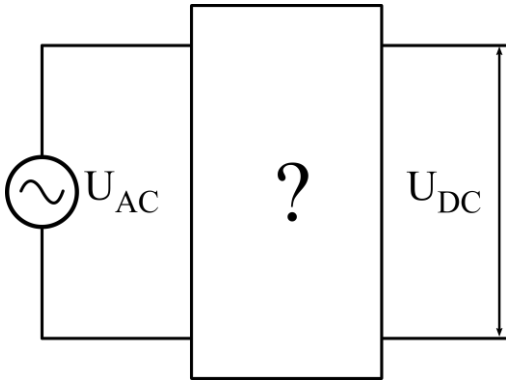
SINGLE-PHASE RECTIFIERS

- What are rectifiers?
- Types of rectifiers.
- Single-phase diode rectifiers.
- Single-phase thyristor rectifiers.

RECTIFIERS

What are rectifiers?



Rectifiers are devices that convert **AC** voltages/currents into **DC** voltages/currents.

Important note – they provide “either” small ΔU_{DC} “or” small ΔI_{DC}.

What is a DC and what is an AC variable?

Types of rectifiers:

Uncontrolled vs Controlled (vs Half/semi-controlled)

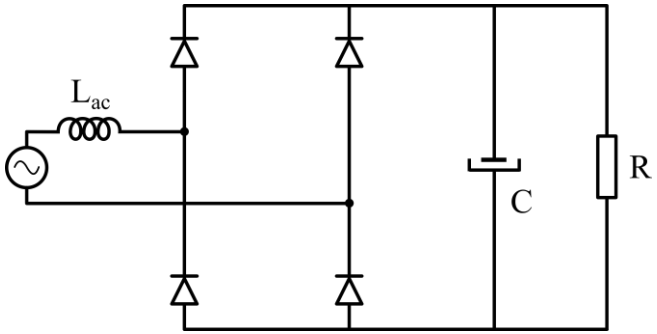
Single-phase vs Three-phase (vs Multi-phase)

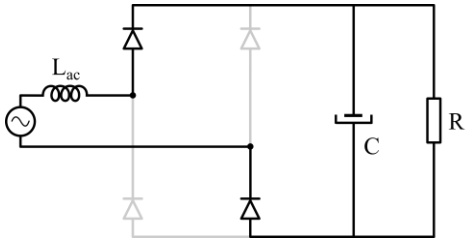
Half-wave vs Full-wave

Voltage multipliers

RECTIFIERS

Single-phase diode (uncontrolled) rectifier

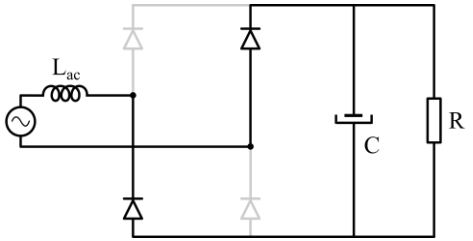




$U_{LDmax} = \sqrt{2} \cdot U_{AC} - 2 \cdot V_D$

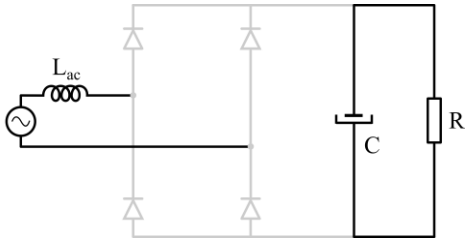
$u_{LD} = u_{AC} - 2 \cdot V_D$

$i_C = i_D - i_{LD} \quad i_{AC} = i_D$



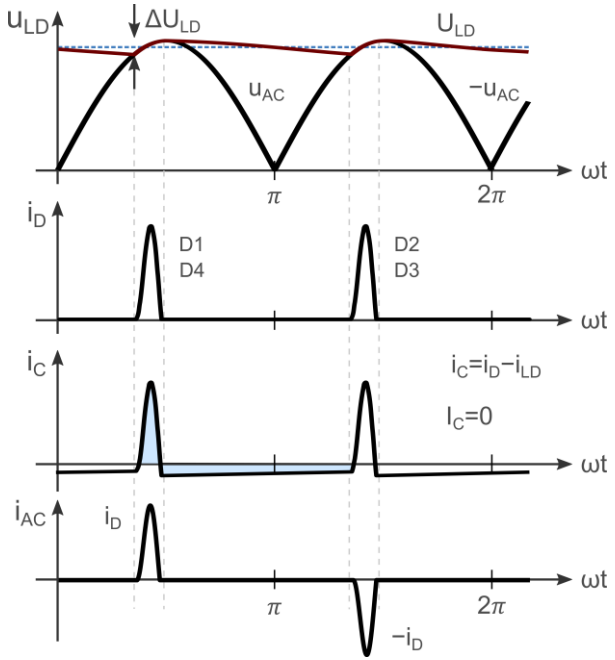
$U_{LDmax} = \sqrt{2} \cdot U_{AC} - 2 \cdot V_D$

