HUST

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HANOI UNIVERSITY OF SCIENCE AND TECHNOLOGY

ONE LOVE. ONE FUTURE.

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EE3410E POWER ELECTRONICS

AC/AC CONVERTERS

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Advance Power Electronic Systems Laboratory (APES Lab.)

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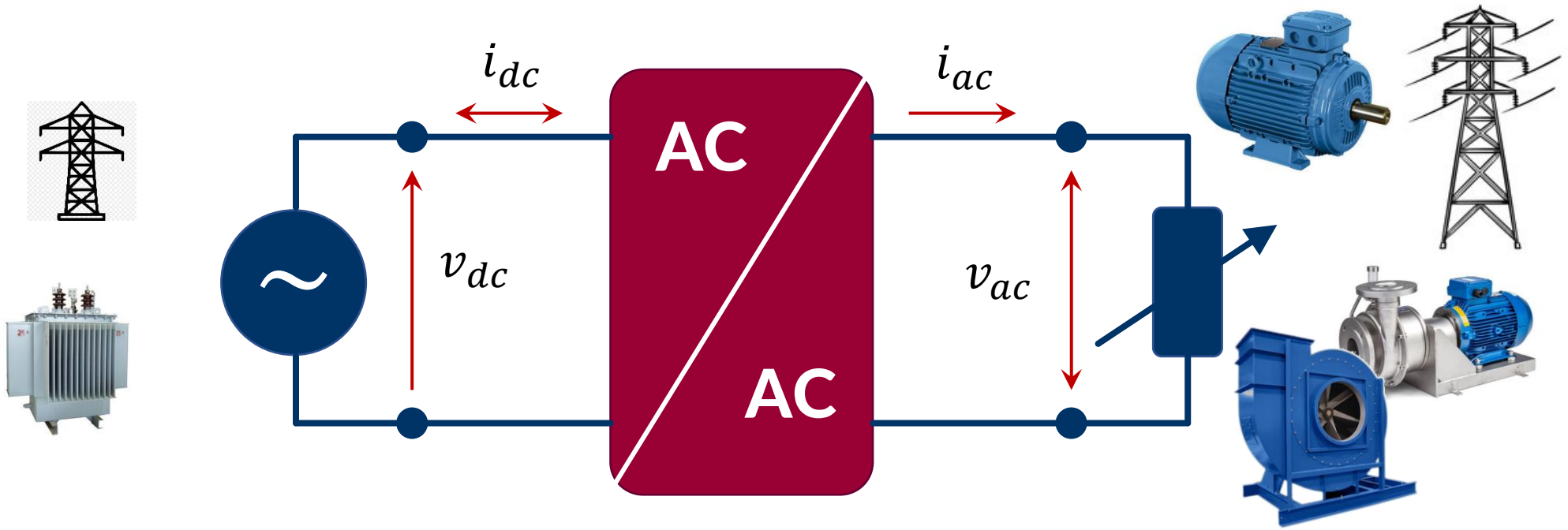
General introduction



AC source

AC grid,
secondary winding of line transformers,
secondary side of high freq. isolated converters,
Generator outputs

AC/AC inverters

AC chopper,
Cycloconverters,
Matrix converters,

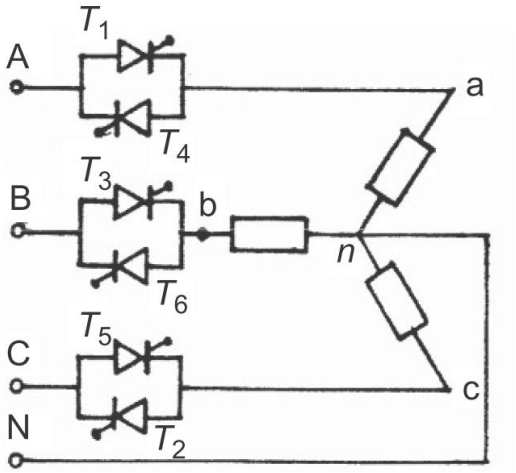
AC loads

AC motors,
AC grids,
Fan, pumps,
Lighting systems,
Heating systems,
etc.

