

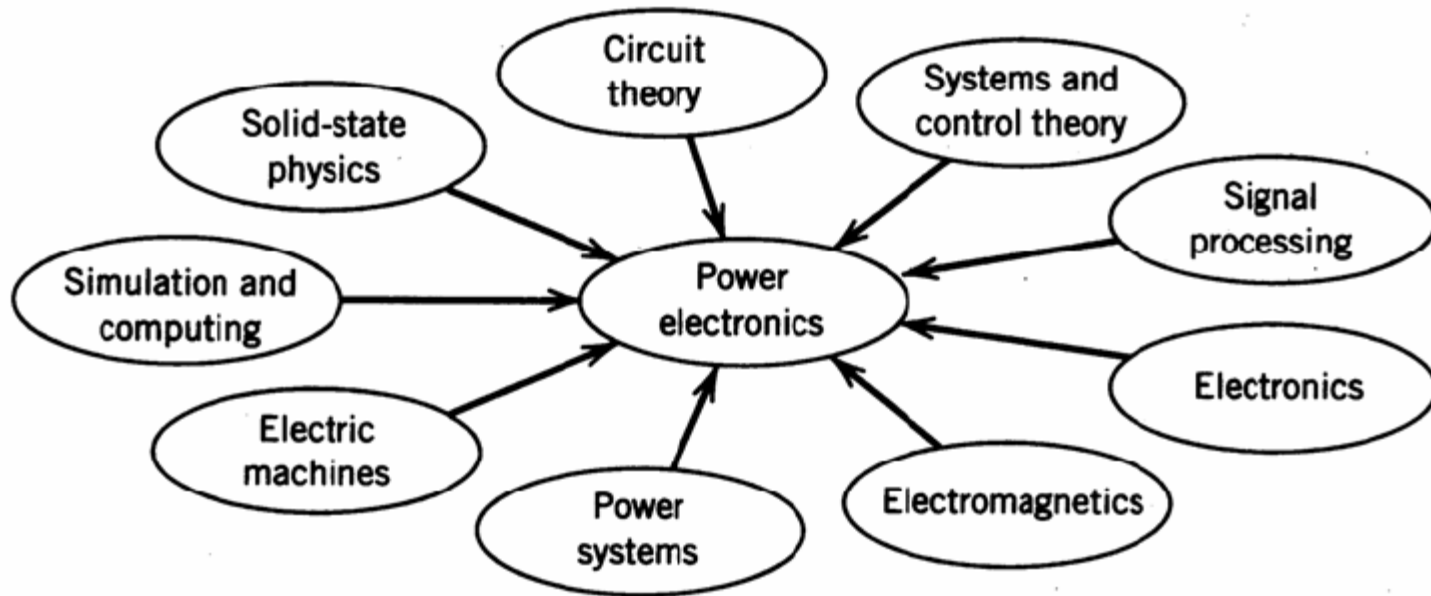
## CHAPTER SIX

### Power Electronic Systems

#### Learning outcomes

- Learn the basic concept of power semiconductor devices
- Name the main components in AC to DC power supply and explain the purpose and function of each.
- List the principal semiconductor devices used in power electronic systems
- Define rectifier and name two common types.
- Describe the converter that transforms constant DC into pulsating DC.
- Define ripple and identify its origins
- Describe single inverter circuits and explain different topologies.
- Learn the basic concept operation of typical power converter circuits

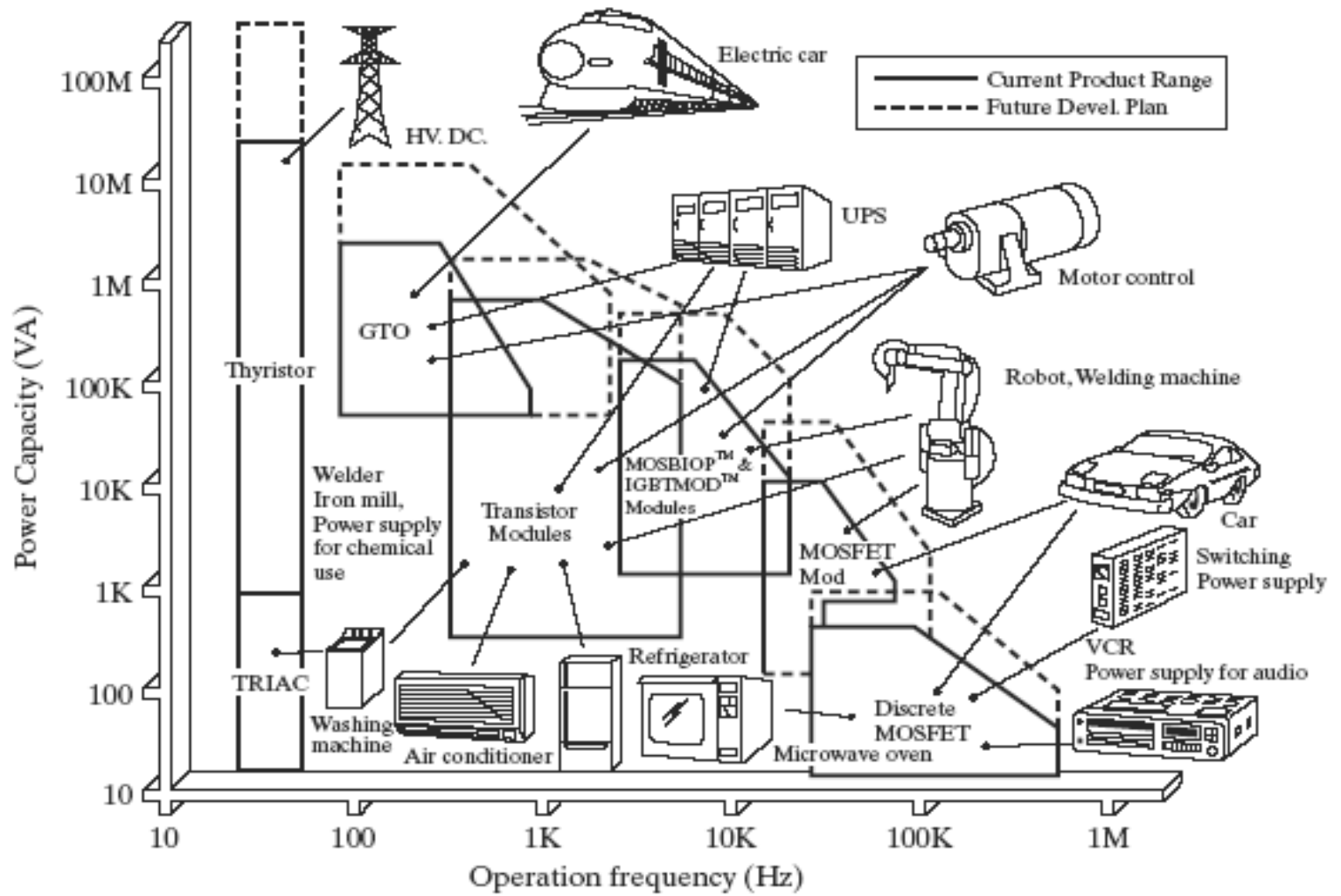
# Interdisciplinary Nature of Power Electronics



