

Instituto Federal de Educação, Ciência e Tecnologia de Santa Catarina

Departamento Acadêmico de Eletrônica

Eletrônica de Potência



# **Conversores CA-CA**

## **Gradadores e Variadores CA-CA**

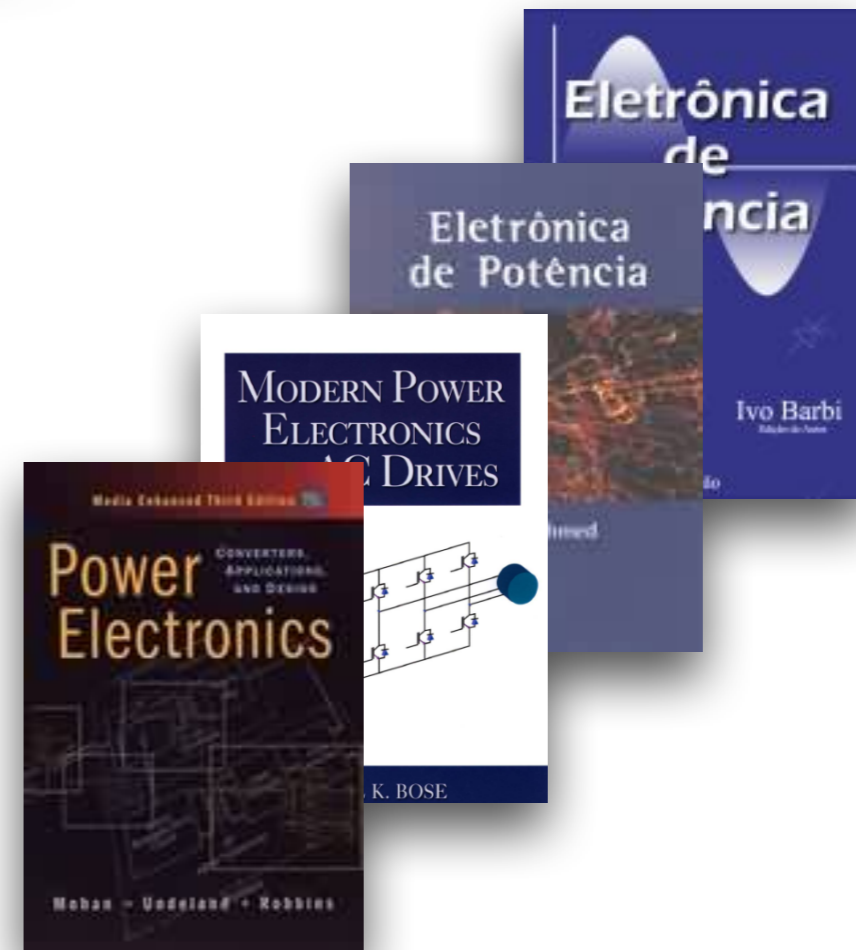
Prof. Clovis Antonio Petry.

Florianópolis, outubro de 2014.