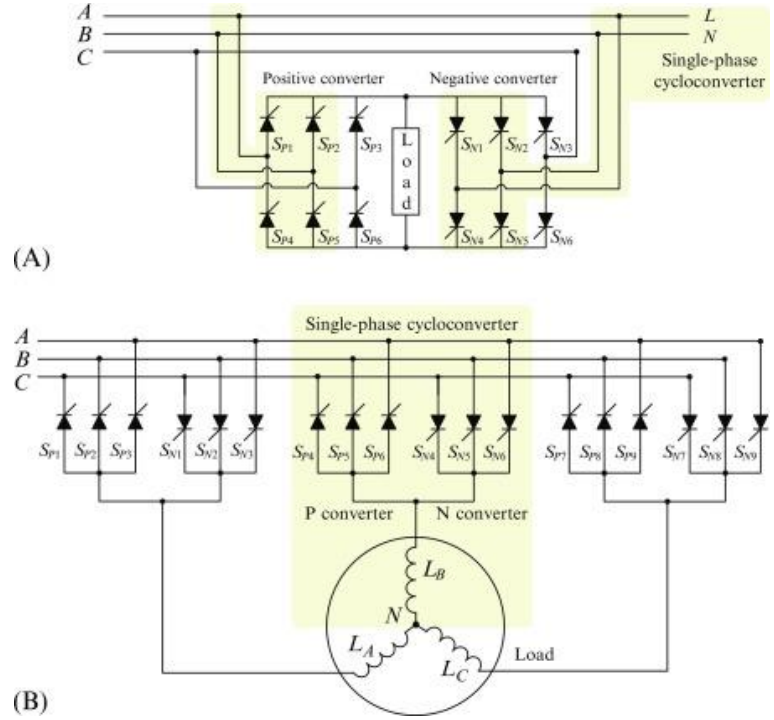
Classification

AC/AC converters

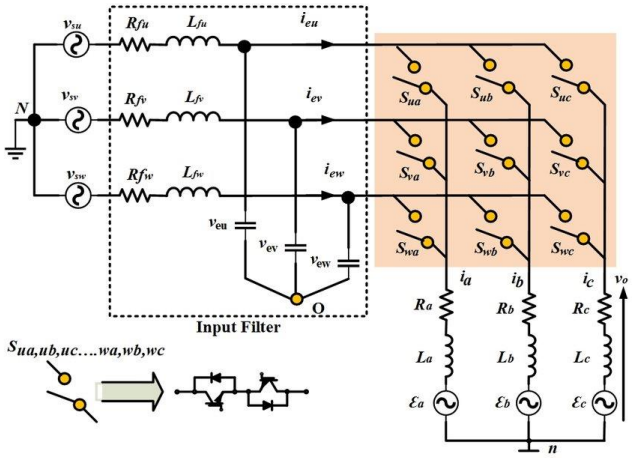
AC chopper



Cyclo-converters

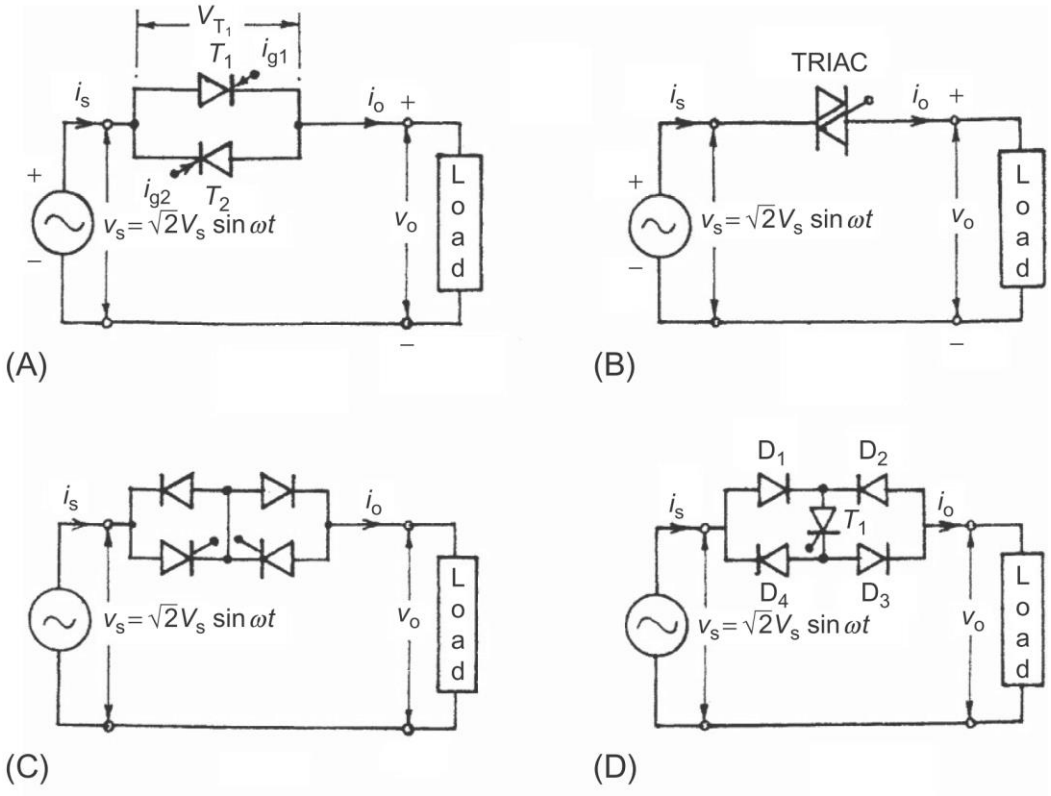


Matrix Converters

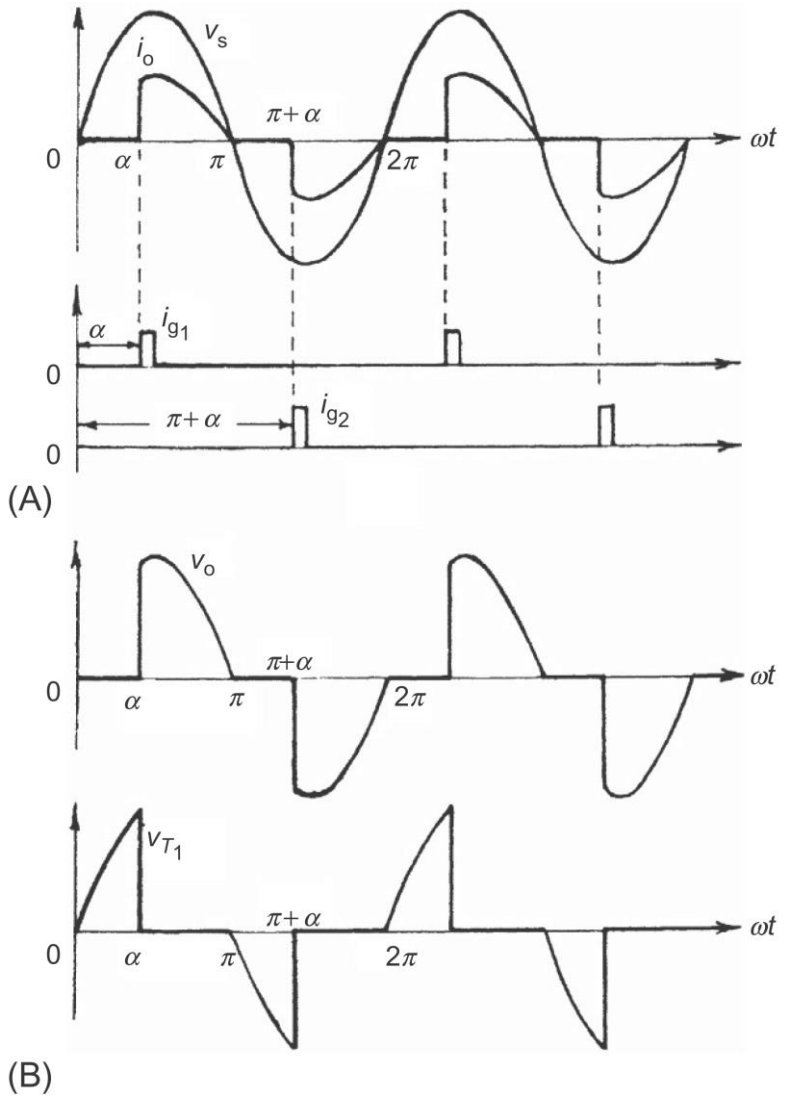


AC chopper: R-Load

- Single phase AC chopper



Various types of single phase AC voltage controllers



Typical waveform with R-load

AC chopper: R-Load

- Output RMS voltage

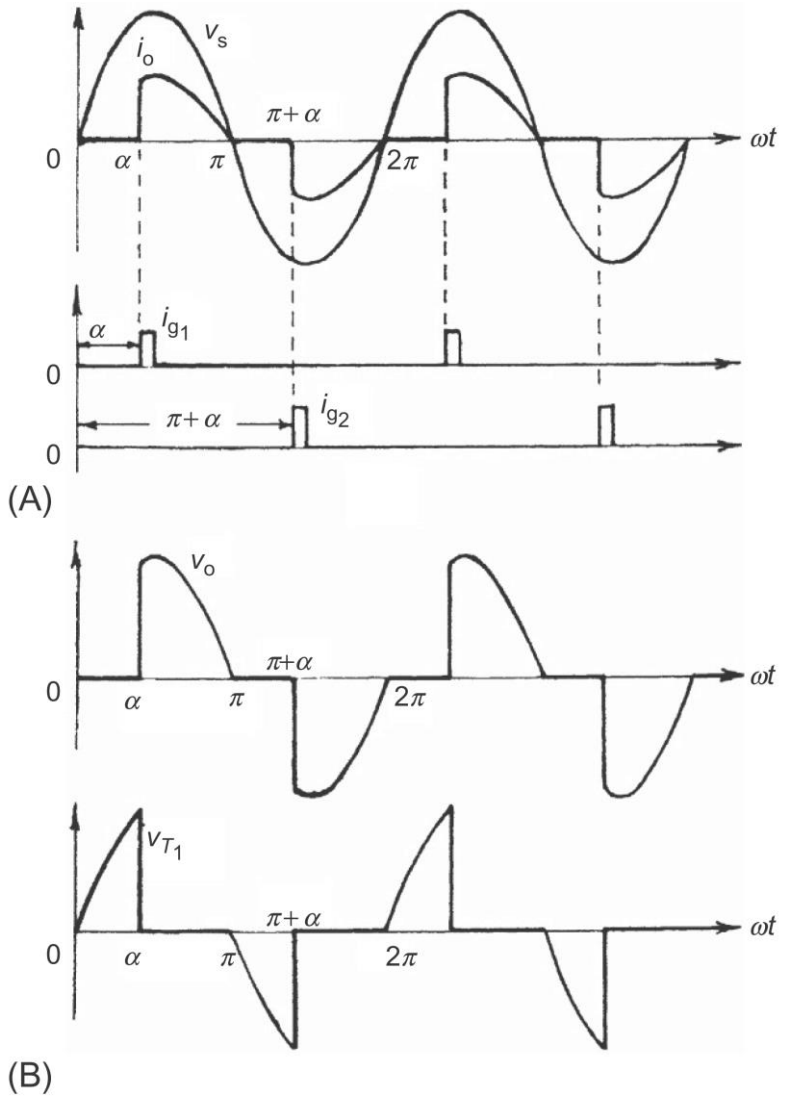
$$V_o = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi} 2V_s^2 \sin^2\theta \, d\theta}$$

$$= V_s\sqrt{1 - \frac{\alpha}{\pi} + \frac{\sin 2\alpha}{2\pi}}$$

where α is the firing angle

- RMS current in SCR

$$I_{SCR,rms} = \frac{I_{o,rms}}{\sqrt{2}}$$



Typical waveform with R-load

AC chopper: RL-Load

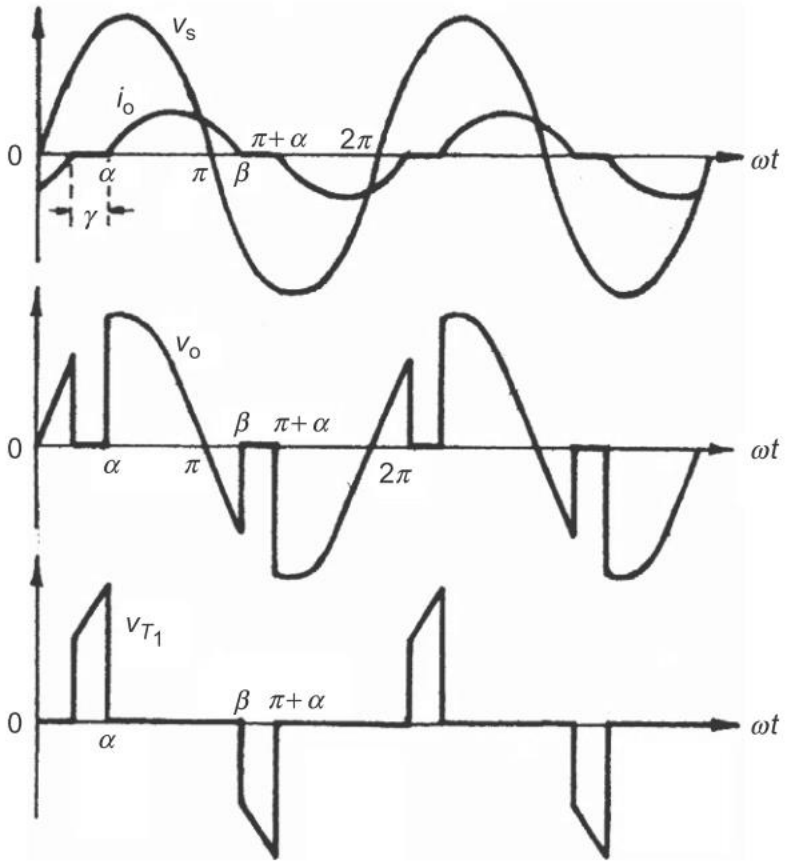
- Output RMS voltage

$$V_o = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\beta} 2V_s^2 \sin^2\theta \, d\theta}$$

$$= \frac{V_s}{\pi}\sqrt{\beta - \alpha + \frac{\sin 2\alpha}{2} - \frac{\sin 2\beta}{2}}$$

where α is the firing angle, β is the extinction angle, ϕ is the load angle:

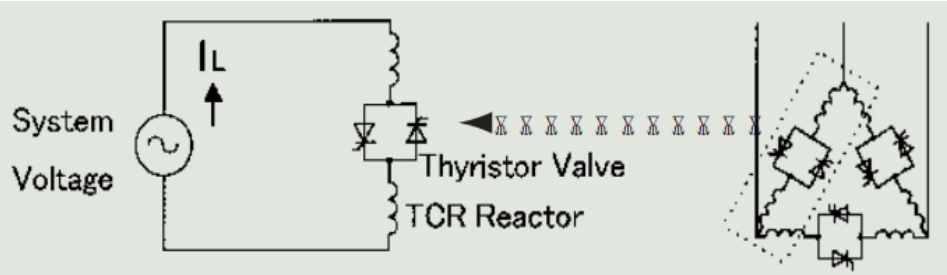
$$\sin(\beta - \alpha) = \sin(\alpha - \phi)\left[1 - e^{(\alpha-\beta)/tan\,\phi}\right]$$



Typical waveform with R-load

AC chopper: L-Load

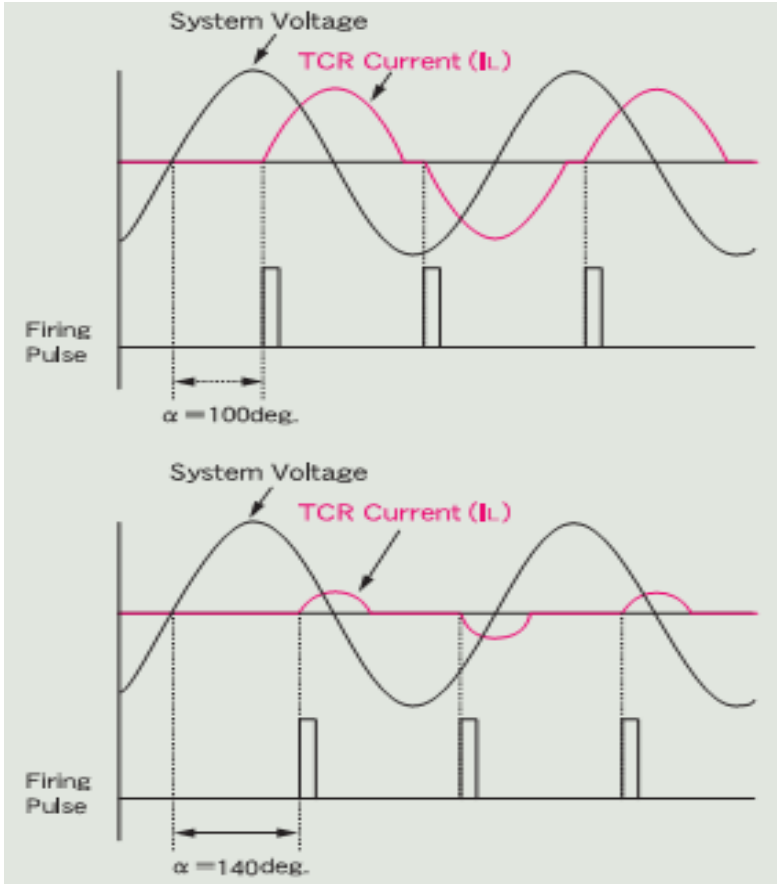
Thyristor Controlled Reactor – TCR



$$I_L(\alpha) = \frac{V}{\omega L}\left(1 - \frac{2}{\pi}\alpha - \frac{1}{\pi}\sin 2\alpha\right)$$

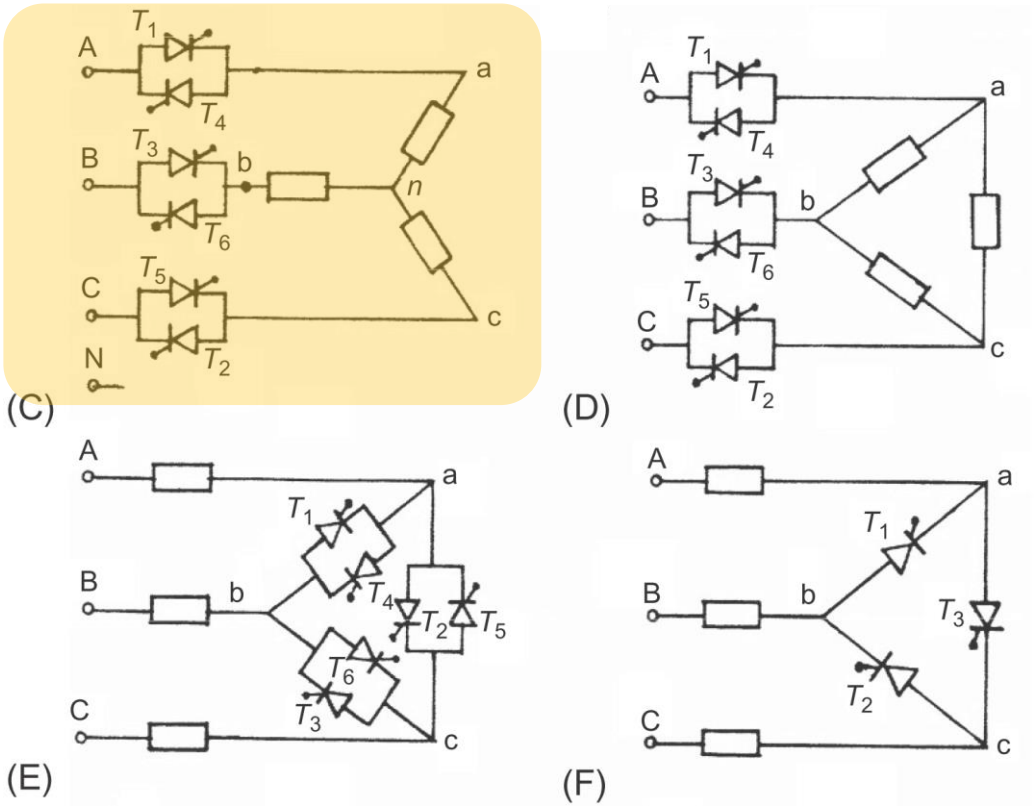
Equivalent inductance:

$$L(\alpha) = \frac{L}{\left(1 - \frac{2}{\pi}\alpha - \frac{1}{\pi}\sin 2\alpha\right)}$$

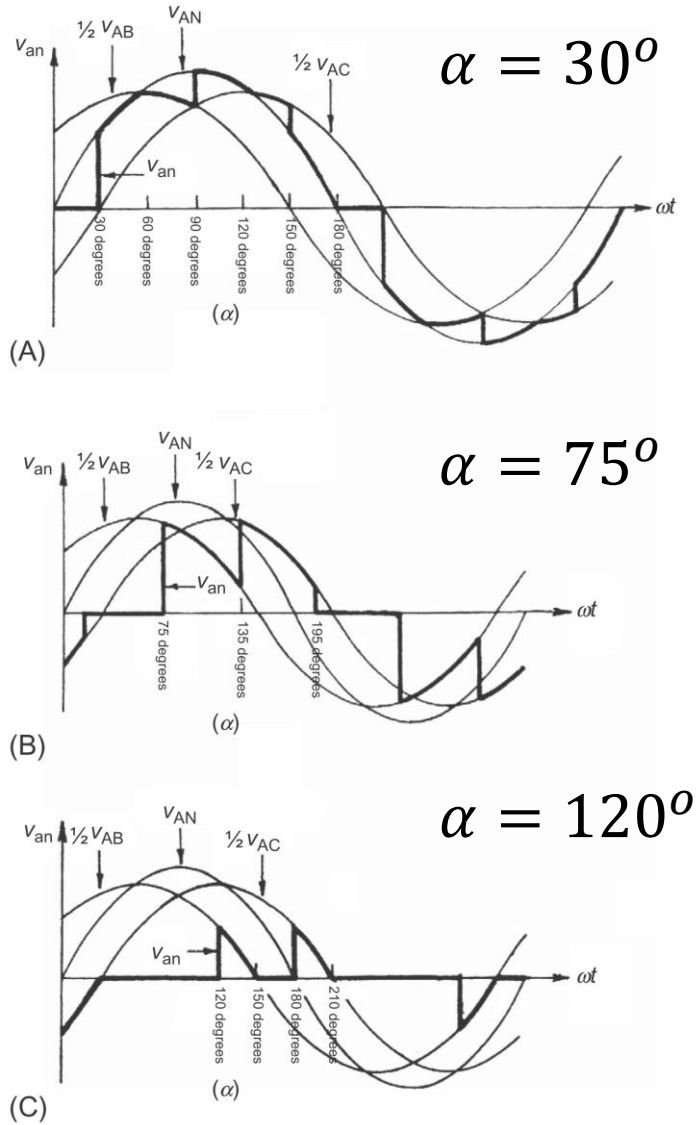


AC chopper: R-Load

- Three phase AC chopper



Various types of three phase AC voltage controllers



Typical waveform with R-load

AC chopper: R-Load

- Output voltage depends on α

$\gg 0 < \alpha < 60^o$:

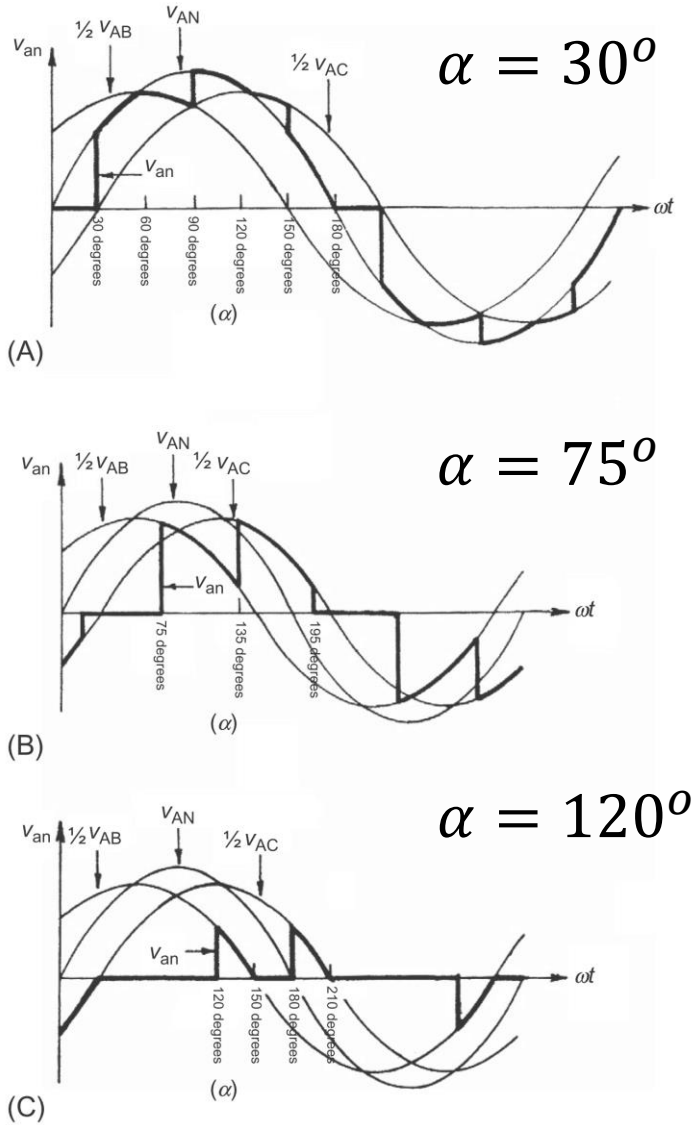
$$V_o = V_s \sqrt{1 - \frac{3\alpha}{2\pi} + \frac{3}{4\pi}\sin 2\alpha}$$

$\gg 60^o < \alpha < 90^o$

$$V_o = V_s \sqrt{\frac{1}{2} + \frac{3}{4\pi}\sin 2\alpha + \sin\left(2\alpha + \frac{\pi}{3}\right)}$$

$\gg 90^o < \alpha < 150^o$

$$V_o = V_s \sqrt{\frac{5}{4} - \frac{3\alpha}{2\pi} + \frac{3}{4\pi}\sin\left(2\alpha + \frac{\pi}{3}\right)}$$



Typical waveform with R-load

AC chopper: RL-Load

- For L-Load (R = 0 Ω)

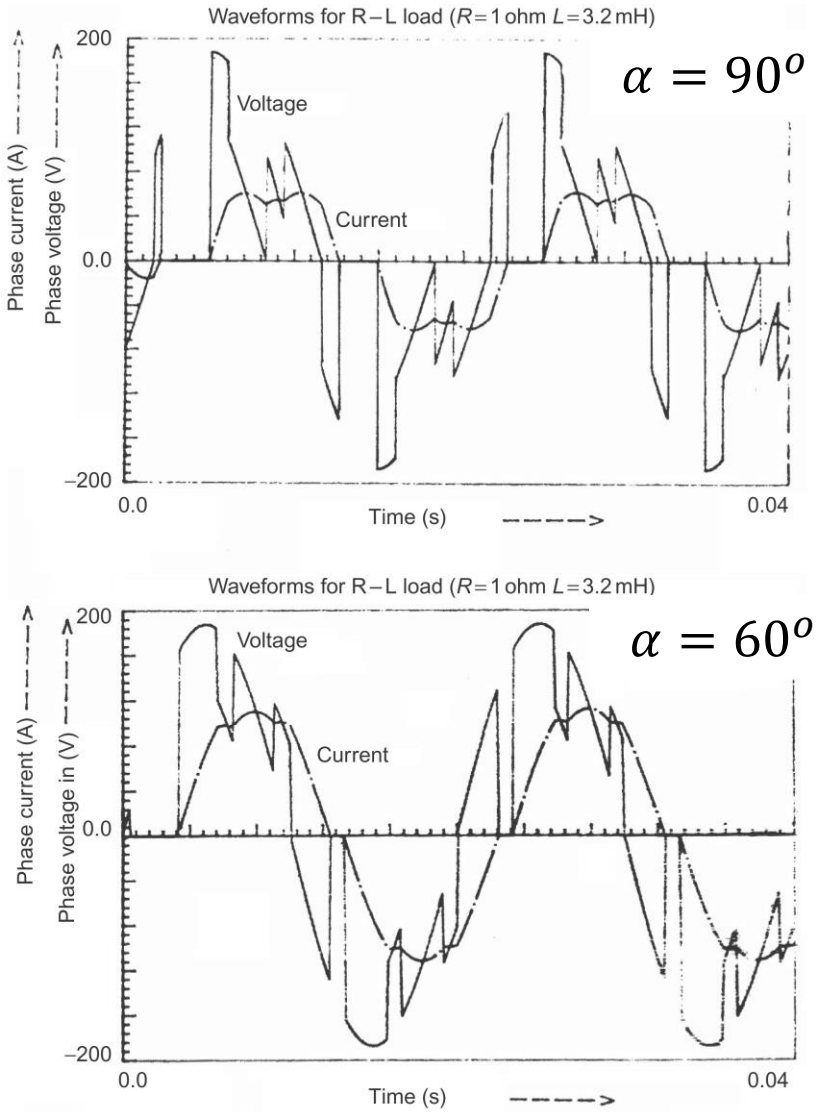
» $90^o < \alpha < 120^o$

$$V_o = V_s\sqrt{\frac{5}{2} - \frac{3\alpha}{\pi} + \frac{3}{2\pi}\sin 2\alpha}$$

» $120^o < \alpha < 150^o$

$$V_o = V_s\sqrt{\frac{5}{2} - \frac{3\alpha}{\pi} + \frac{3}{2\pi}\sin\left(2\alpha + \frac{\pi}{3}\right)}$$