# Applications

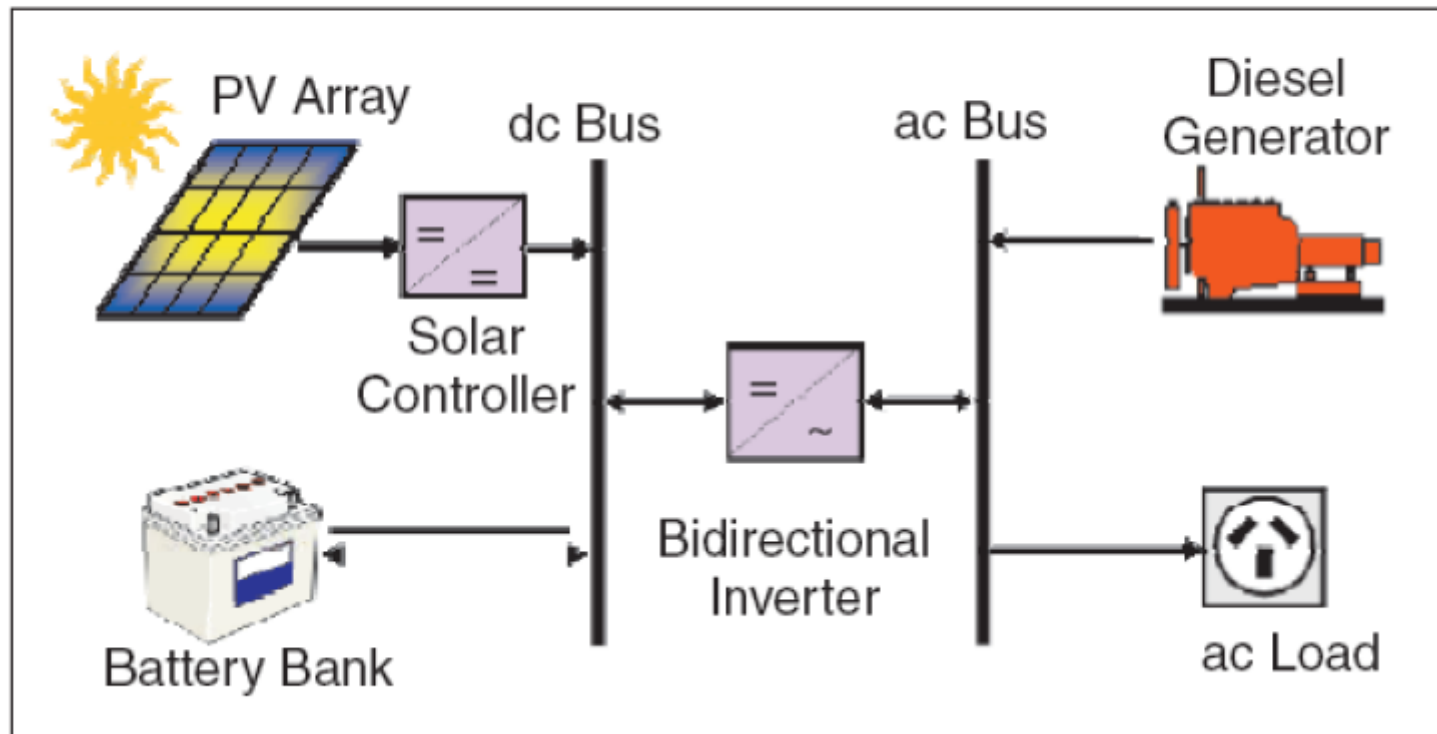
- Heating and lighting control
- Induction heating
- Uninterruptible power supplies (UPS)
- Fluorescent lamp ballasts: Passive; Active
- Electric power transmission
- Automotive electronics
- Electronic ignitions
- Motor drives
- Battery chargers
- Alternators
- Energy storage
- Electric vehicles
- Alternative power sources: Solar; Wind; Fuel Cells

# Applications of Power Devices

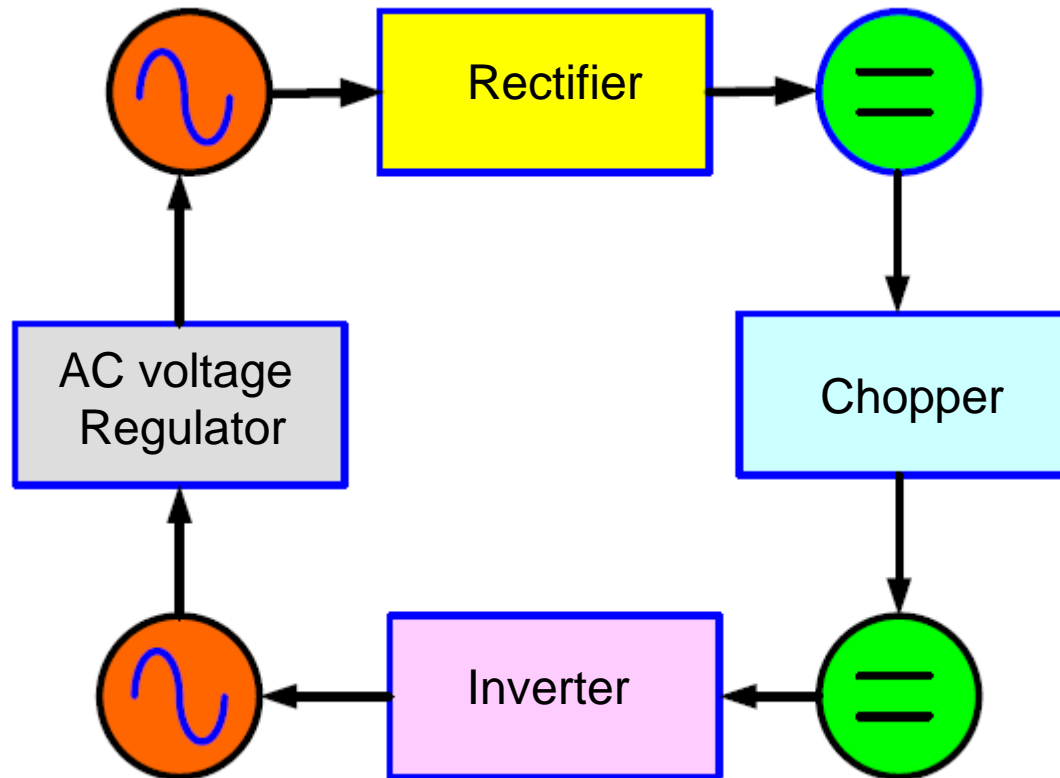


# Example

## Photovoltaics



# Diagram Block of Converters

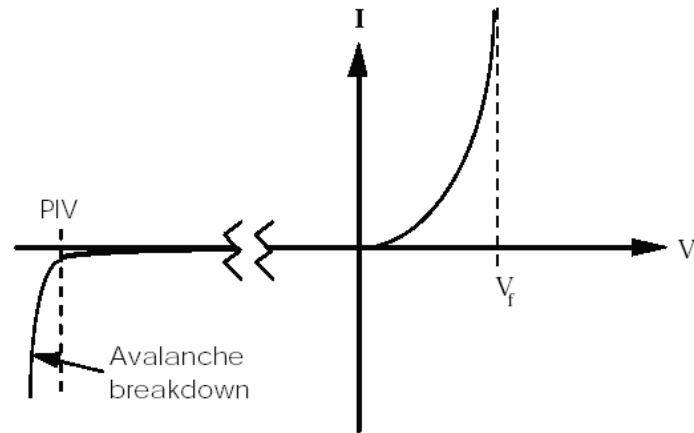


Silicon Controlled Rectifiers (SCR)