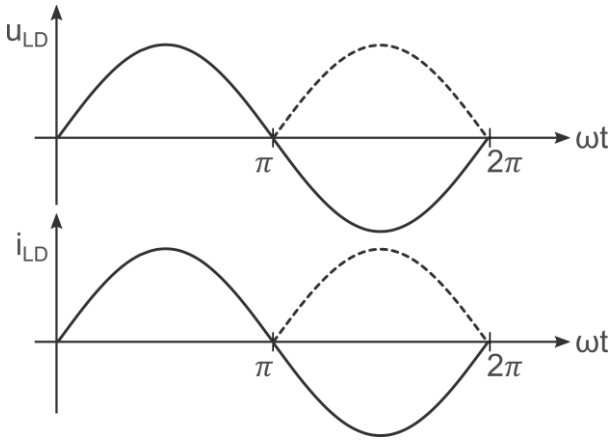
$i_C = i_D - i_{LD} \quad i_{AC} = - i_D$



$u_{DC} \approx U_{LDmax} \cdot e^{-\frac{\omega t - \frac{\pi}{2}}{\omega \cdot \tau}}, \tau = C \cdot R$

$i_C = - i_{LD} \quad i_{AC} = i_D = 0A$

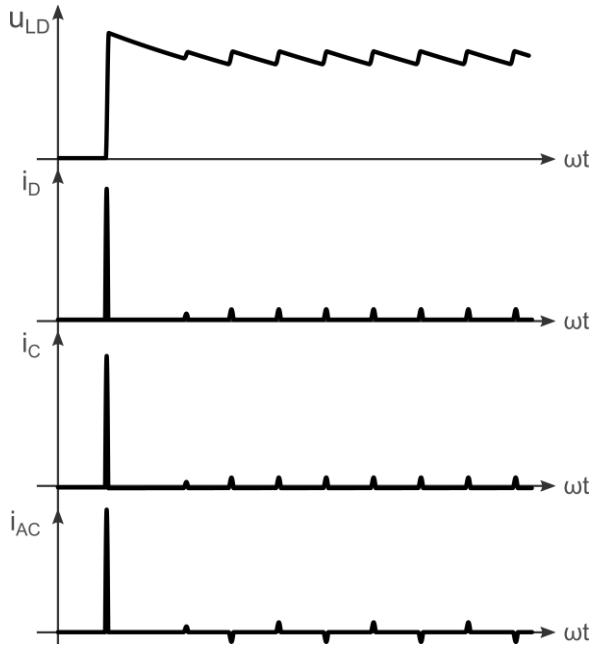


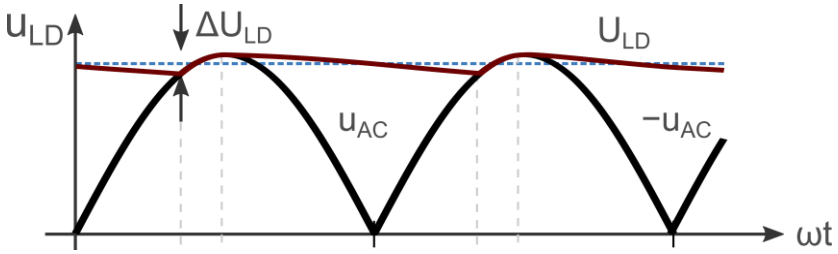


RECTIFIERS

Single-phase diode (uncontrolled) rectifier

Direct start with a discharged capacitor:





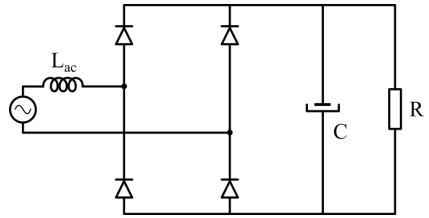
Capacitor sizing:

Assumption - $\Delta U_{LD} \ll U_{LD}$ $(\Delta U_{LD} \approx 0)$

=> $i_{LD} \approx I_{LD}$ and the discharge time is (whole) 10ms.

