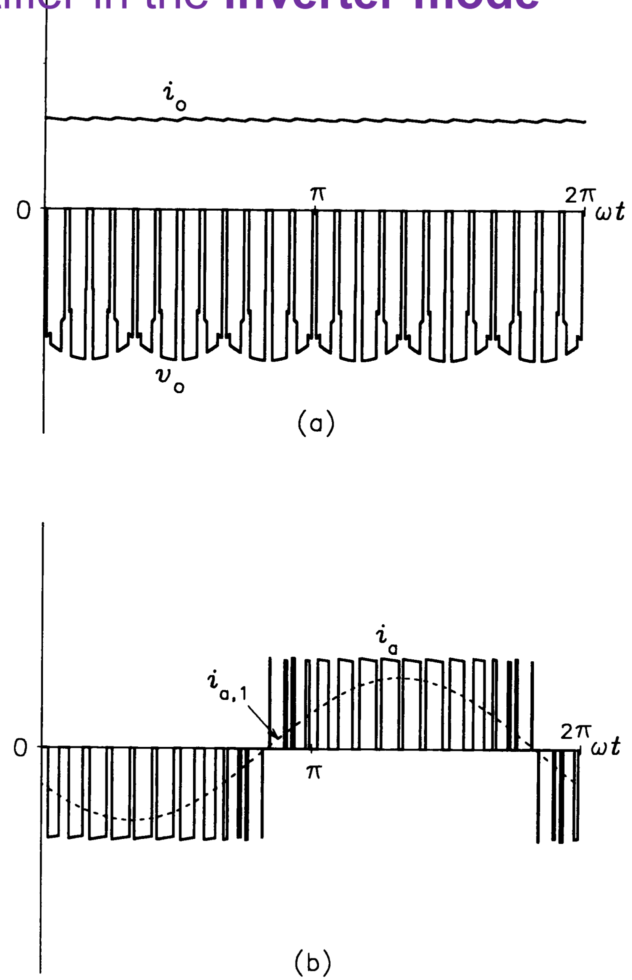


Fig. 4.51

CSI, Current Source Inverter

Current-source inverter supplied from a controlled rectifier

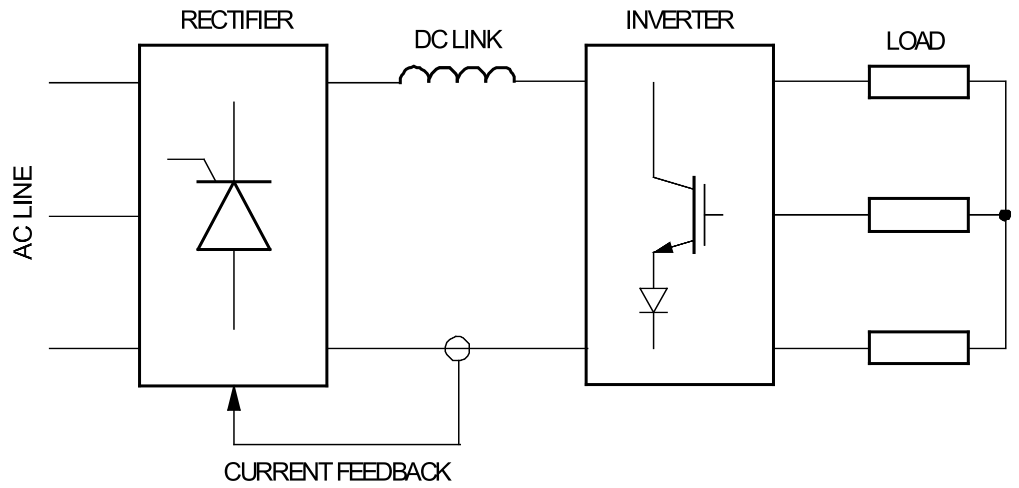


Fig. 7.43