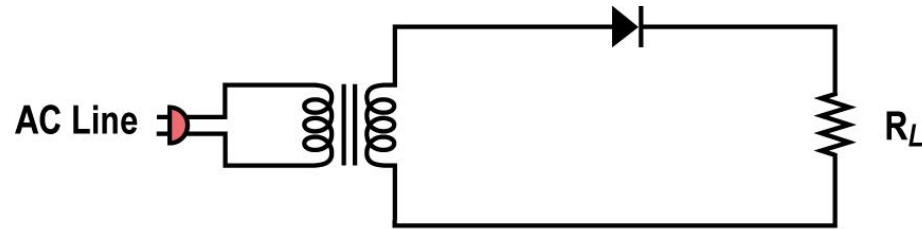
# Thyristors



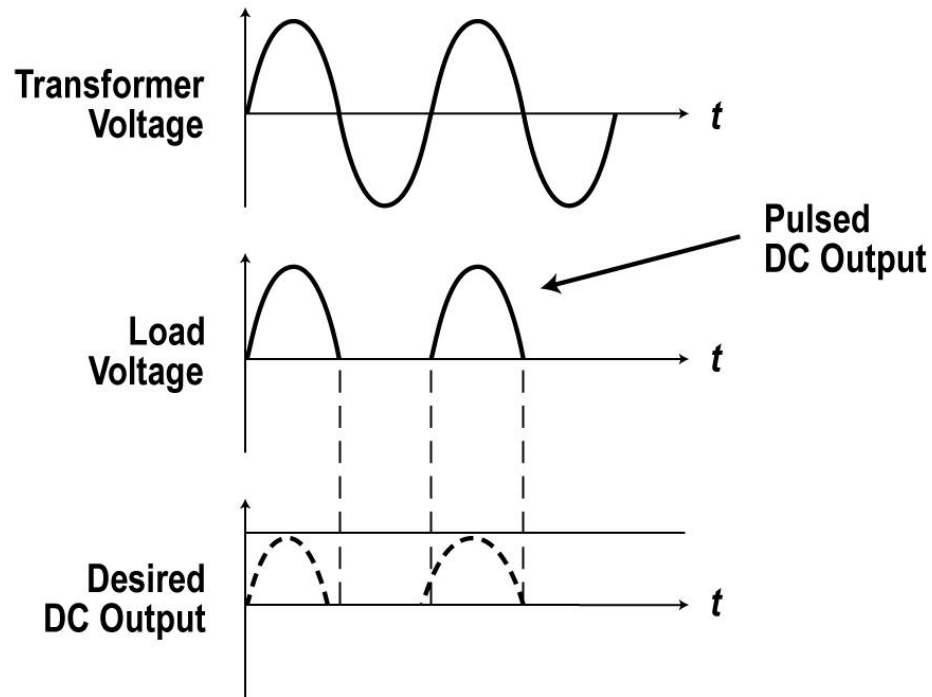
# Diodes



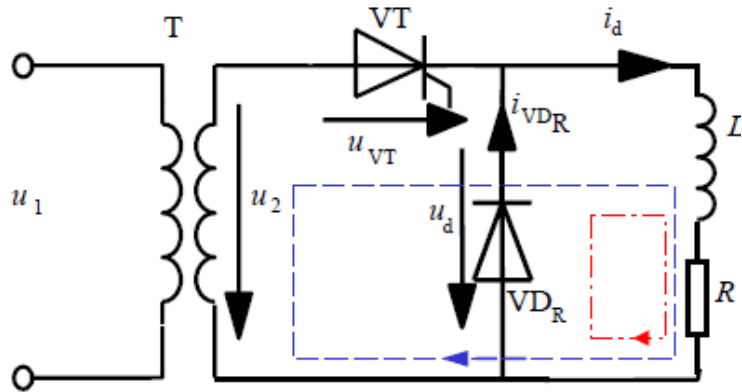
# AC to DC Conversion: Half-Wave Rectifier



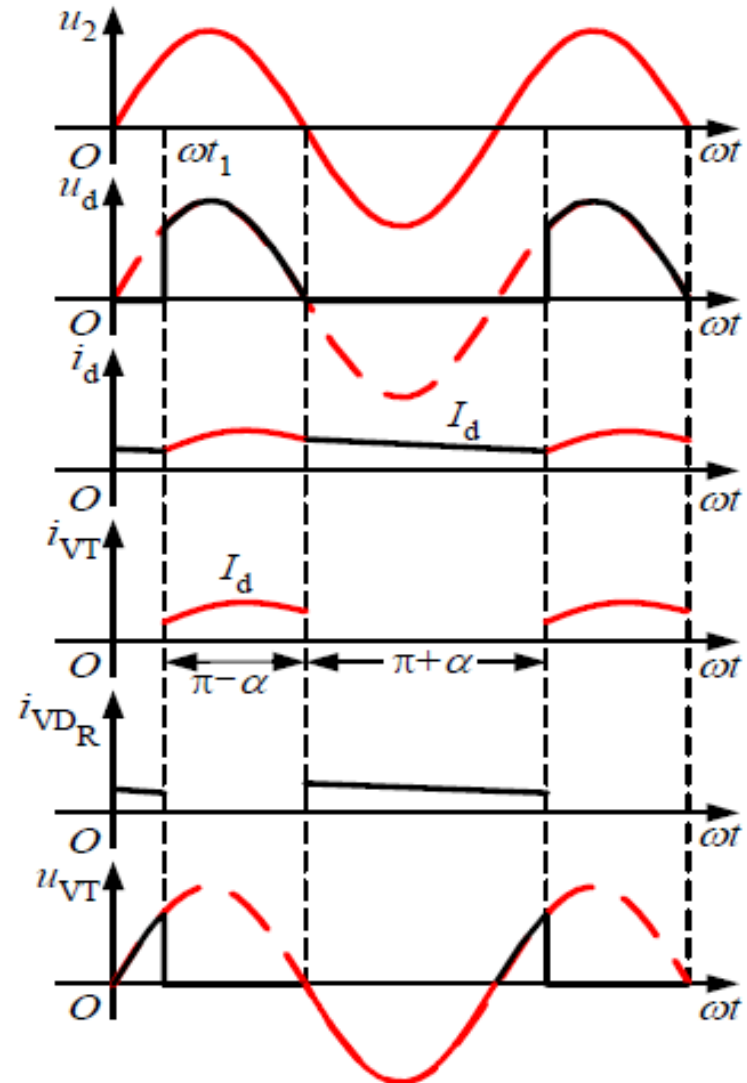
$$V_{0(average)} = \frac{V_m}{\pi}$$



## AC-DC Converter Half-Wave Rectifier



$$V_{DC} = \frac{V_m}{2\pi} (1 + \cos \alpha)$$



## Exercise

A single phase half wave controlled rectifier circuit has a **free wheeling diode**. The load is a combination of R and L. The firing angle is  $\alpha$ . The period of conduction of SCR and free wheeling diode respectively are:

A.  $\alpha < \theta < \pi$  and  $\pi < \theta < (2\pi + \alpha)$

B.  $\alpha < \theta < \pi$  and  $\pi < \theta < (2\pi)$

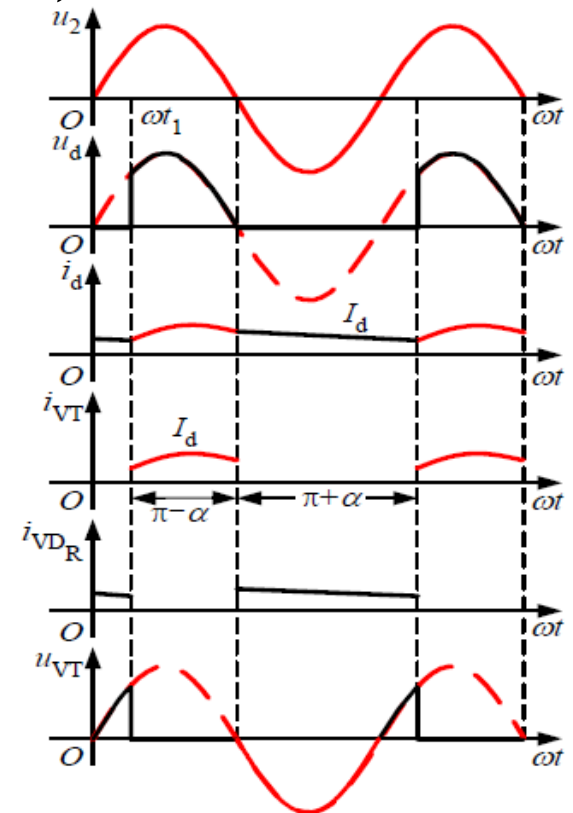
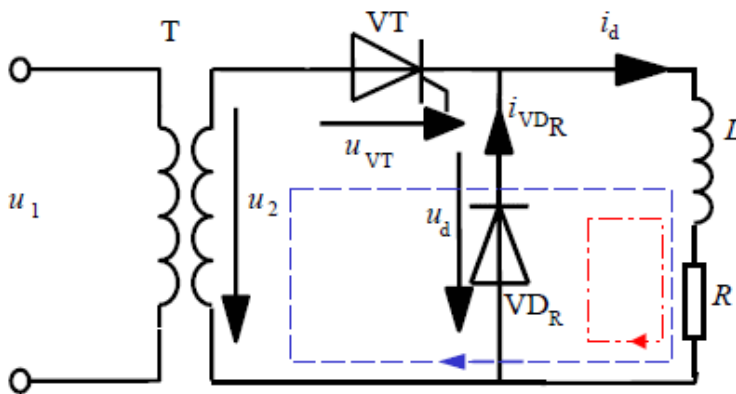
C.  $\alpha < \theta < (\pi + \alpha)$  and  $\pi + \alpha < \theta < (2\pi)$