=> $\Delta U_{LDmax} = \frac{Q}{C} = \frac{I_{LD} \cdot 10ms}{C}$ or $C = \frac{I_{LD} \cdot 10ms}{\Delta U_{LDmax}}$

Example:



$U_{AC} = 230V\ (50Hz),\ R = 150\Omega,\ C = 470\mu F$

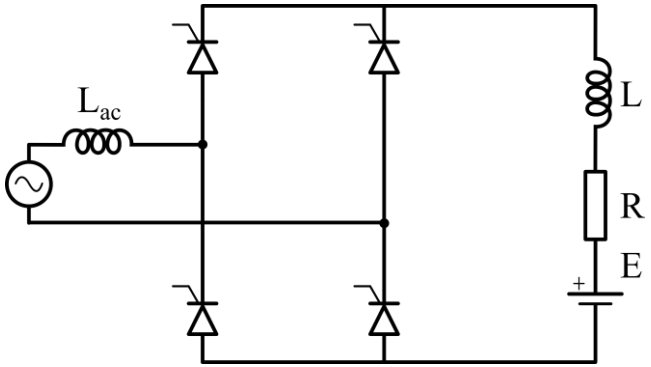
$U_{LDmax} = \sqrt{2} \cdot 230V = 325V$

$I_{LD} \approx \frac{U_{LDmax}}{R} = \frac{325V}{150\Omega} = 2{,}17A$

$\Delta U_{LD} = \frac{2{,}17 \cdot 10m}{470\mu} = 46V$

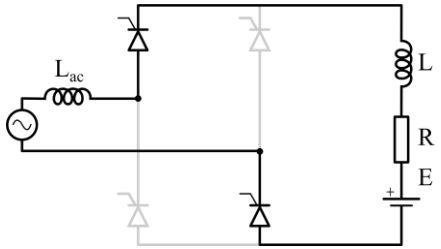
RECTIFIERS

Single-phase thyristor (controlled) rectifier

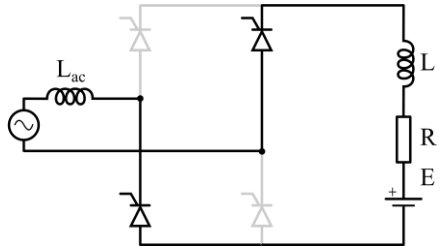


$L >> L_{ac}$ => u_{LAC} <<

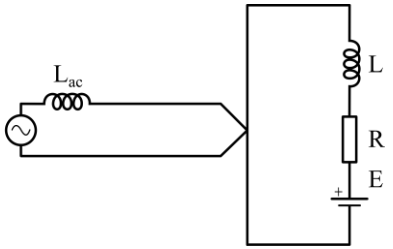
$u_{LD} \approx u_{AC}$ $i_{AC} = i_{LD}$