Three-phase current-source inverter

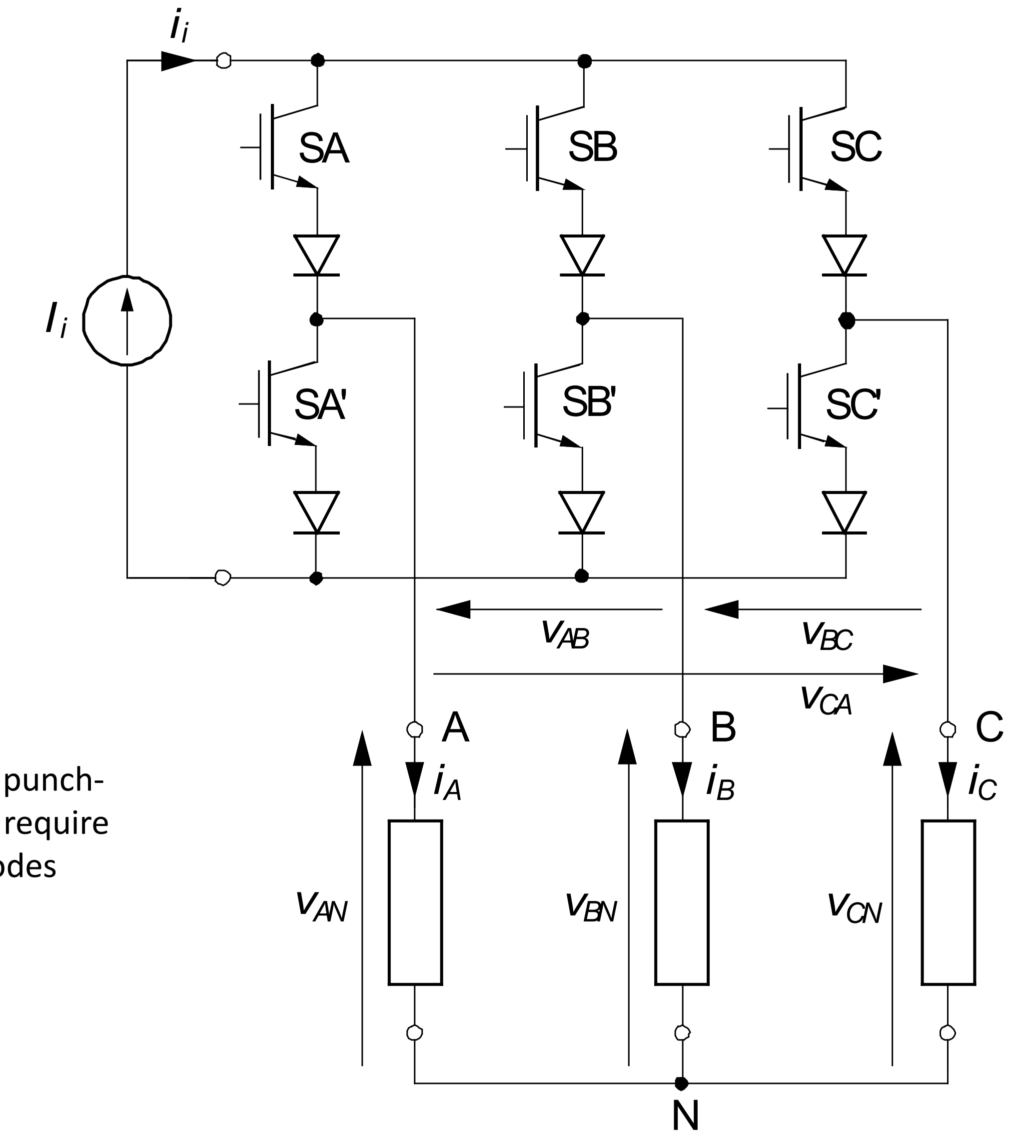


Fig. 7.44

Note:
Symmetrical power semiconductors like punch-through IGBTs don't require series connected diodes