Solution

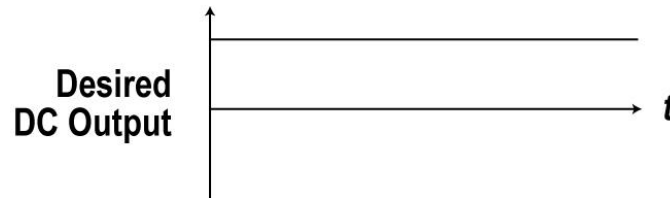
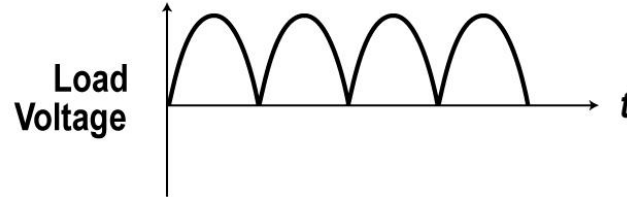
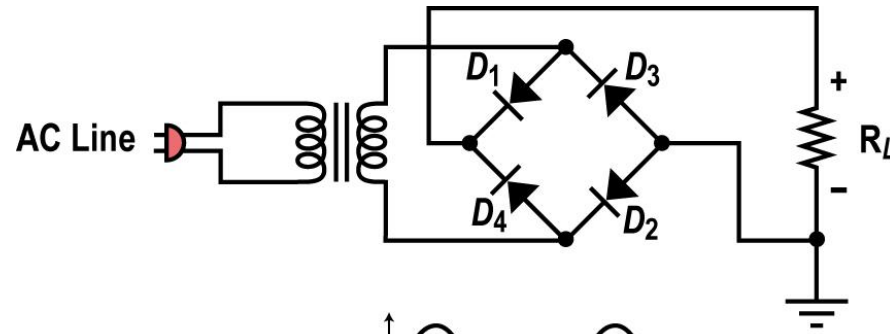
**Answer:** Option A

**Explanation:**

SCR conducts from  $\alpha < \theta < \pi$   
and free wheeling diode from  $\pi < \theta < (2\pi + \alpha)$



# AC-DC Converter Full-Wave Rectifier PD2



$$V_{0(\text{average})} = \frac{2V_m}{\pi}$$

## Exercise

**AC-DC Converter Full-Wave Rectifier PD2**

A PD2 circuit with R load is shown below.

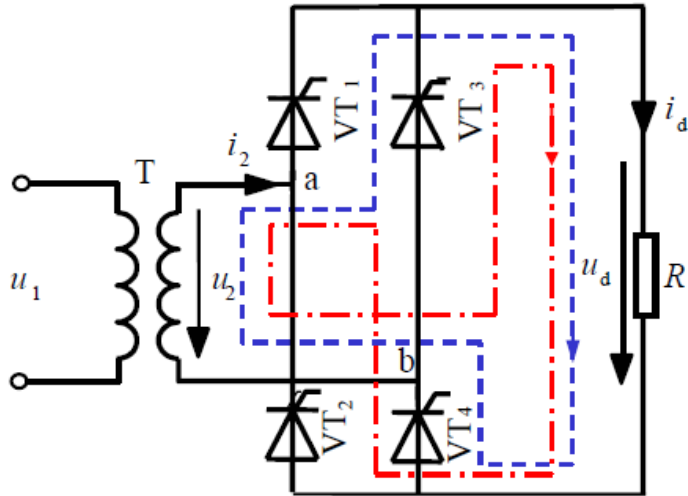
Data:  $U_n = 400$  V (RMS value),  $f = 50$  Hz,  $R = 10$  Ohm

Calculate the maximum ideal DC voltage  $V_{0(\text{average})}$ ?

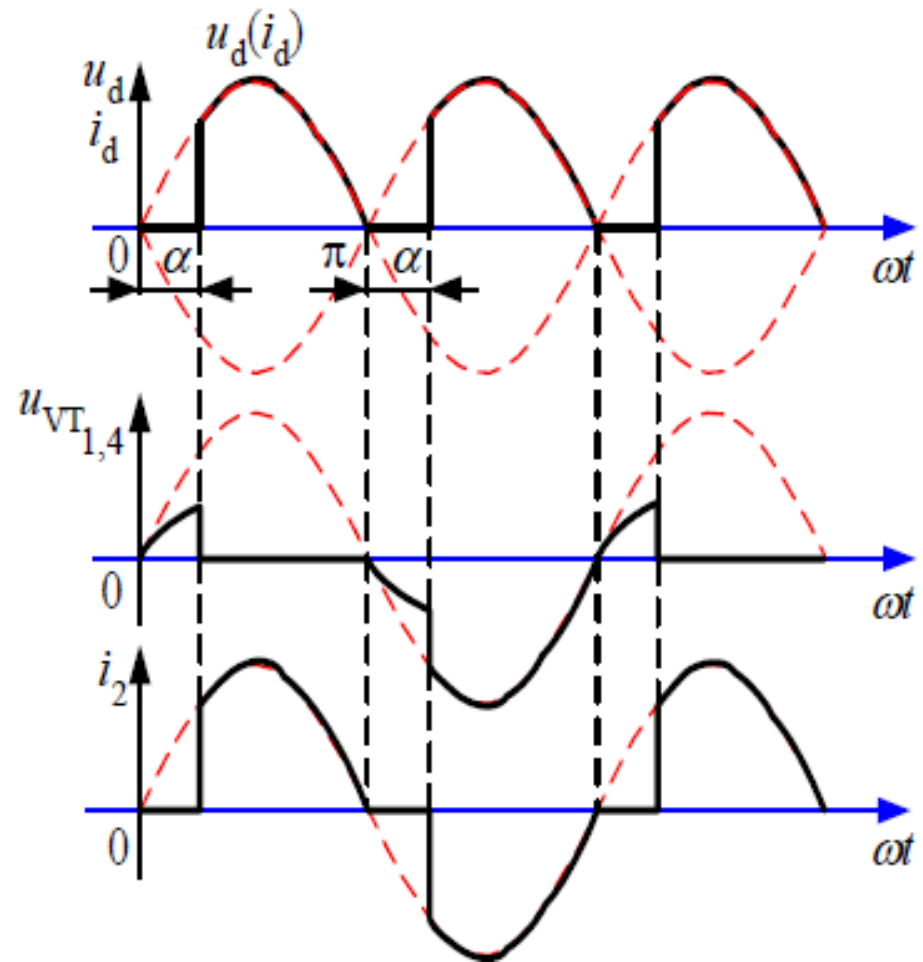
Solution

$$\langle v_c \rangle = \frac{2}{\pi} V_{\max} = \frac{2\sqrt{2}}{\pi} U_n = \frac{2\sqrt{2}}{\pi} \times 230 = 207V$$