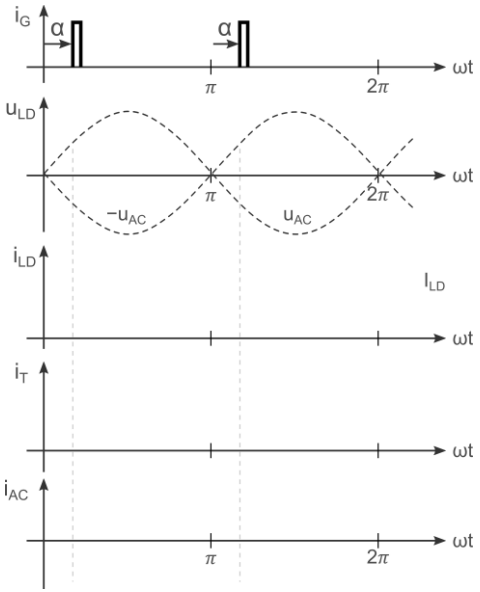


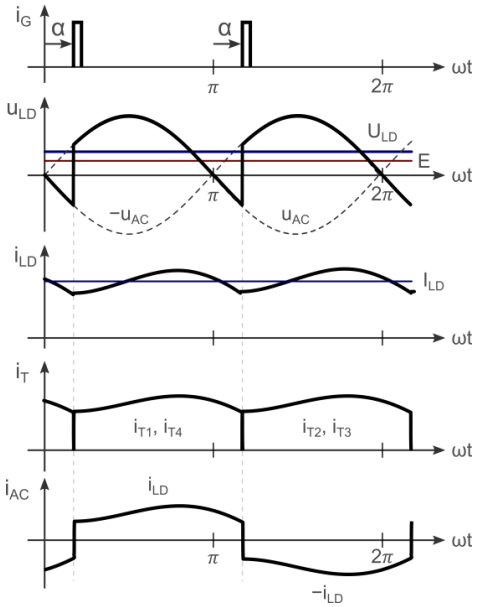
$u_{LD} \approx - u_{AC}$ $i_{AC} = - i_{LD}$

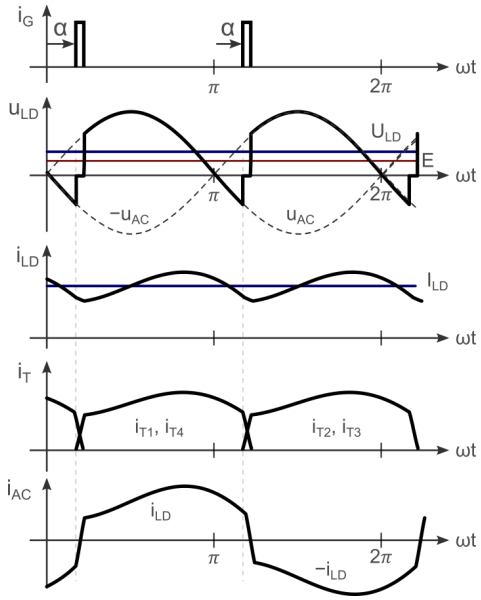


$u_{LD} = 0V$





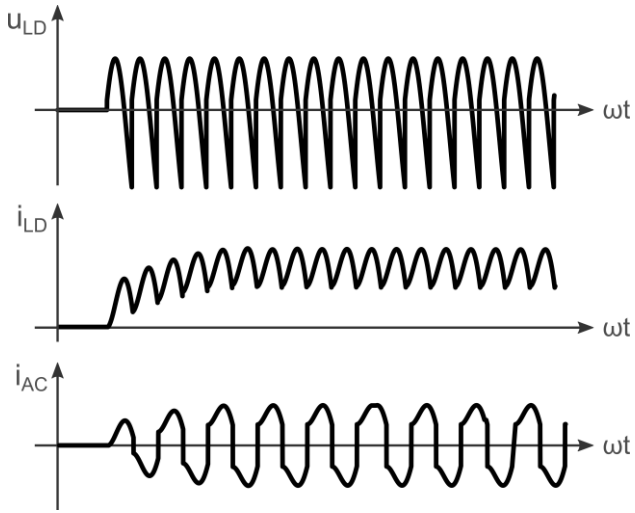


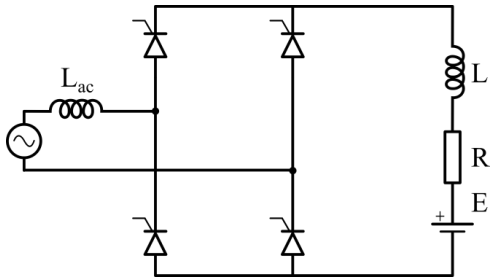


RECTIFIERS

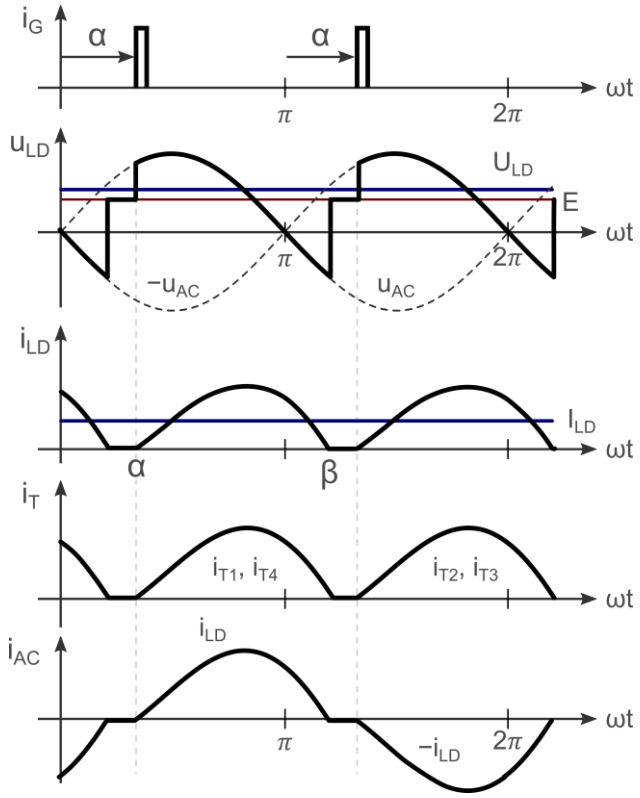
Single-phase thyristor (controlled) rectifier