Switching variables in a three-phase CSI in the square-wave mode

- Same idea as in Current Sourced Rectifier
- a, b or c needs to conduct the positive dc-current
- a’, b’ or c’ needs to conduct the current back to dc minus

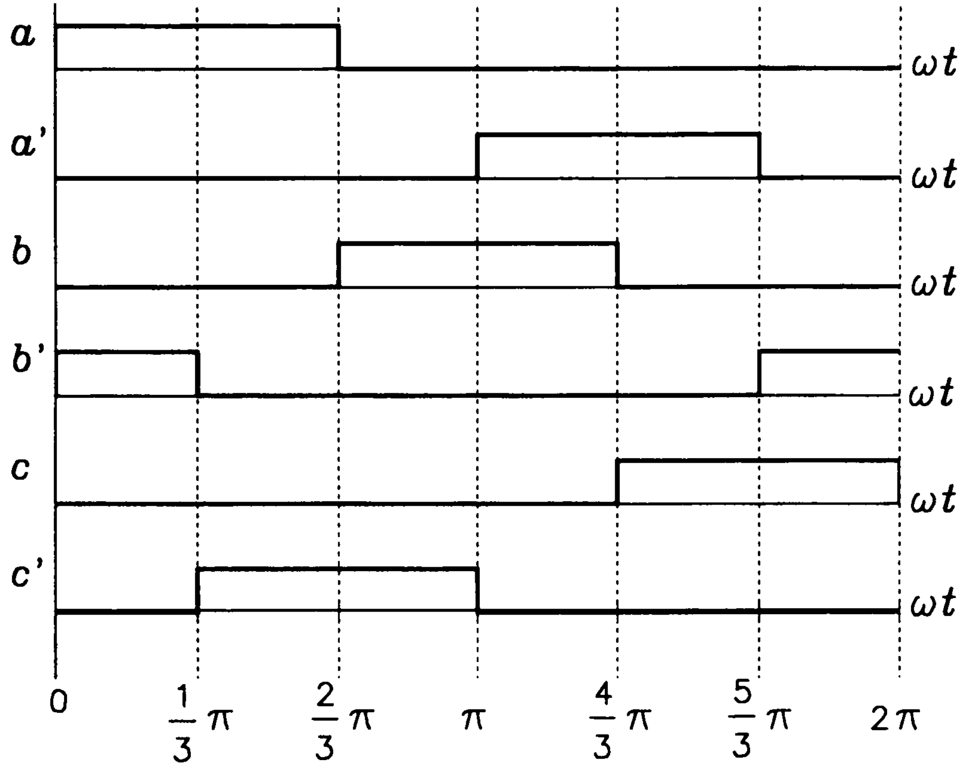


Fig. 7.45

Idealized waveforms of output currents in a three-phase CSI in the square-wave mode

Wye-connected load

$$\begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix} = \begin{bmatrix} a - a' \\ b - b' \\ c - c' \end{bmatrix} I_i$$

Delta-connected load

$$\begin{bmatrix} i_{AB} \\ i_{BC} \\ i_{CA} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix}$$