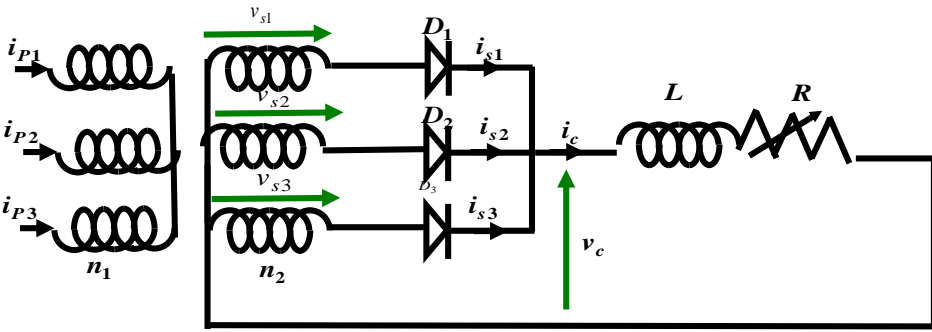
## AC-DC Converter Full-Wave Rectifier



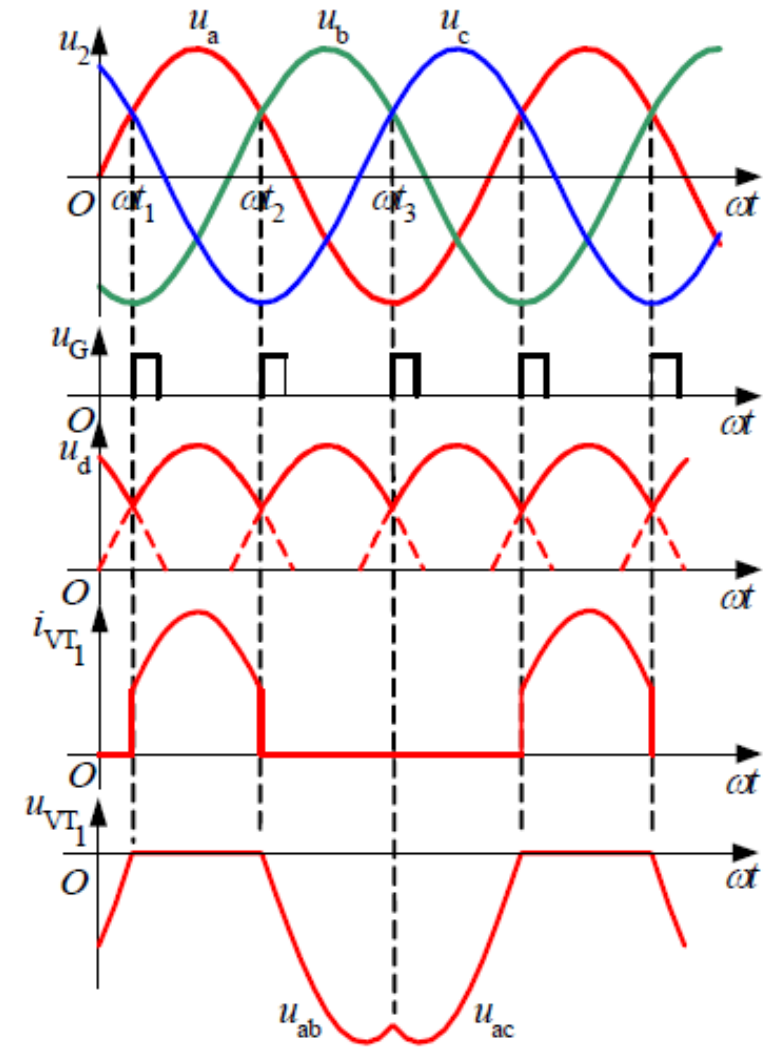
$$\langle v_c \rangle = \frac{2}{\pi} V_{\max} \cos \alpha$$



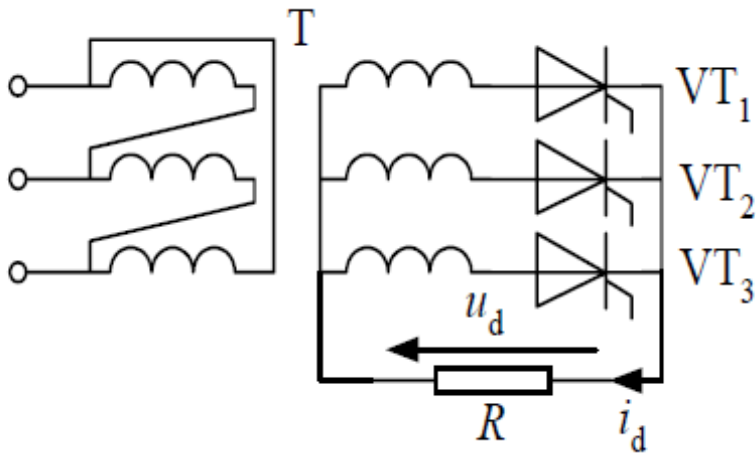
# Three phase uncontrolled rectifier



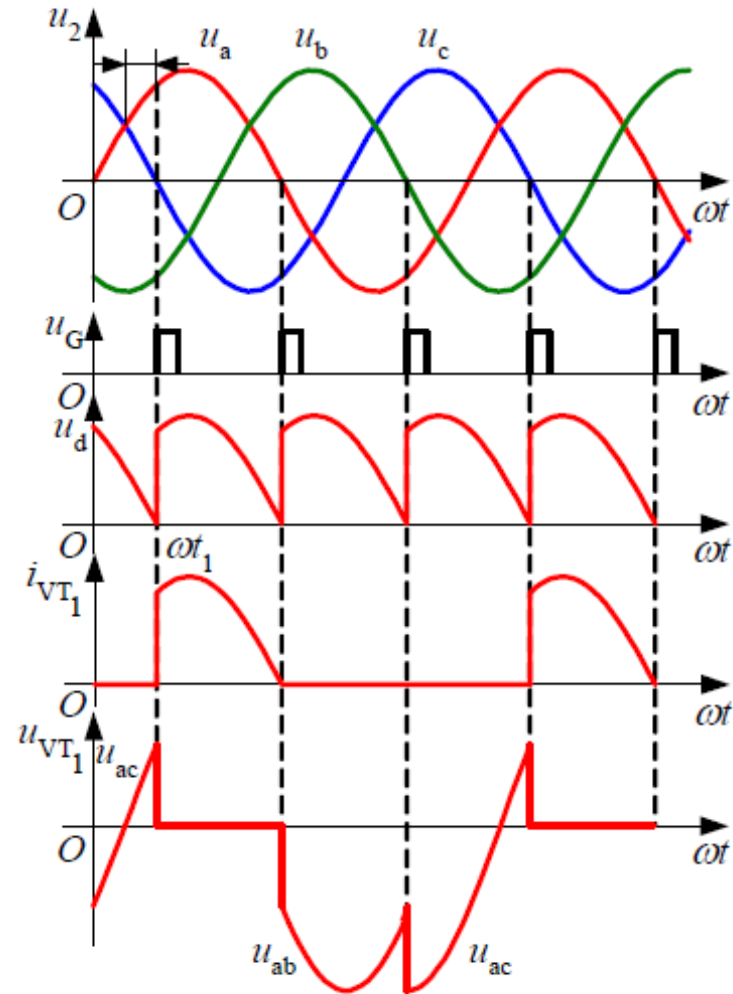
$$V_{0(\text{average})} = \frac{3\sqrt{3}}{2\pi} V_m$$



# Three-phase half-wave controlled rectifier



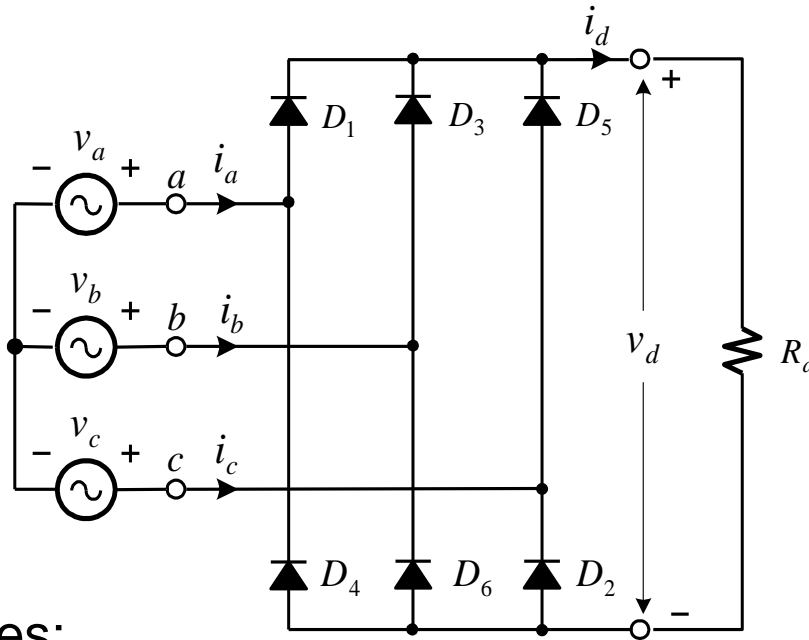
$$\langle v_c \rangle = \frac{3\sqrt{3}}{2\pi} V_{\max} \cos \alpha$$