Direct start:

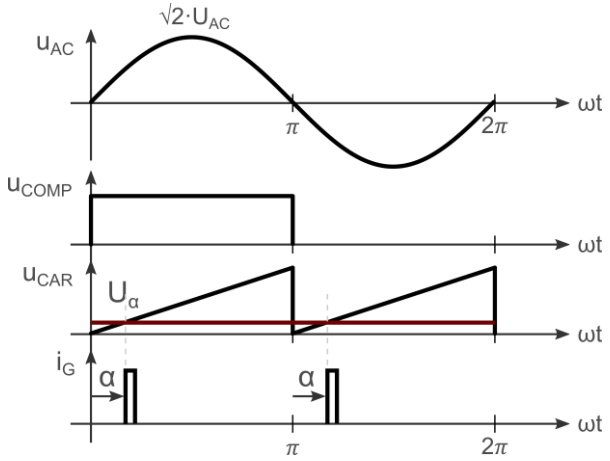




Discontinuous i_{LD}:



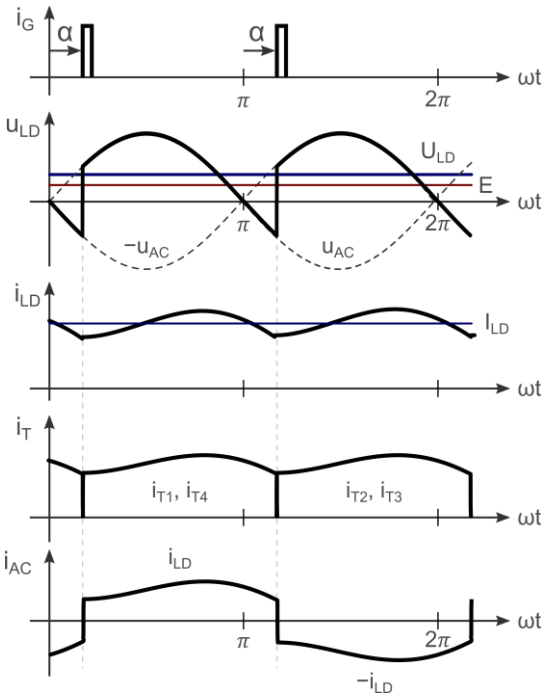
Synchronization:



RECTIFIERS

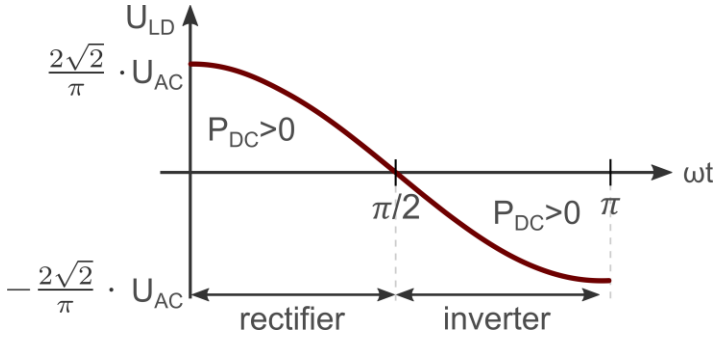
Single-phase thyristor (controlled) rectifier

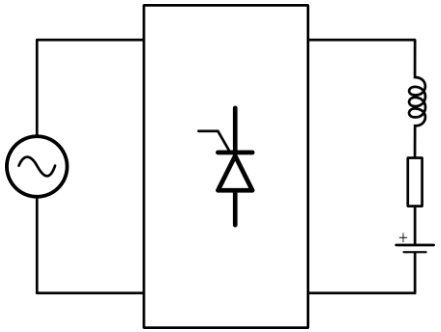
Continuous conduction mode (continuous i_{LD}):