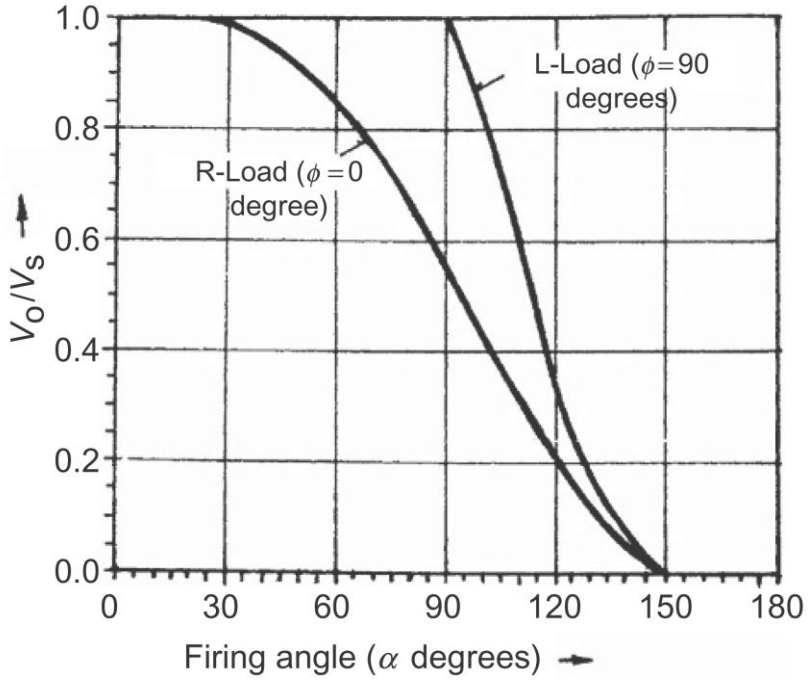
- For RL Load, analysis is complicated



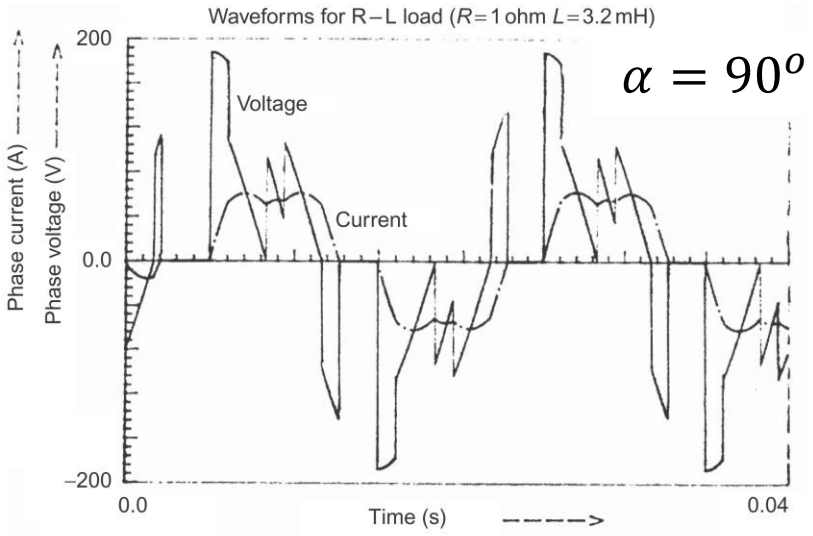
Typical waveform with R-load

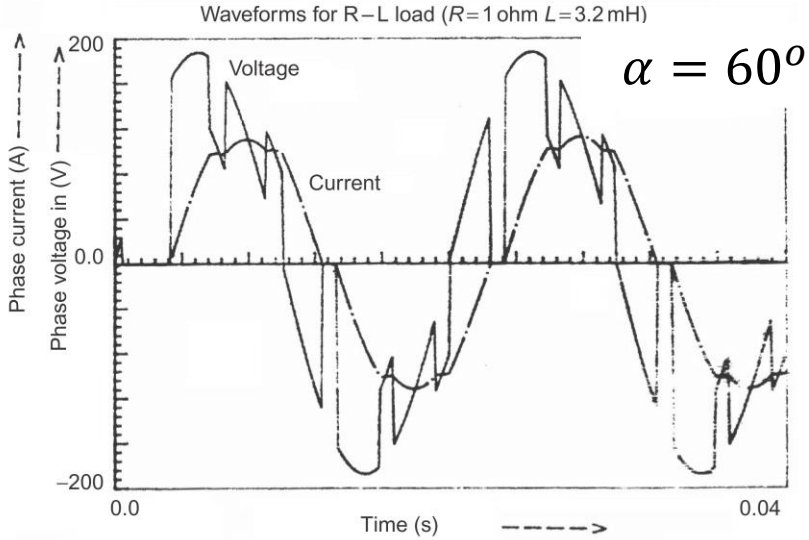
AC chopper: RL-Load

- Control range of three-phase AC chopper



Control range with various types of load

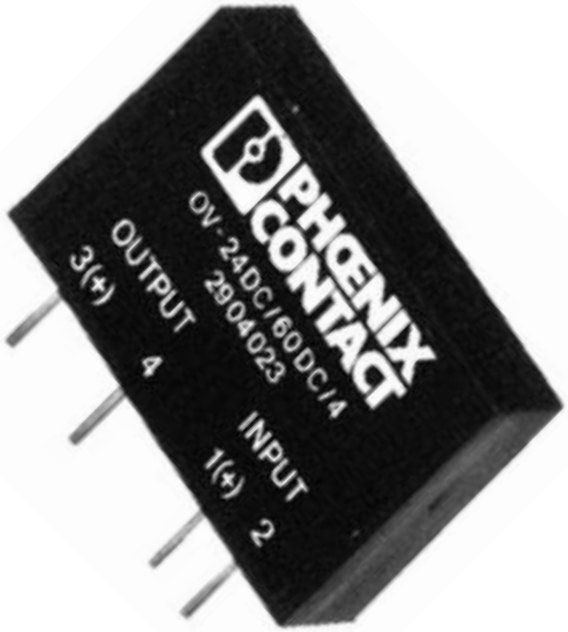




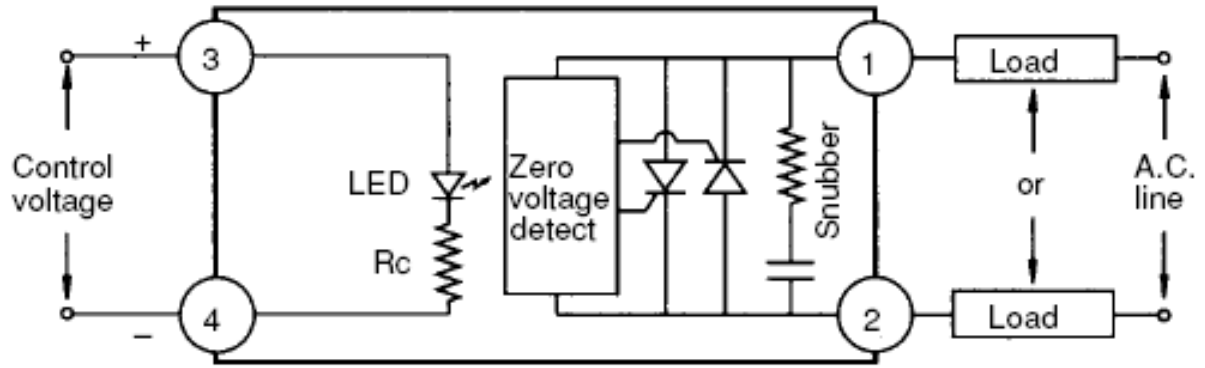
Typical waveform with RL-load

AC chopper: Application

SSR: Solid state relay