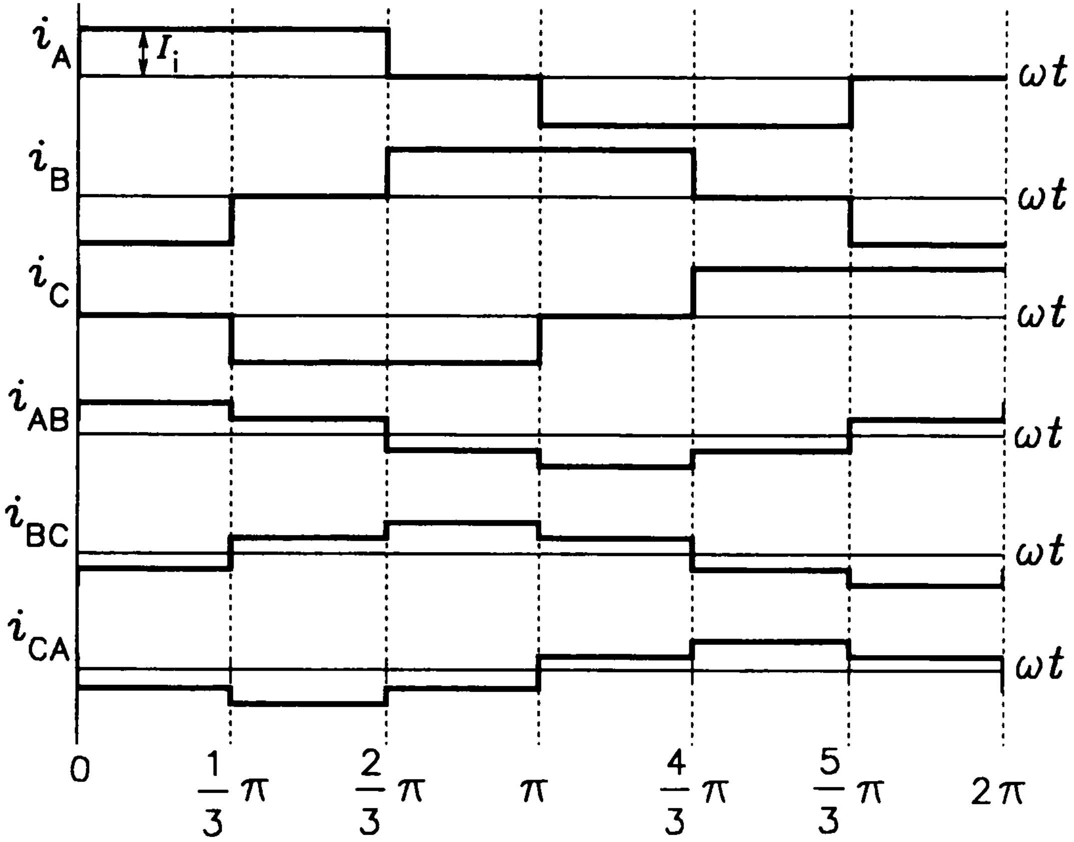
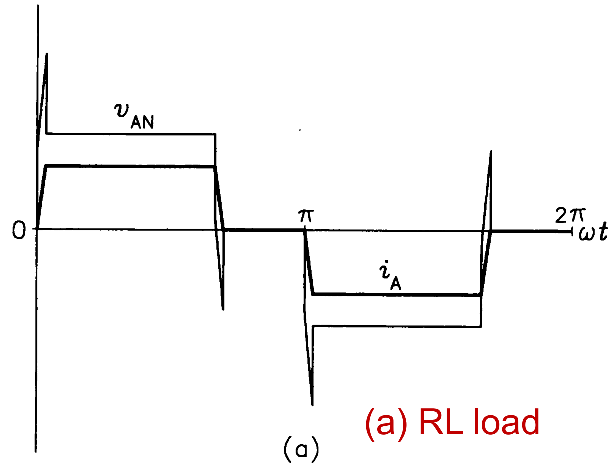


Fig. 7.46

Waveforms of output voltage and current in a three-phase CSI in the square-wave mode:

- Load current is given by the CSI
- In an inductive load current cannot change instantaneously => induced voltage spike in voltage waveforms