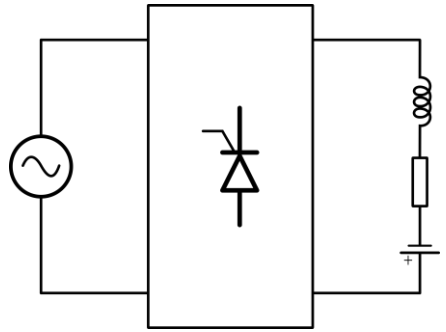


Average load voltage (U_{LD}):

Average load current (I_{LD}):







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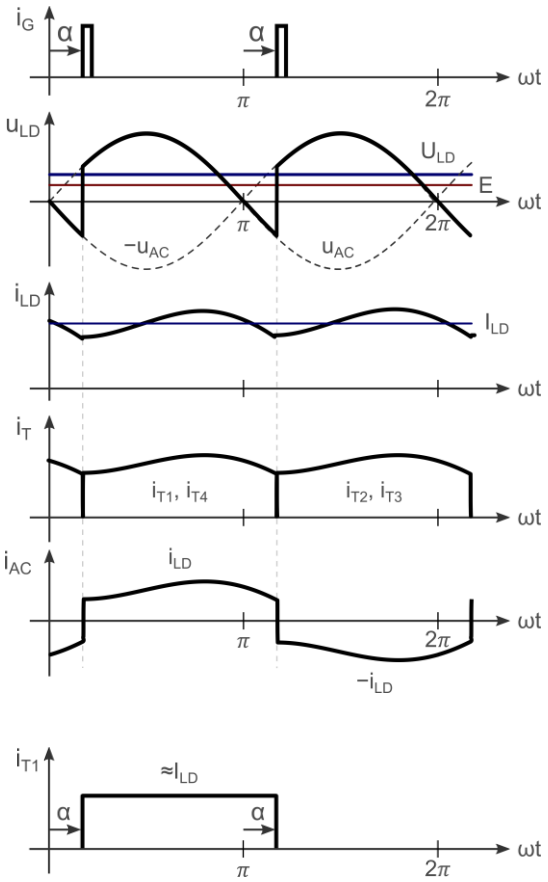
Single-phase thyristor (controlled) rectifier

Continuous conduction mode (continuous i_{LD}):



$U_{AC} = 230V\ (50Hz),\ R = 5\Omega,$

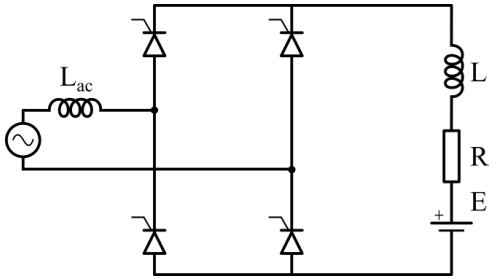
$L = 100mH,\ E = 129{,}3V$

Average load voltage - example:

$$U_{LD} = \frac{2\sqrt{2}}{\pi} \cdot U_{AC} \cdot cos\alpha = \frac{2\sqrt{2}}{\pi} \cdot 230 \cdot \cos\left(\frac{\pi}{6}\right) = 179{,}3V$$

Average load current – example:

$$I_{LD} = \frac{U_{LD} - E}{R} = \frac{179{,}3 - 129{,}3}{5} = 10A$$

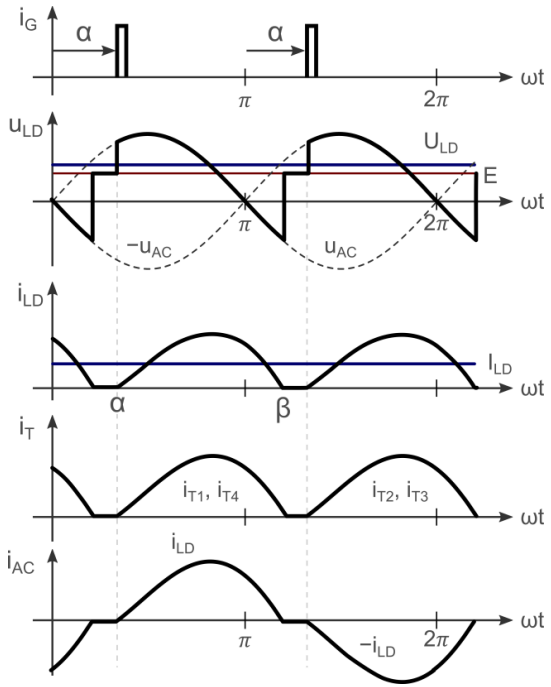


Choose thyristors:

RECTIFIERS

Single-phase thyristor (controlled) rectifier

Discontinuous conduction mode (discontinuous i_{LD}):



Average load voltage (U_{LD}):

$$U_{LD} = \frac{1}{\pi}\left[\int_{\alpha}^{\beta} \sqrt{2} \cdot U_{AC} \cdot \sin(\omega t) \cdot d(\omega t) + \int_{\beta}^{\pi+\alpha} E \cdot d(\omega t)\right]$$

$$= \frac{\sqrt{2} \cdot U_{AC}}{\pi} \cdot [cos\alpha - cos\beta] + E \cdot \frac{\pi + \alpha - \beta}{\pi}$$

Load current (i_{LD}):

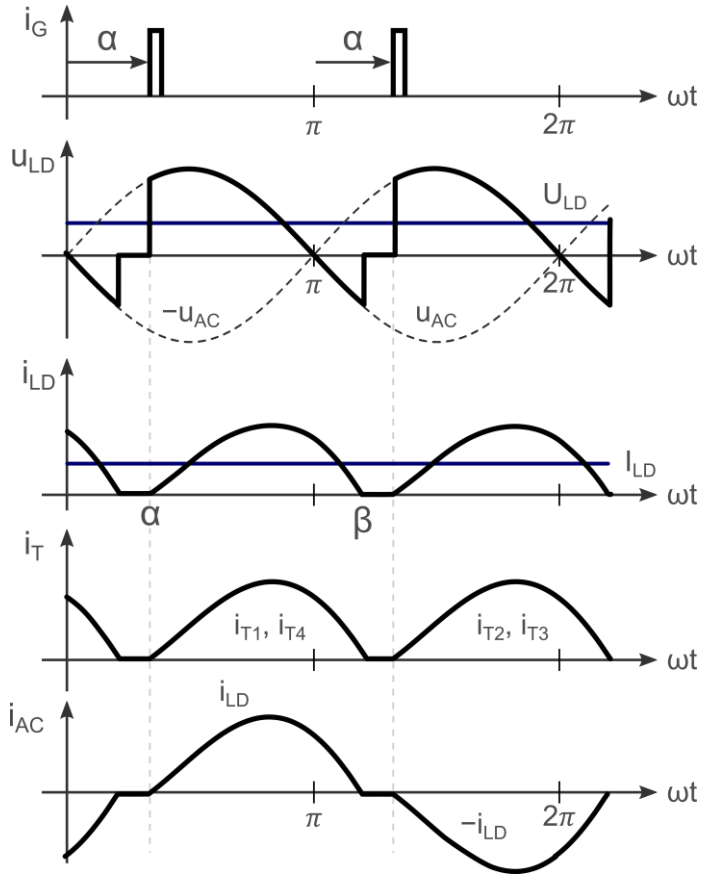
$$i_{LD} = A \cdot \sin(\omega t - \varphi) + B \cdot e^{-\frac{\omega t - \alpha}{\omega \tau}} + C$$