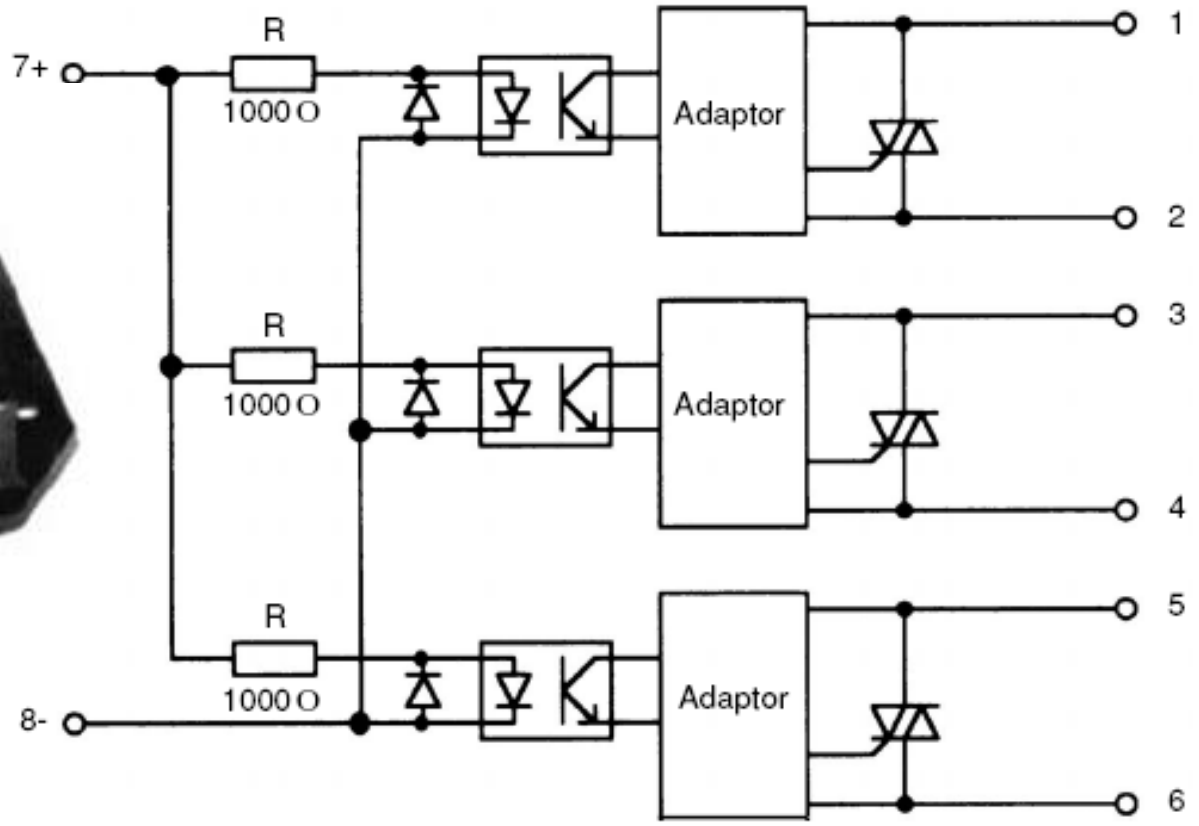


Single-phase SSR



AC chopper: Application

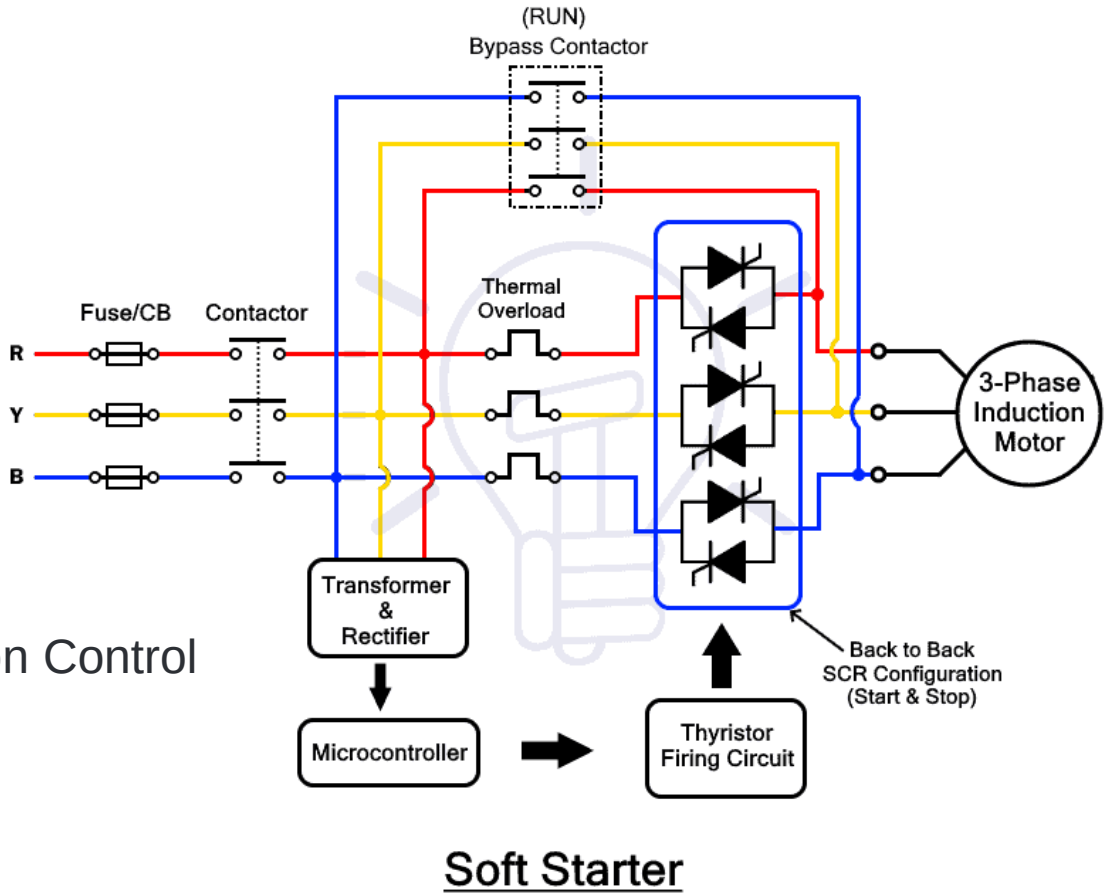
SSR: Solid state relay



Three-phase SSR

AC chopper: Application

Soft-Starter



Soft Starter

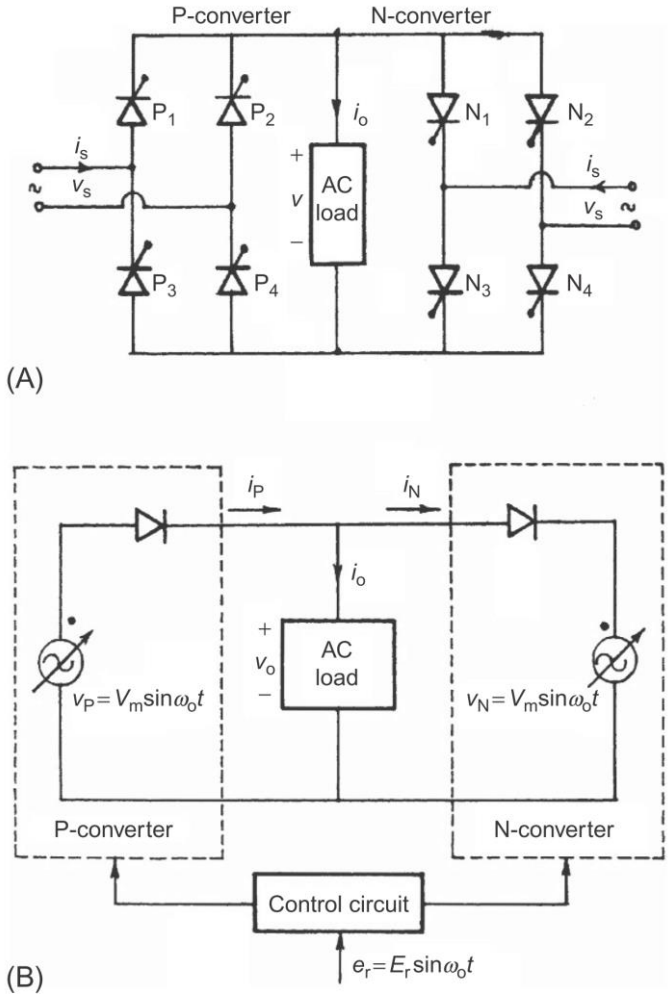
- Smooth Startup
- Acceleration & Deceleration Control
- No Power Surges

Applications

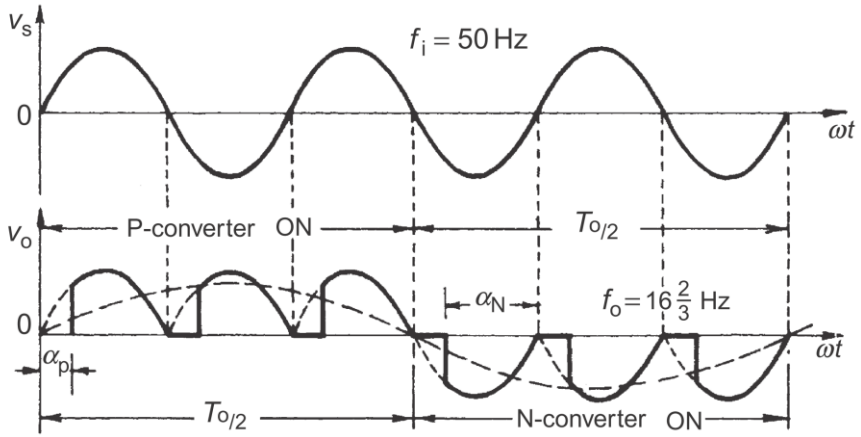
- Fans
- Conveyer belts
- Motors using belt & pulleys
- Water or liquid Pump