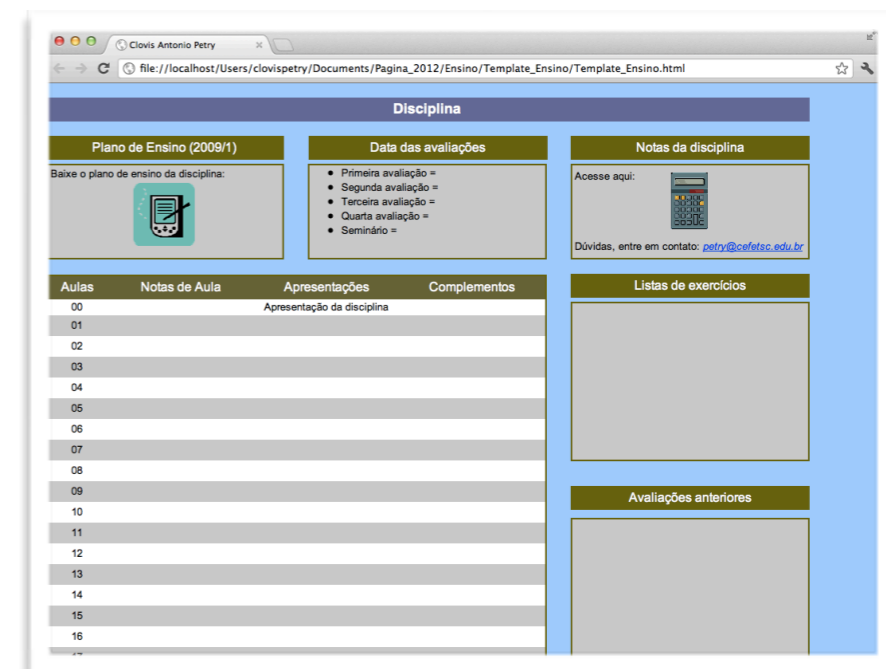
# Biografia para Esta Aula

## Capítulo 11 - Controlador de tensão AC:

- Gradadores;
- Variadores CA monofásicos.



[www.ProfessorPetry.com.br](http://www.ProfessorPetry.com.br)



A screenshot of a web page titled 'Disciplina' (Discipline). The page is organized into several sections:

- Plano de Ensino (2009/1)**: Baixe o plano de ensino da disciplina: [Download icon]
- Data das avaliações**:
  - Primeira avaliação =
  - Segunda avaliação =
  - Terceira avaliação =
  - Quarta avaliação =
  - Seminário =
- Notas da disciplina**: Acesse aqui: [Calculator icon]. Dúvidas, entre em contato: [petry@cefetsc.edu.br](mailto:petry@cefetsc.edu.br)
- Table with 4 columns**: Aulas, Notas de Aula, Apresentações, Complementos.

Aulas	Notas de Aula	Apresentações	Complementos
00		Apresentação da disciplina	
01			
02			
03			
04			
05			
06			
07			
08			
09			
10			
11			
12			
13			
14			
15			
16			
- Listas de exercícios**: [Empty box]
- Avaliações anteriores**: [Empty box]