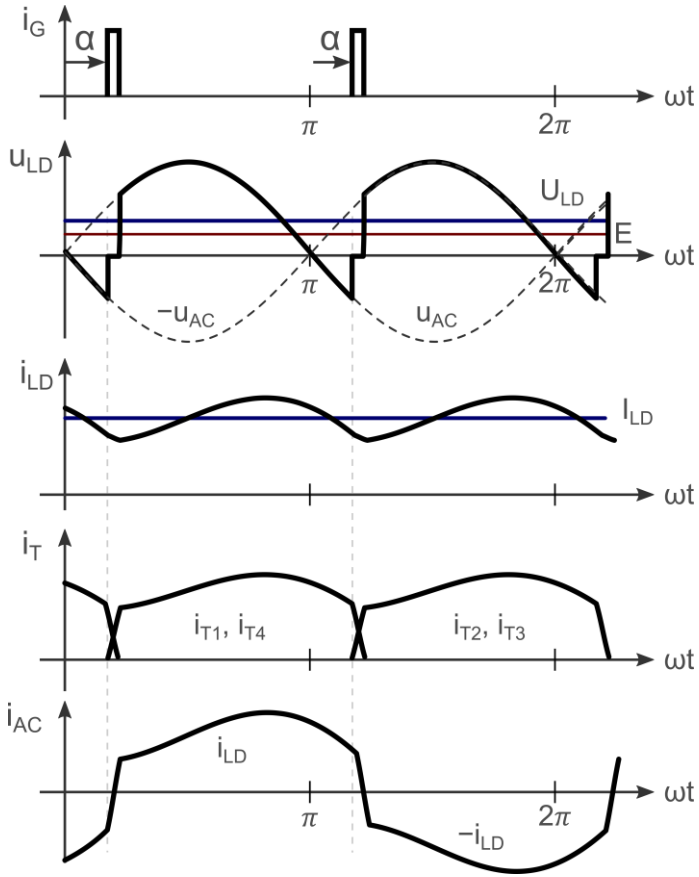
$$i_{LD}(\beta) = 0 \implies 0 = A \cdot \sin(\beta - \varphi) + B \cdot e^{-\frac{\beta - \alpha}{\omega \tau}} + C$$

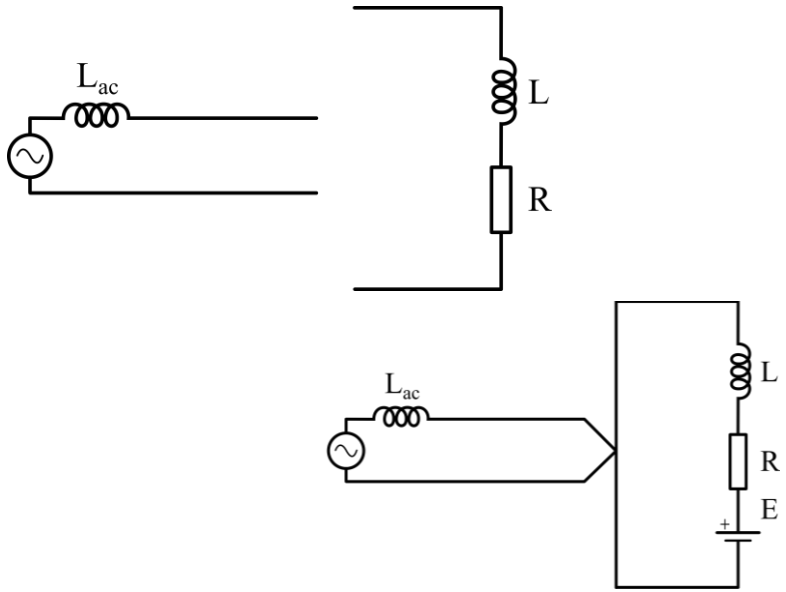
RECTIFIERS

Single-phase thyristor (controlled) rectifier

Discontinuous conduction mode
(discontinuous i_{LD}):

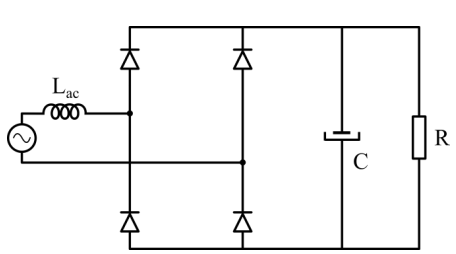


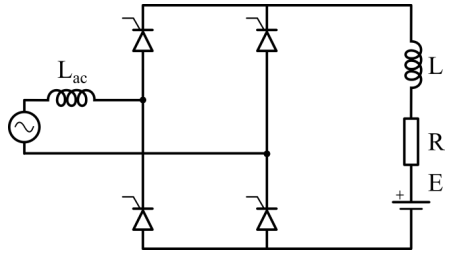




RECTIFIERS

Single-phase rectifiers - important notes





- There are controlled and uncontrolled rectifiers,
- Filtering is extensively used,
- Filters influence the semiconductor devices conduction times,
- Diode bridge secures output voltage with small ripple,
- Thyristor bridge secures output current with small ripple,
- They drive different types of load,
- Load current can be discontinuous in thyristor bridges,
- Thyristor bridges necessitate synchronization unit,
- Comutation is process of importance for thyristor bridges,
- For continuous load current, the thyristor bridge can behave both as a rectifies and as an inverter (depending on firing angle).