Cycloconverters

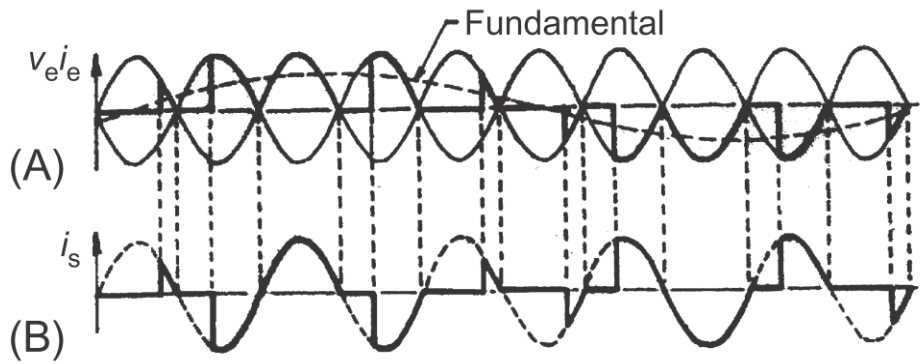
- Single phase Cycloconverters



Structure and equivalent circuit



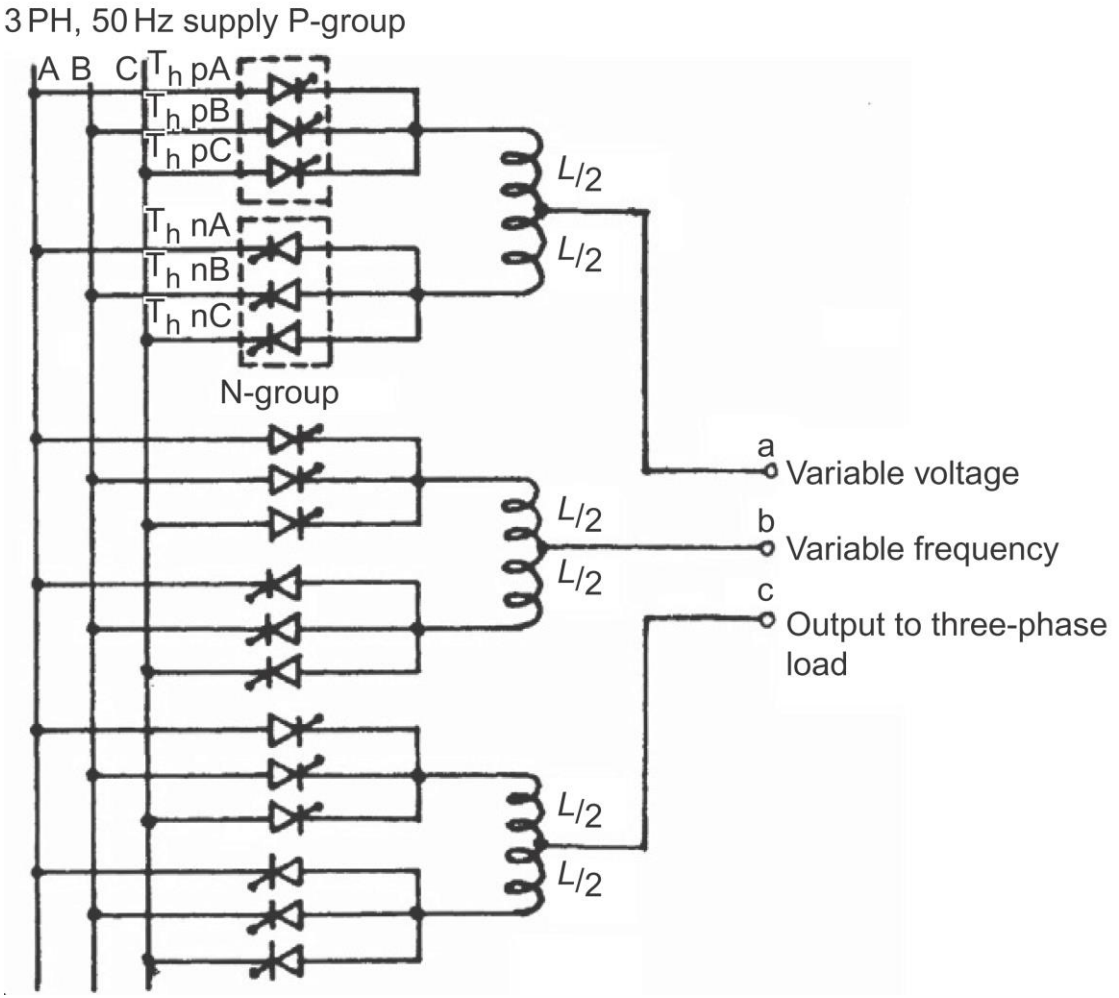
50 Hz to 16 $^{2}/_{3}$ Hz conversion



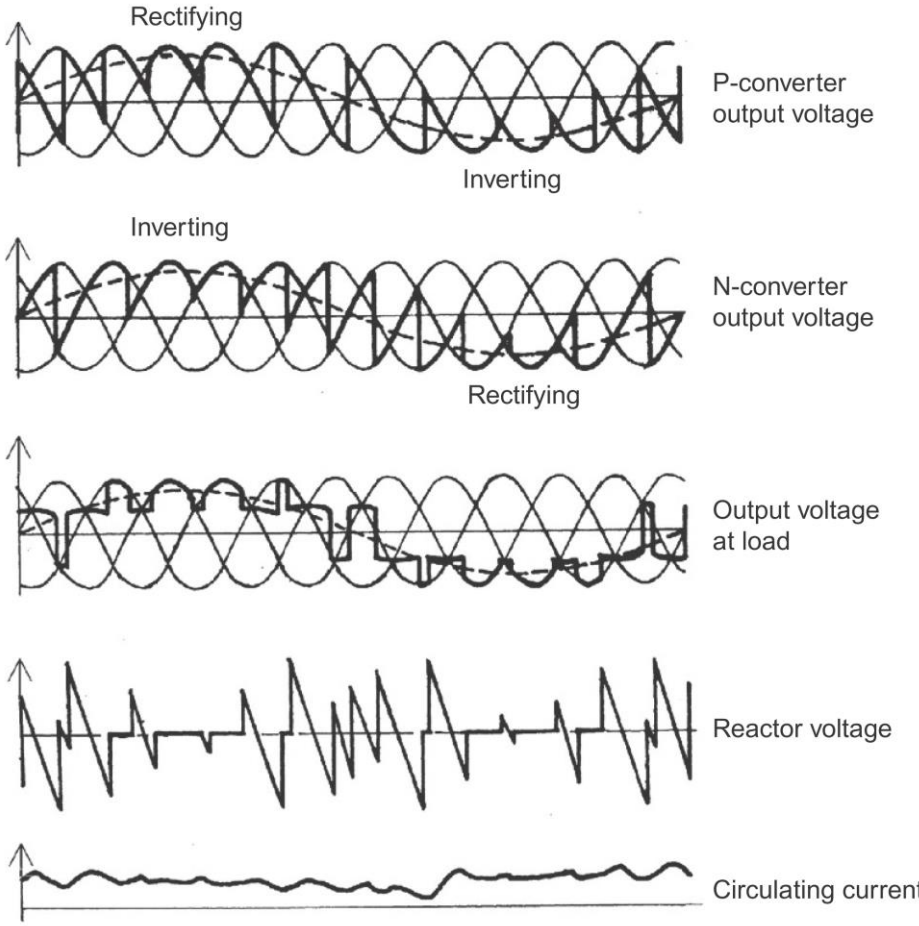
50 Hz to 10 Hz conversion

Cycloconverters

- Three phase Cycloconverters



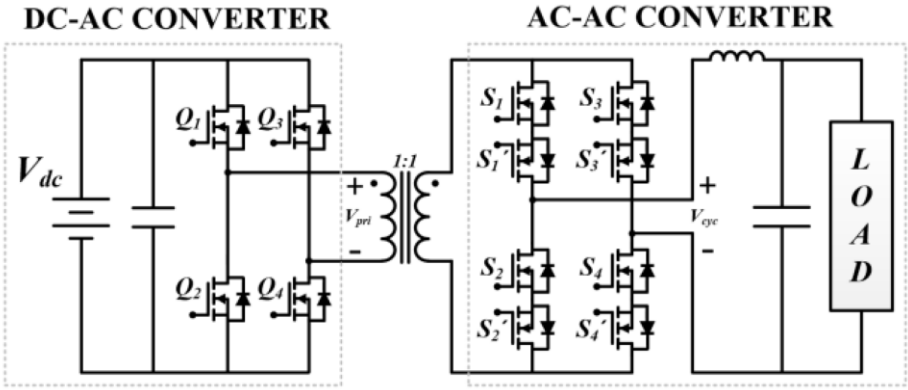
Structure



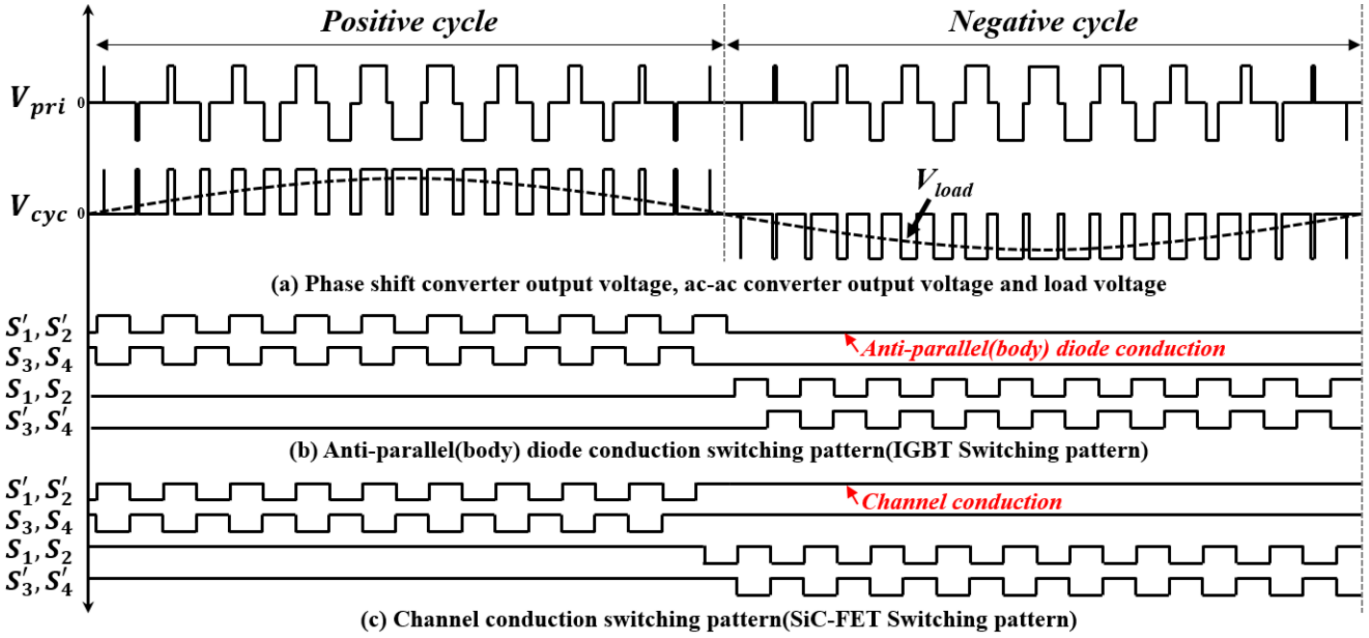
Typical waveforms

High frequency cycloconverter

- High frequency input from transformer
- SPWM is done in the primary side



Cyclo-inverter

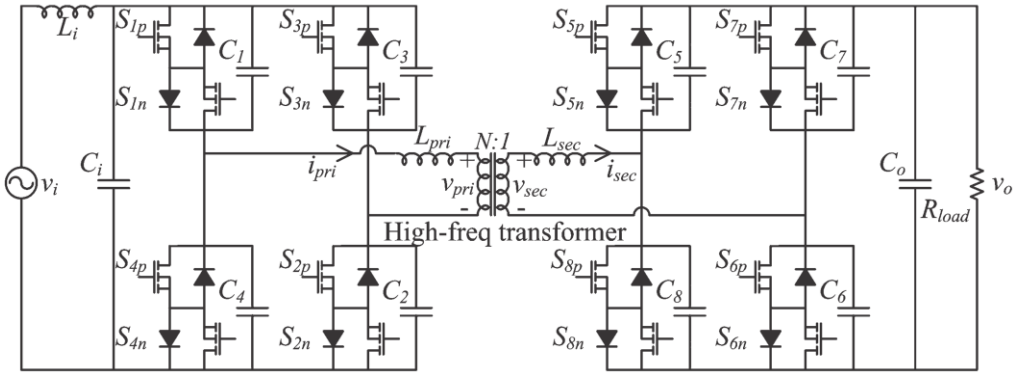


Typical waveforms

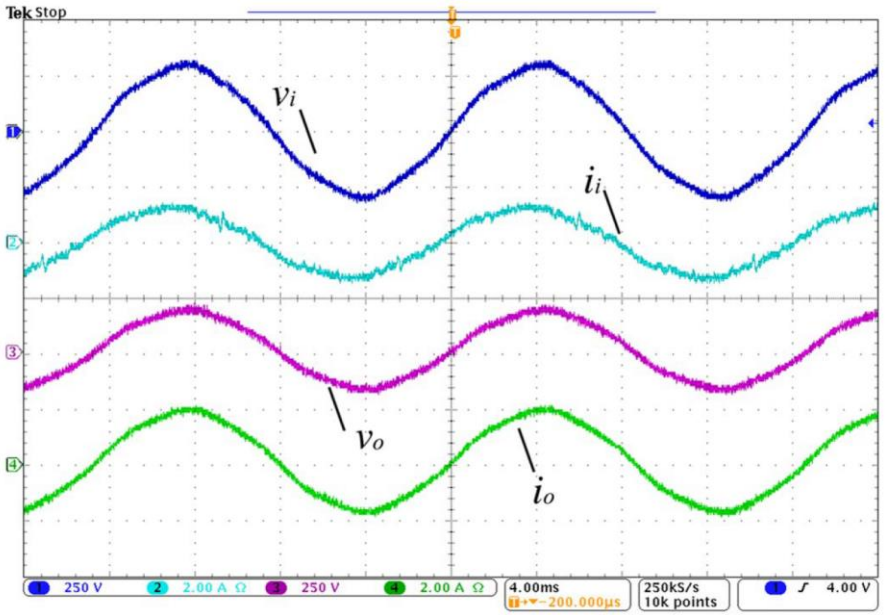
(*) Kim, J.K., Kim, S.G. and Park, S.M., 2019, October. Analysis of Switch Losses in Cycloconverter-Type High Frequency Link Converter for Bidirectional Battery Chargers. In *2019 IEEE Vehicle Power and Propulsion Conference (VPPC)* (pp. 1-6). IEEE.