# Three phase Full-Wave Uncontrolled Rectifier

- Resistive Load

$$V_{0(\text{average})} = \frac{3\sqrt{3}}{\pi} V_m$$



Supply Voltages:

$$v_a = \sqrt{2} V_{PH} \sin(\omega t)$$

$$v_b = \sqrt{2} V_{PH} \sin(\omega t - 2\pi/3)$$

$$v_c = \sqrt{2} V_{PH} \sin(\omega t - 4\pi/3)$$

$$v_{ab} = v_a - v_b = \sqrt{2} V_{LL} \sin(\omega t + \pi/6)$$

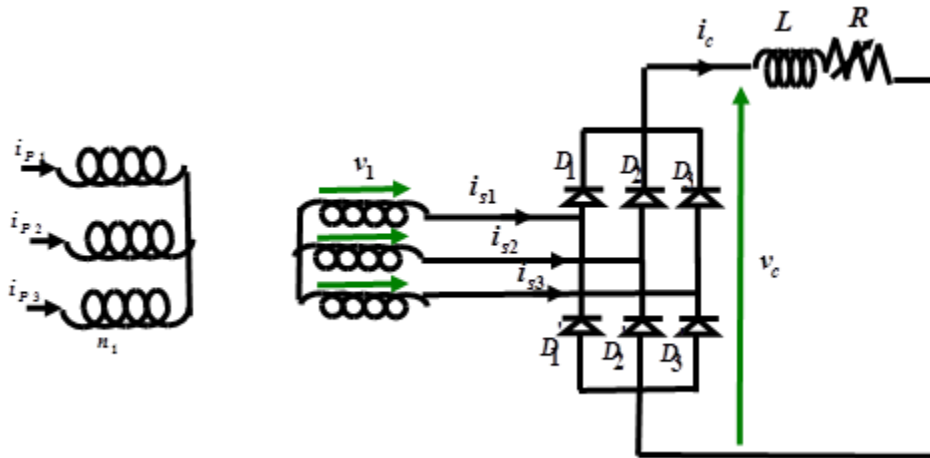
# Three phase Full-Wave Uncontrolled Rectifier

## Exercise

A six pulse PD3 circuit with RL load is shown below.

Data;: line to line voltage (RMS value):  $U = 400 \text{ V}$

Calculate the maximum ideal DC voltage  $V_{0(\text{average})}$ ?

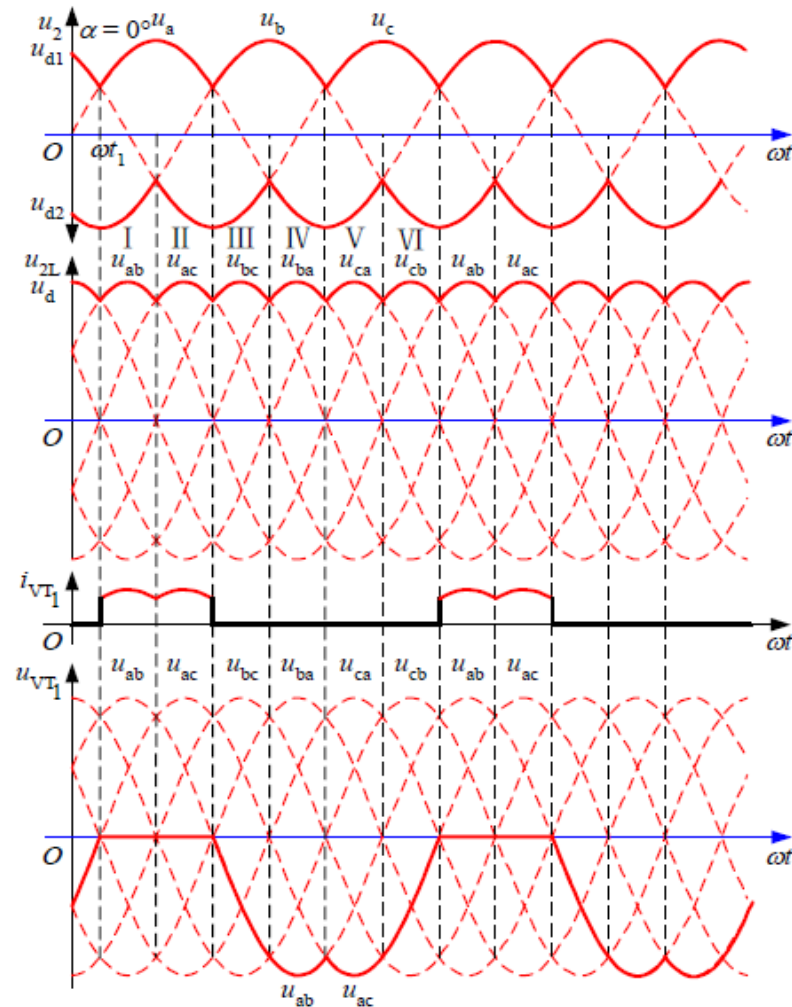


## Solution

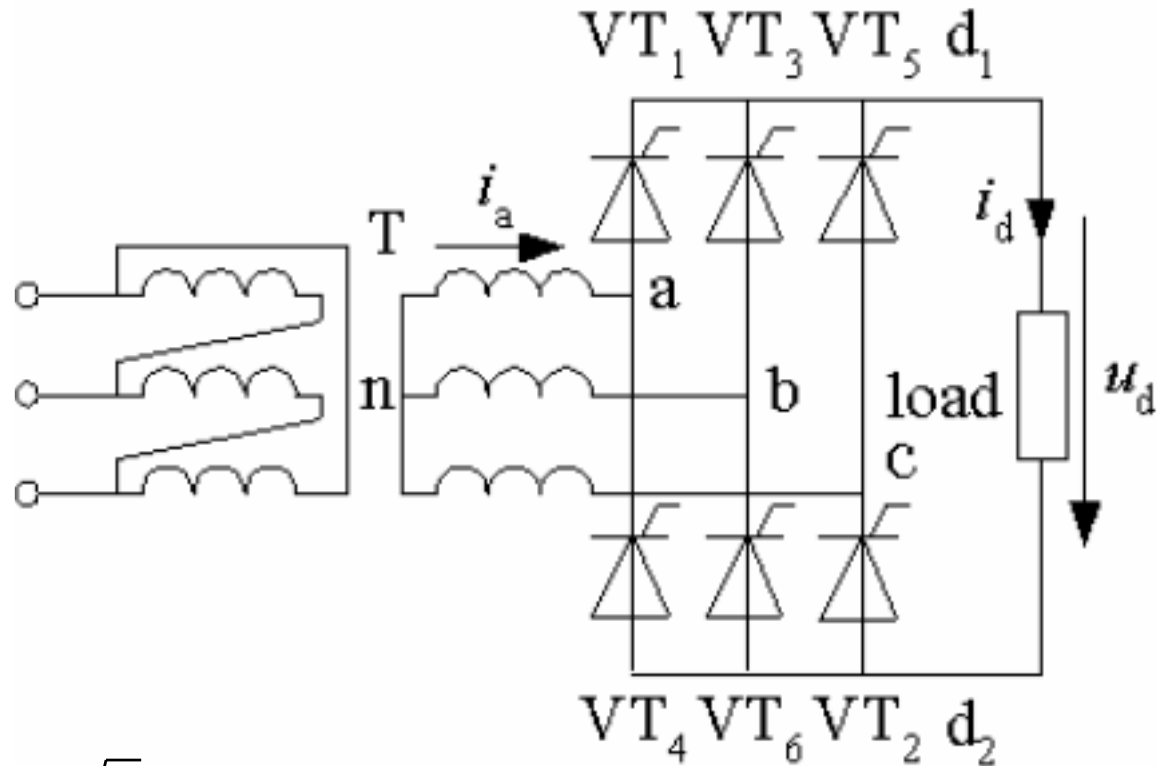
$$\langle v_c \rangle = \frac{3\sqrt{3}}{\pi} V_{\max} = \frac{3\sqrt{2}}{\pi} \times 400 = 540 \text{ V}$$