(a) RL load

(b) LE load

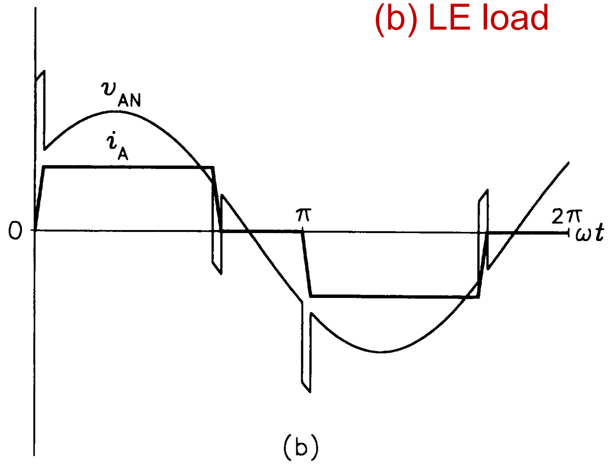


Fig. 7.47

Carrier-comparison method for the PWM CSI

- Pulse width modulation can be used to reduce the fundamental component of current
- Directly same PWM methods as for VSI cannot be used
- In CSI PWM must guarantee that the dc bus current is always connected to the load

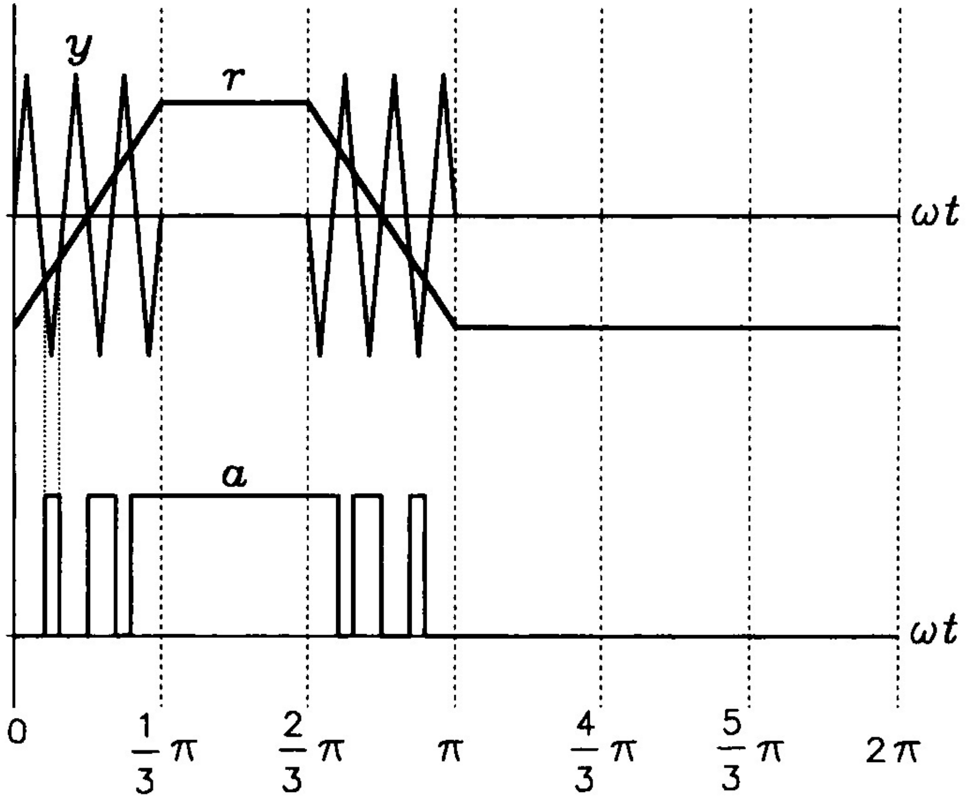


Fig. 7.49

Waveforms of the output current, capacitor current, and output voltage in a three-phase PWM CSI (wye-connected RL load, P = 9)