Dual-Active-Bridge AC/AC converters

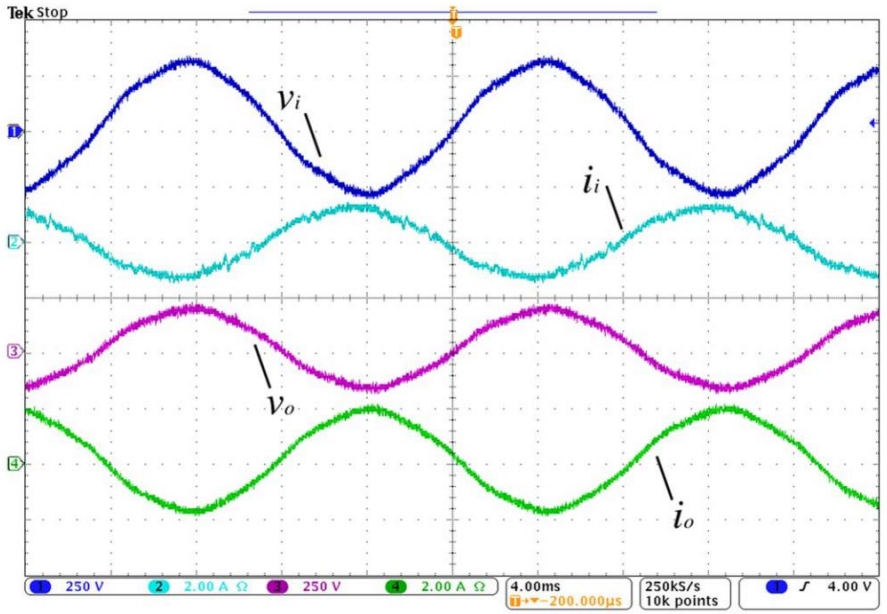
- Bidirectional switches
- High-frequency transformer
- Phase-shift modulation



DAB AC/AC converter



Forward mode

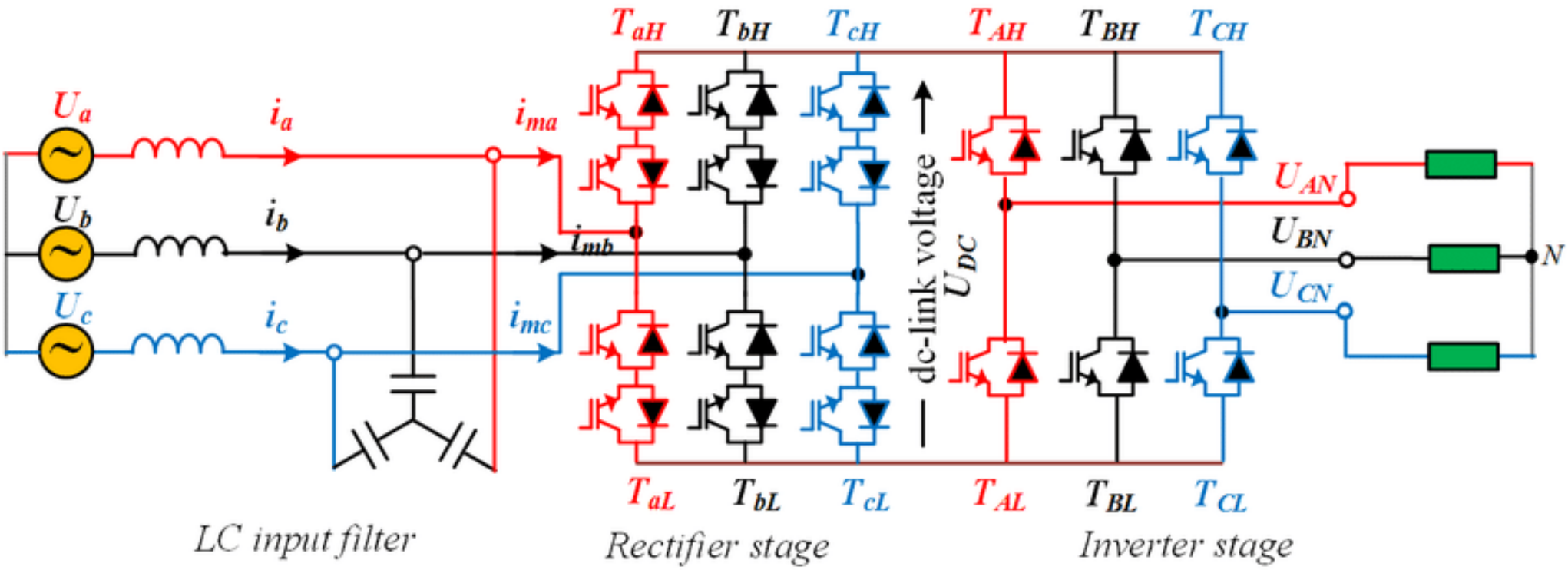


Reverse mode

(*) Qin, H. and Kimball, J.W., 2012. Solid-state transformer architecture using AC–AC dual-active-bridge converter. IEEE Transactions on Industrial Electronics, 60(9), pp.3720-3730.

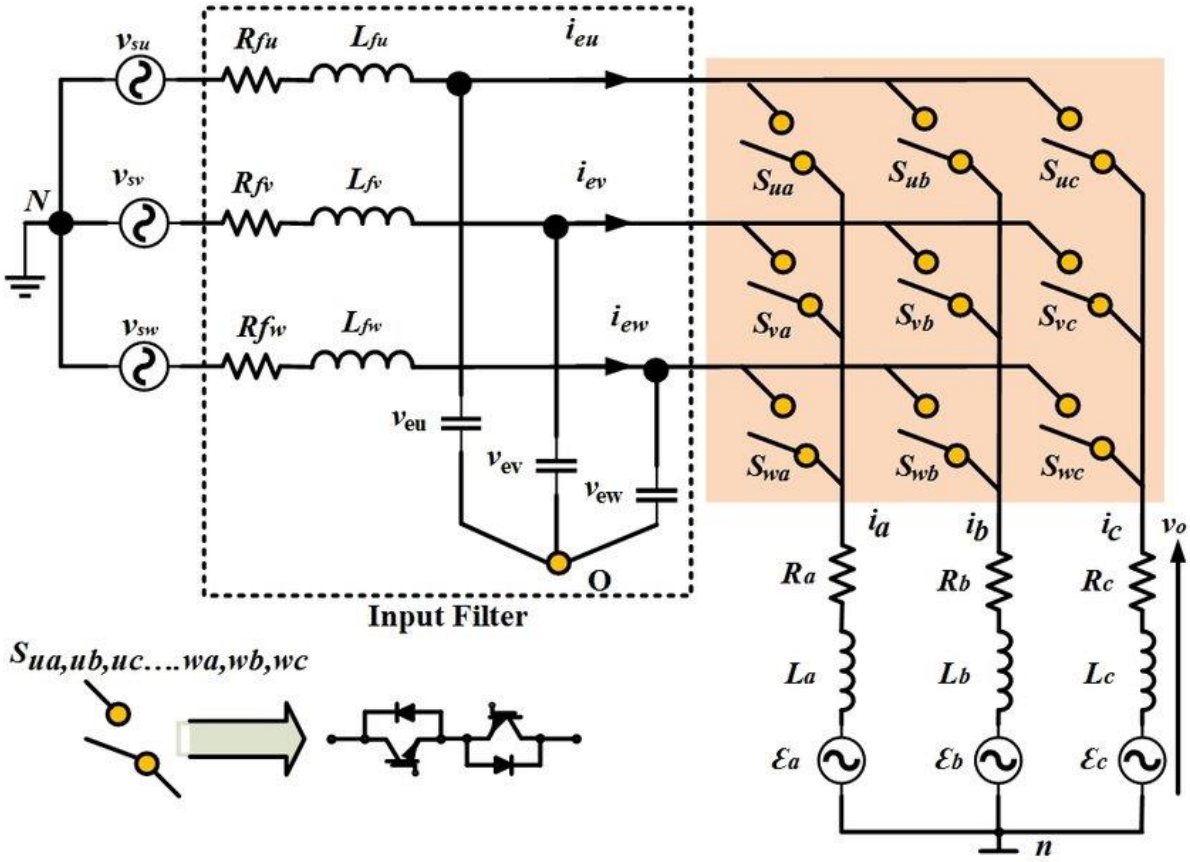
Matrix converters

- Indirect matrix converters
- There is a “virtual” DC bus
- Capacitor-free



Matrix converters

- Direct matrix converters
- Direct AC/AC conversion
- NO DC-bus at all
- Bidirectional switches
- Complicated switch selection table



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THANKS FOR ATTENTIONS