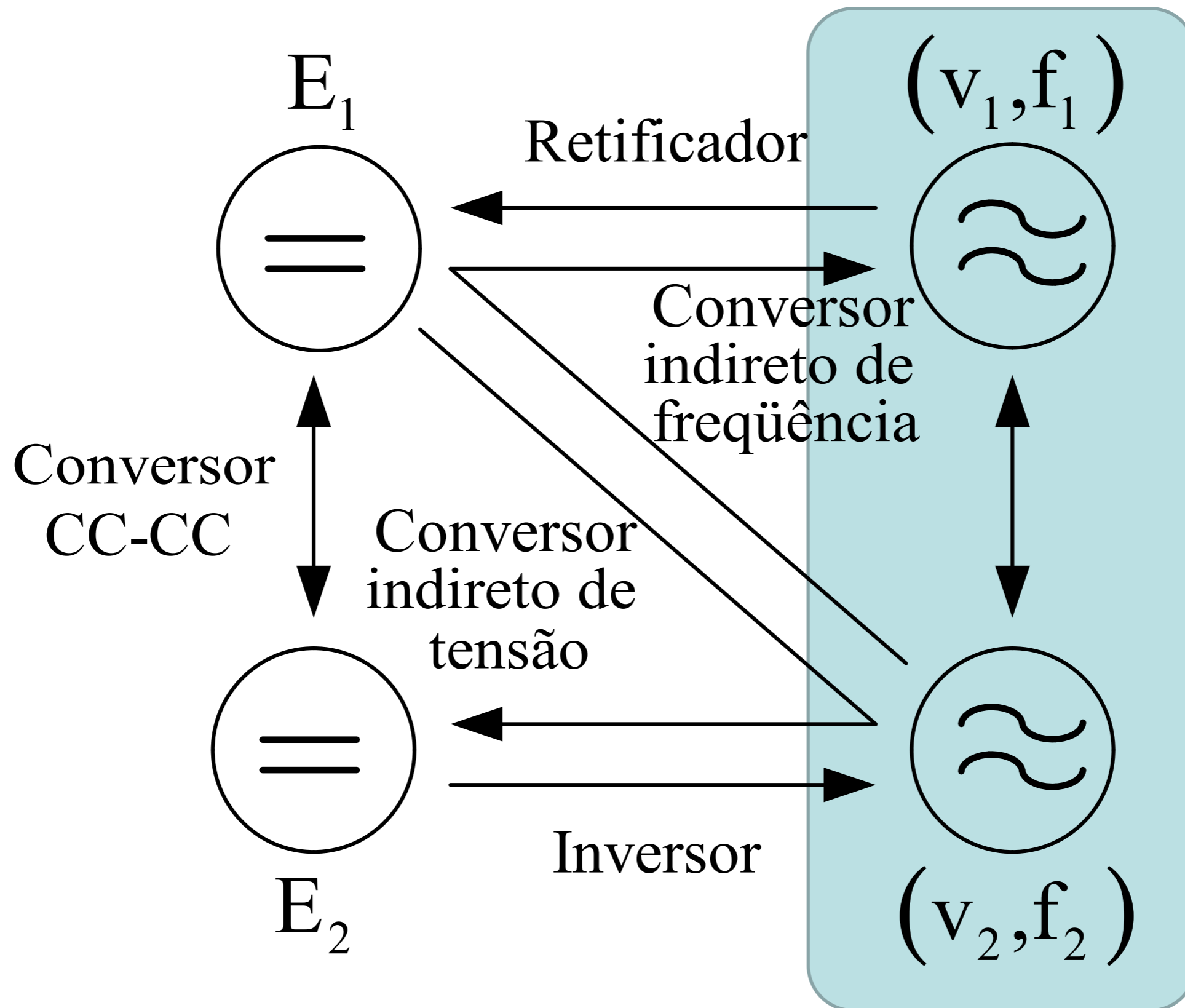
## Gradadores:

1. Introdução;
2. Gradadores monofásicos:
  - Carga resistiva;
  - Carga RL.
3. Gradadores trifásicos;
4. Controle por ciclos inteiros;
5. R, L e C controlados por tiristores;
6. Compensador estático de potência reativa.