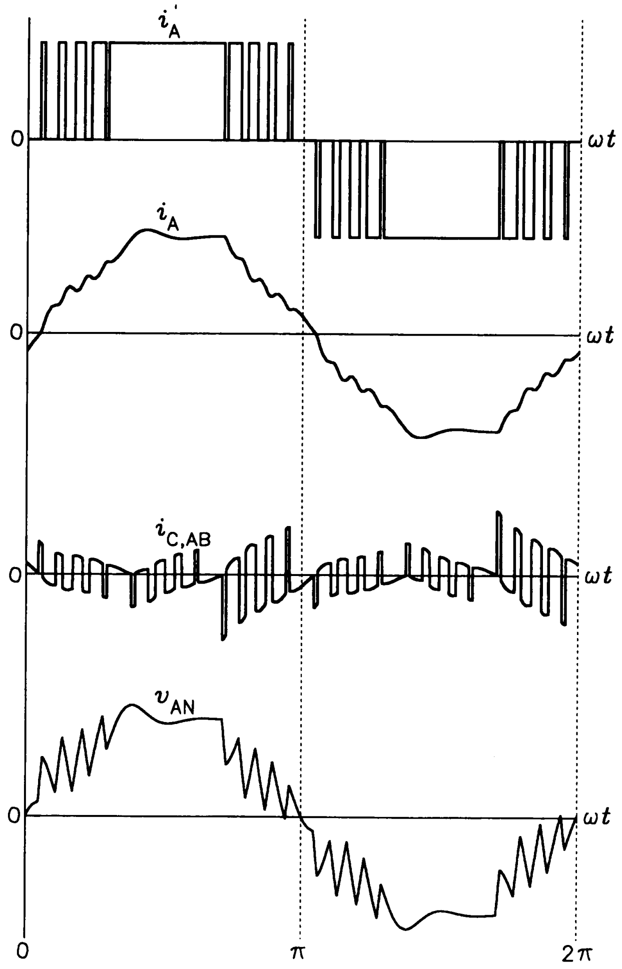


Fig. 7.51

Three-phase PWM current-source converter

- Thyristor converter is used as a rectifier
- It can also feed power to the ac grid when dc voltage is reversed
- Amplitude of the dc link current is adjusted with the rectifier