# Three phase Full-Wave Uncontrolled Rectifier

- Waveforms

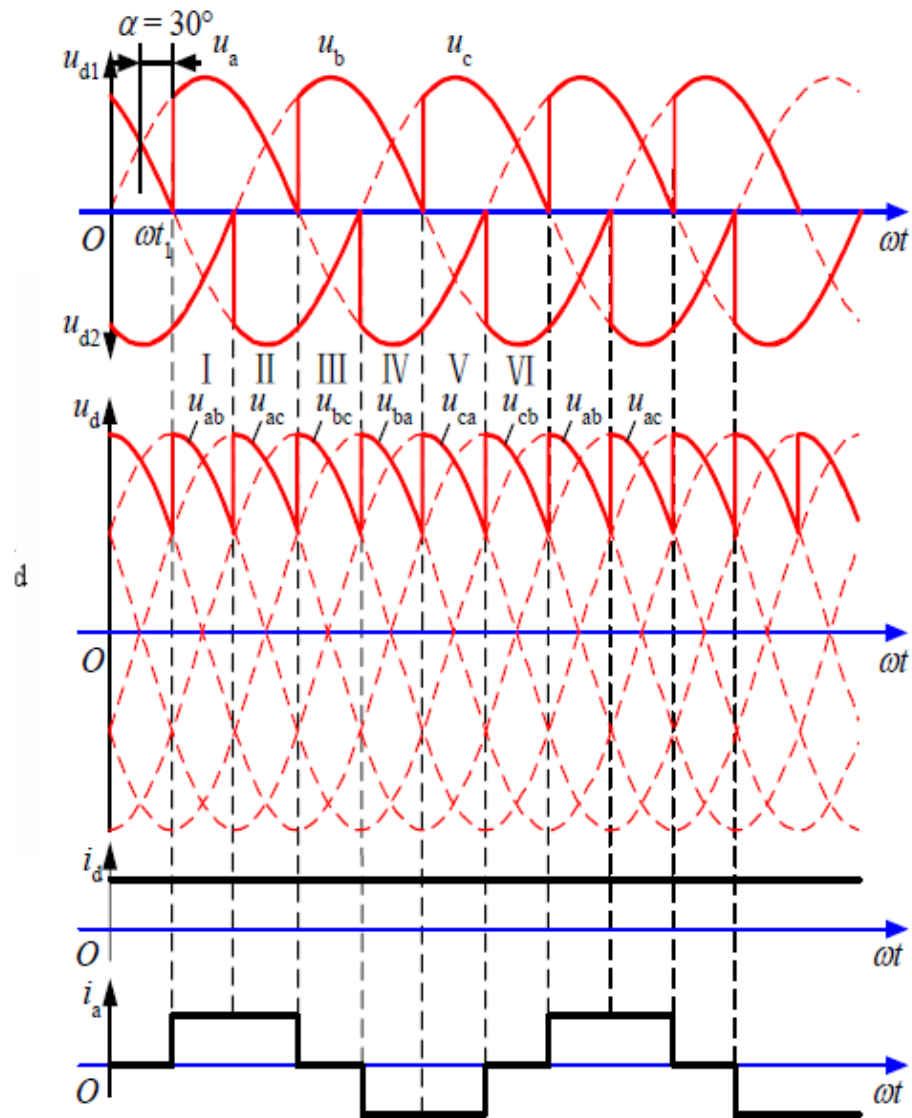


# Three phase Full-Wave Controlled Rectifier

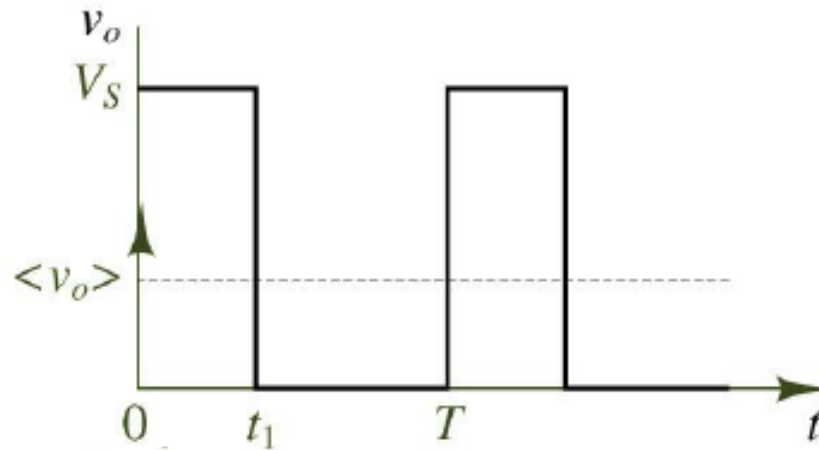
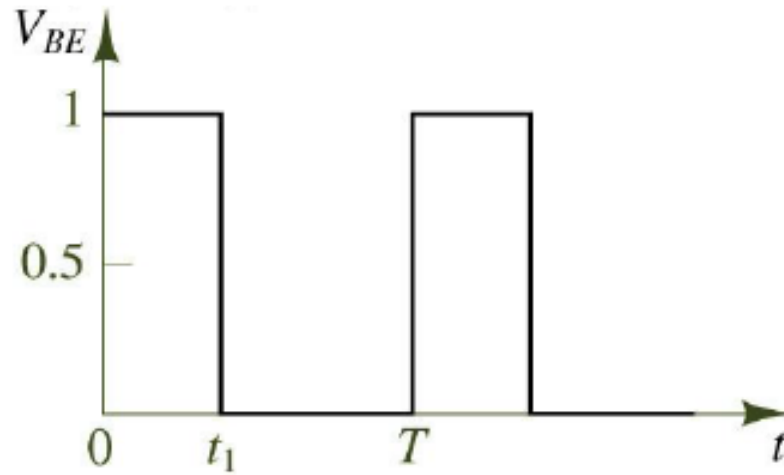
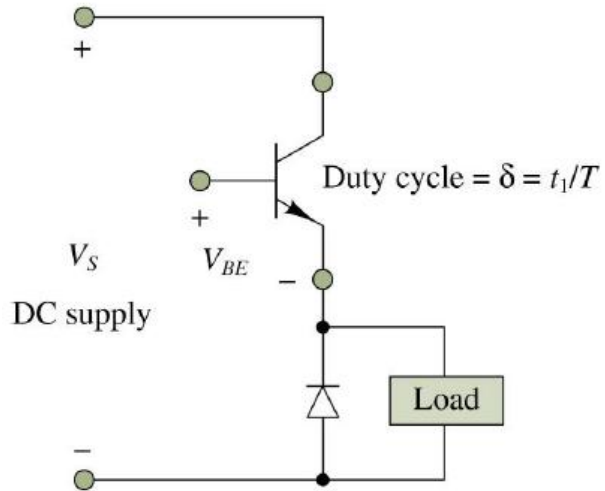


$$\langle v_c \rangle = \frac{3\sqrt{3}}{\pi} V_{\max} \cos \alpha$$

- Waveforms



# DC-DC Converter Circuit and Waveform



$$V_{out} = \frac{1}{T} \int_0^{t_1} V_{in} dt = \frac{t_1}{T} V_{in}$$

$$k = \frac{t_1}{T} = \frac{V_{out}}{V_{in}}$$

$k$  is the duty cycle

## Exercise

## Chopper

In a step down chopper using pulse width modulation,  $T_{on} = 3 \times 10^{-3}$  and  $T_{off} = 1 \times 10^{-3}$  s. The chopping frequency is:

- A. 333.33
- B. 250
- C. 500
- D. 1000

Solution

Answer: Option B

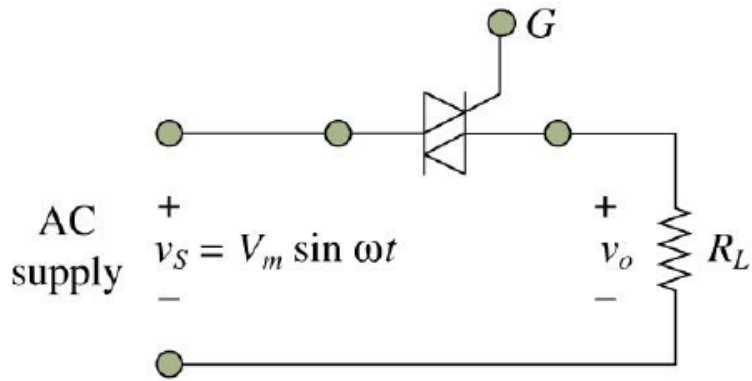
Explanation: They are suitable for both dc and ac circuit breakers.