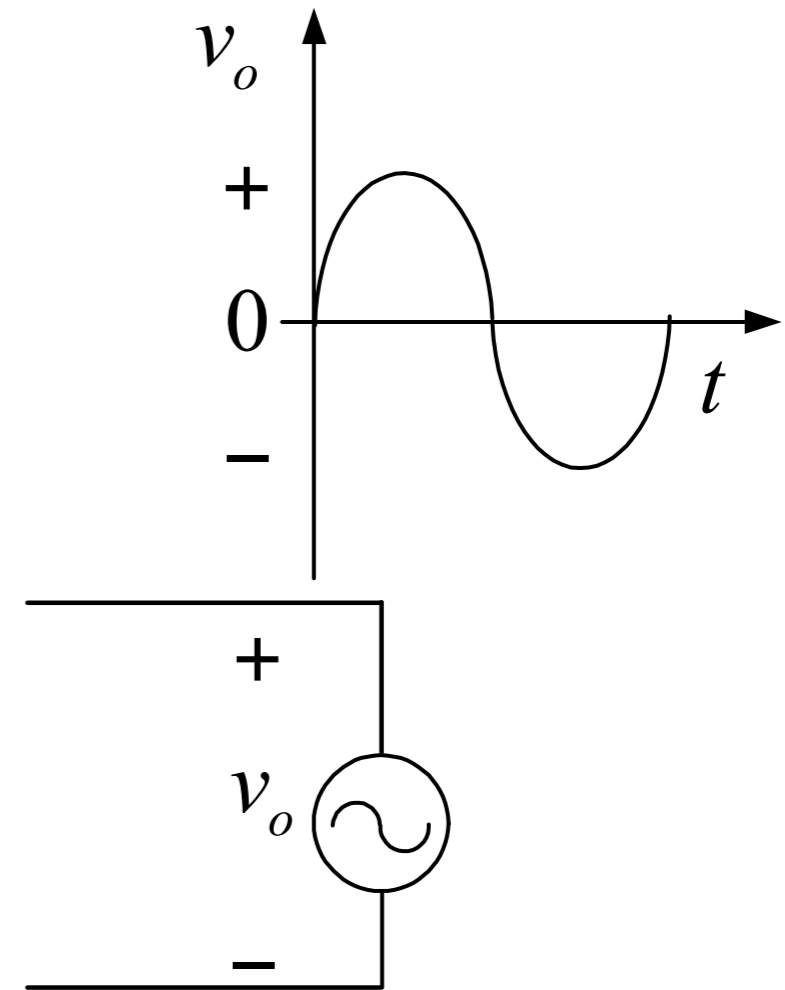
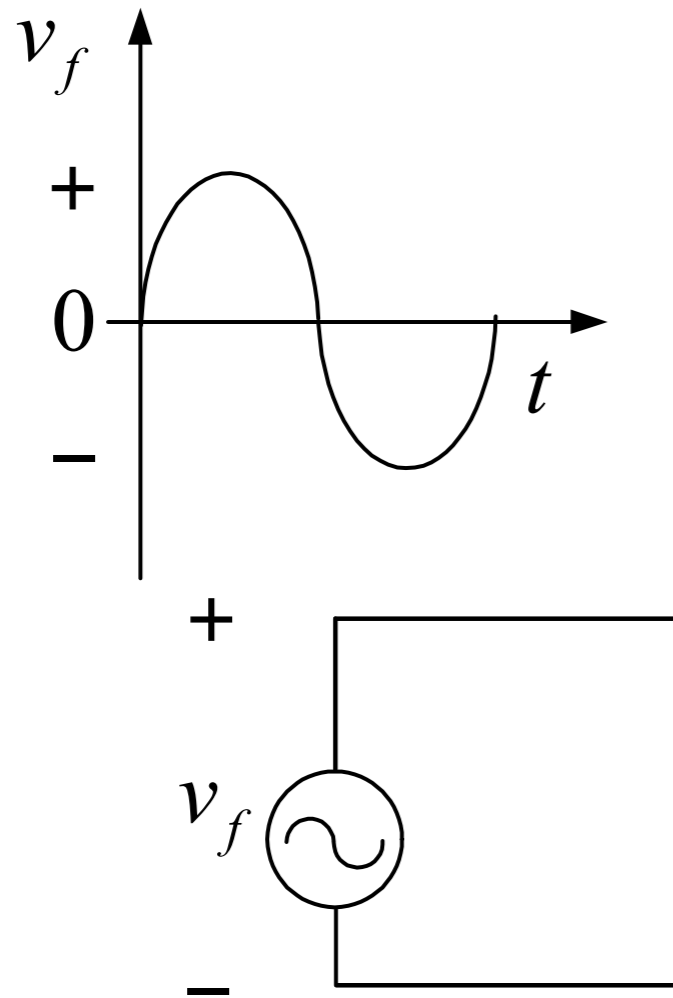
## Variadores CA-CA:

1. Introdução;
2. Implementação de um gradador monofásico;
3. Partida de cargas com gradadores;
4. Disparo de tiristores;
5. Chaves bidirecionais para CA-CA;
6. Estabilizadores com tap variável;
7. Chopper CA-CA;
8. Conversor CA-CA indireto.