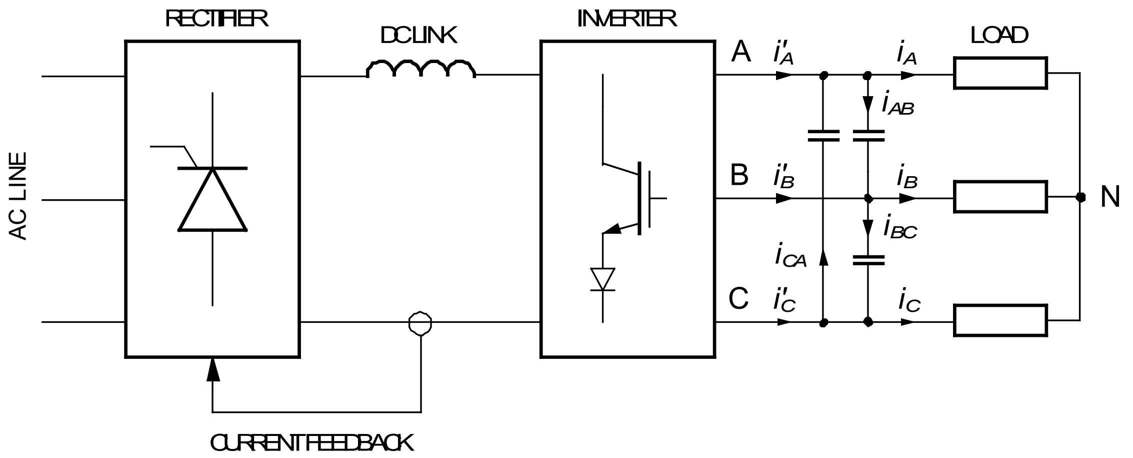
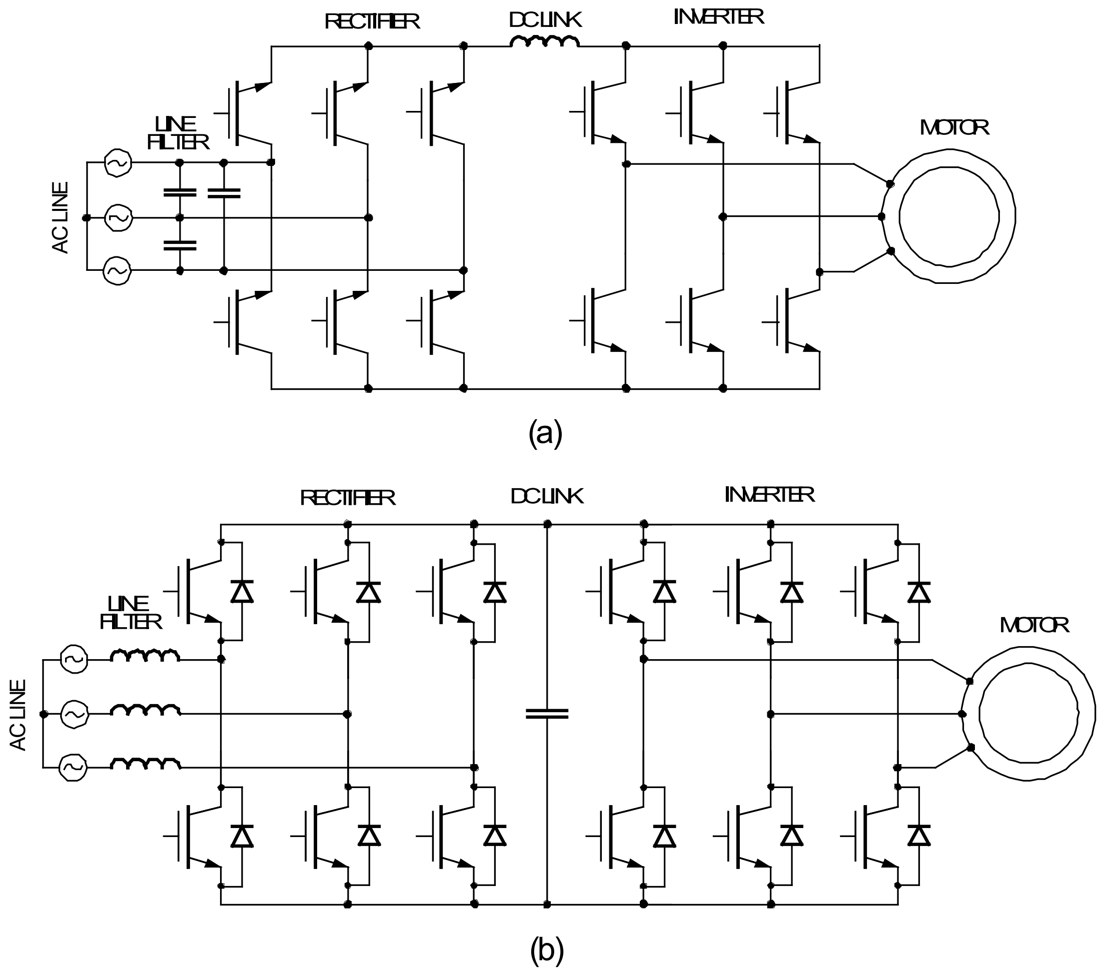


Fig. 7.48

PWM rectifier-inverter cascades for bidirectional power flow in ac motor drives:

- (a) current-type rectifier, inductive dc link, and current-source inverter,
- (b) voltage-type-rectifier, capacitive dc link, and voltage-source inverter



Summary of the module

- Current-type converters have a current source in the dc-bus and in practice it is a large enough series connected inductance.
- Current-type converters can be used as inverters and rectifiers in a same way as voltage-type converters.
- PWM can be used in current-type converters but it is not similar to PWM VSI. In current-type converters a bath for the dc-bus current needs to be guaranteed. In VSI short-circuit of the dc-bus needs to be avoided.