$$f = \frac{1}{T} \quad T = T_{ON} + T_{OF} = 3 + 1 = 4ms$$

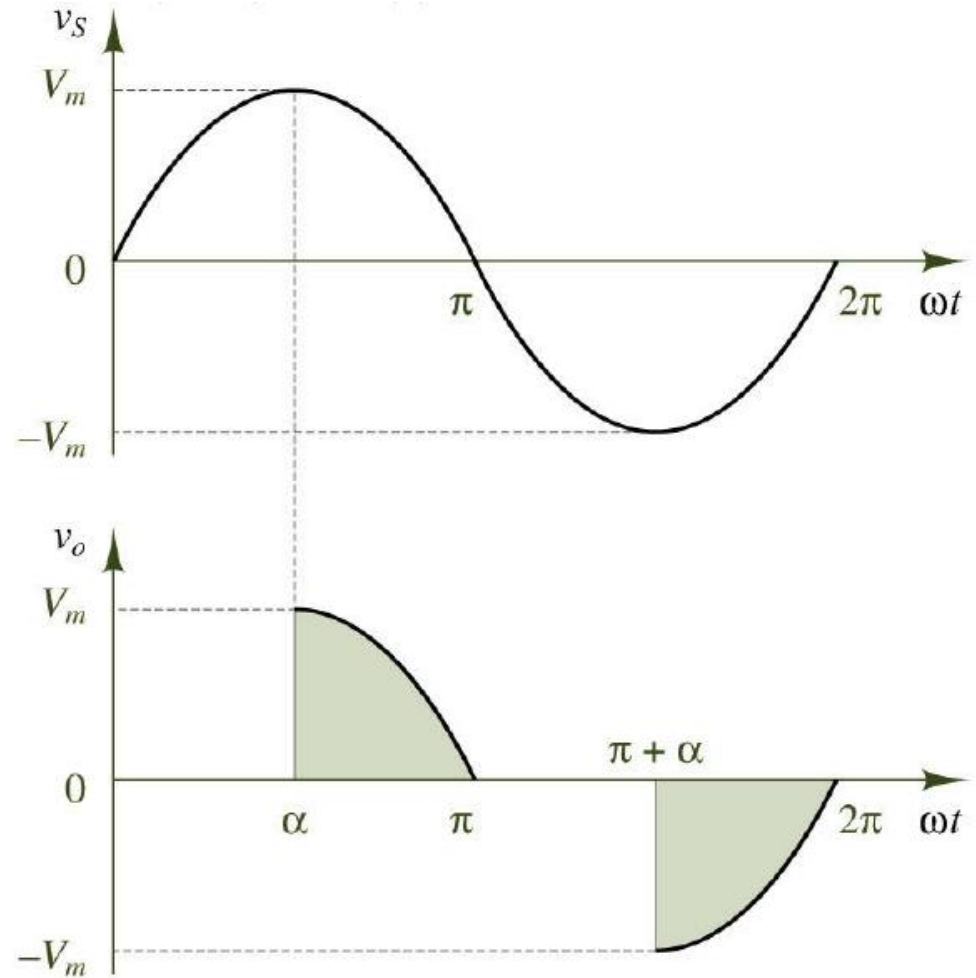
$$f = \frac{1}{4 \times 10^{-3}} = 250Hz$$

# Voltage controller

## AC-AC Converter Circuit and Waveform



$$V_{o(rms)} = \frac{V_M}{\sqrt{2}} \left[ \frac{1}{\pi} \left( \pi - \alpha + \frac{\sin 2\alpha}{2} \right) \right]$$

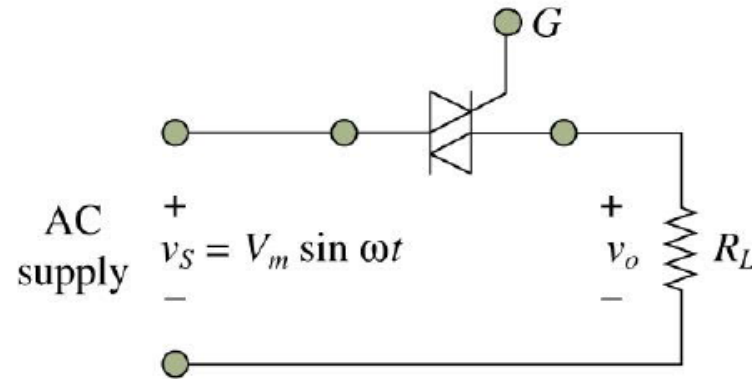


## Exercise

## Voltage controller

In a single phase full wave regulator, the firing angles in the positive and negative half cycles are generally

- A. equal
- B. different
- C. equal or different
- D. different but sometimes equal



Solution

**Answer:** Option A

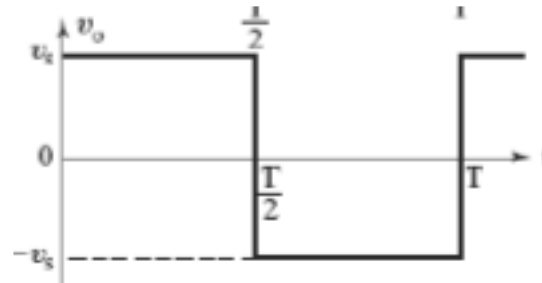
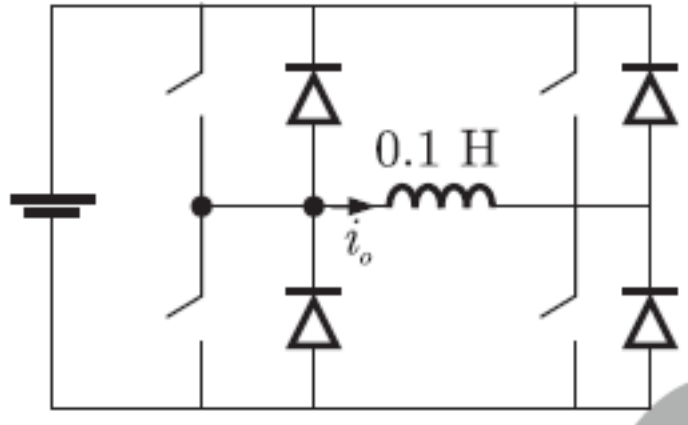
**Explanation:**

Firing angles are kept equal to get symmetrical output voltage.

# Inverter

## DC-AC Converter (Power inverter)

A power inverter, or inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC)



$$V_{O1(\text{rms-fundamental})} = \frac{4}{\sqrt{2} \times \pi} V_s$$

## Review

1. In a 3 phase fully controlled converter the firing frequency is

A. 3 times the line frequency

B. 6 times the line frequency

C. 9 times the line frequency

D. 12 times the line frequency

2. The characteristics of a non-linear resistance is  $i = kv^4$ . If  $i$  becomes 100 times,  $v$  becomes

A. about 100 times

B. about 10 times

C. about 3 times

D. about twice

R:  $v \propto (i)^{1/4} = (100)^{1/4} \approx 3$ .

3. A chopper

A. converts constant voltage dc into ac and then into variable voltage dc

B. converts constant voltage dc into variable voltage dc directly

C. converts ac of one frequency into ac of another frequency

D. converts ac to dc

4. Assertion (A): If the duty cycle of chopper is low the current would not become discontinuous

Reason (R): If the time constant  $L/R$  of the load in chopper is low the current may become discontinuous.

A. Both A and R are correct and R is correct explanation of A

B. Both A and R correct but R is not correct explanation of A

C. A is correct but R is wrong

D. A is wrong but R is correct

5. In a single phase full wave regulator, the firing angles in the positive and negative half cycles are generally

A. equal

B. different

C. equal or different

D. different but sometimes equal

The  
End