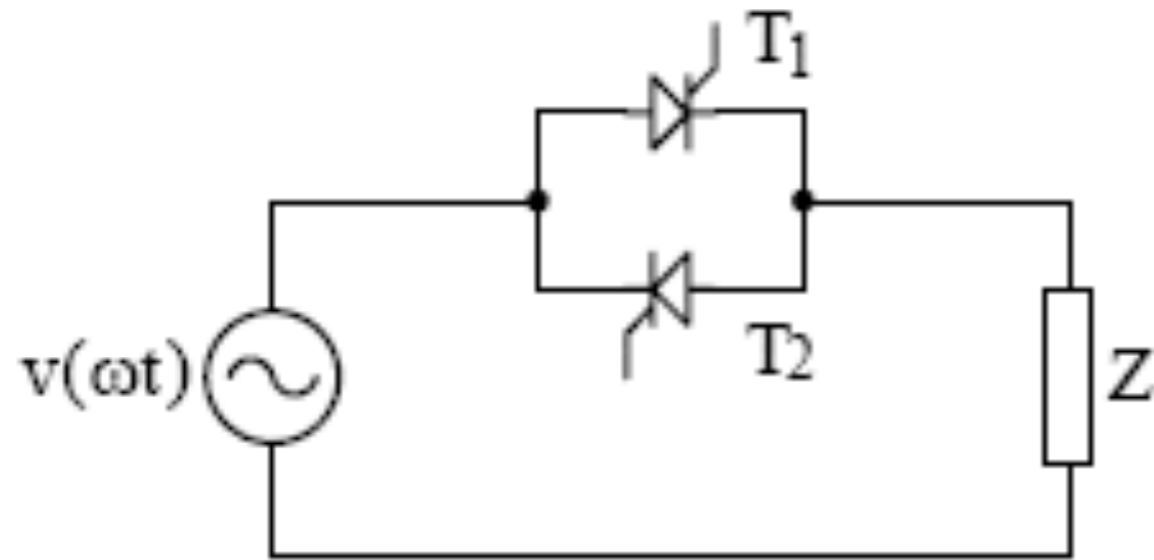
# Divisão da Eletrônica de Potência



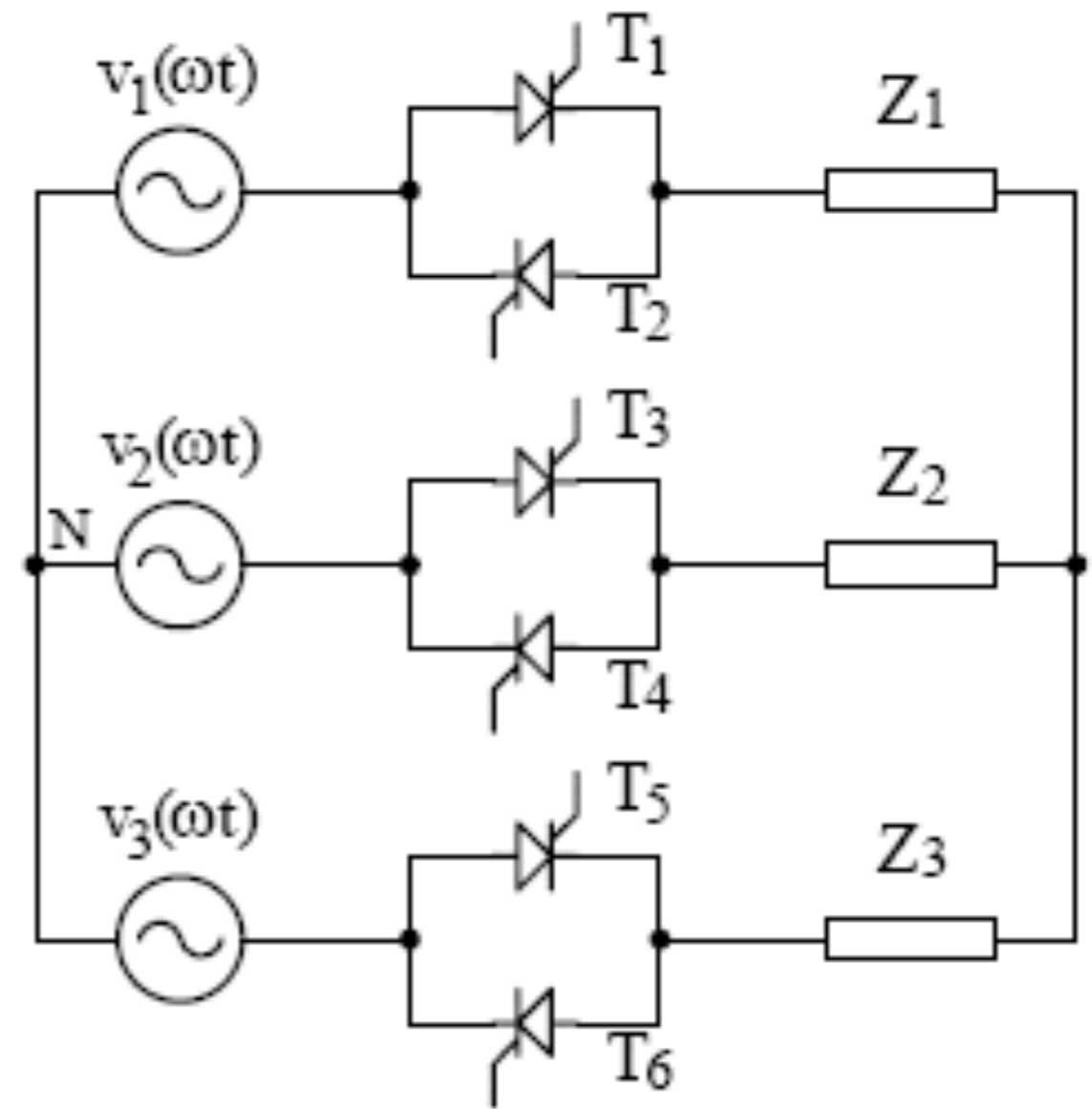
# Conversor CA-CA: Princípio Geral



# Conversor CA-CA: Numero de Fases

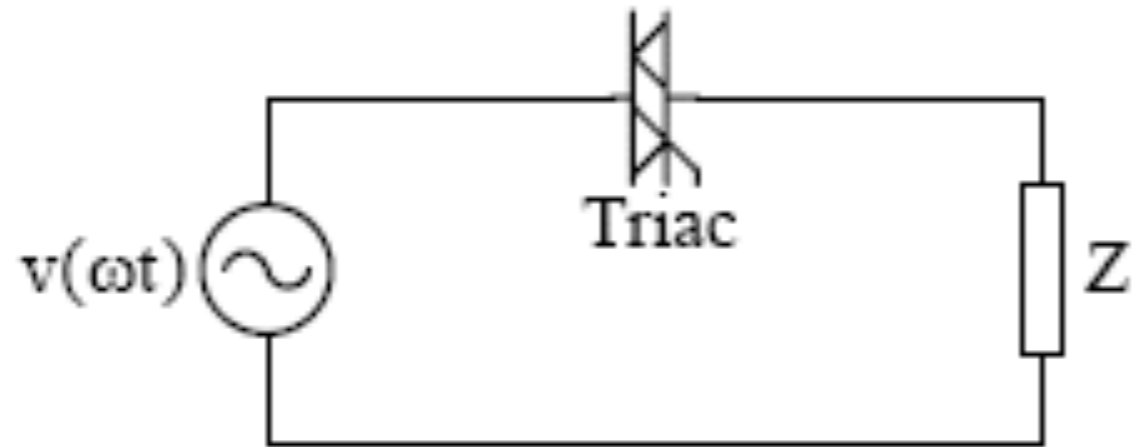


Monofásico

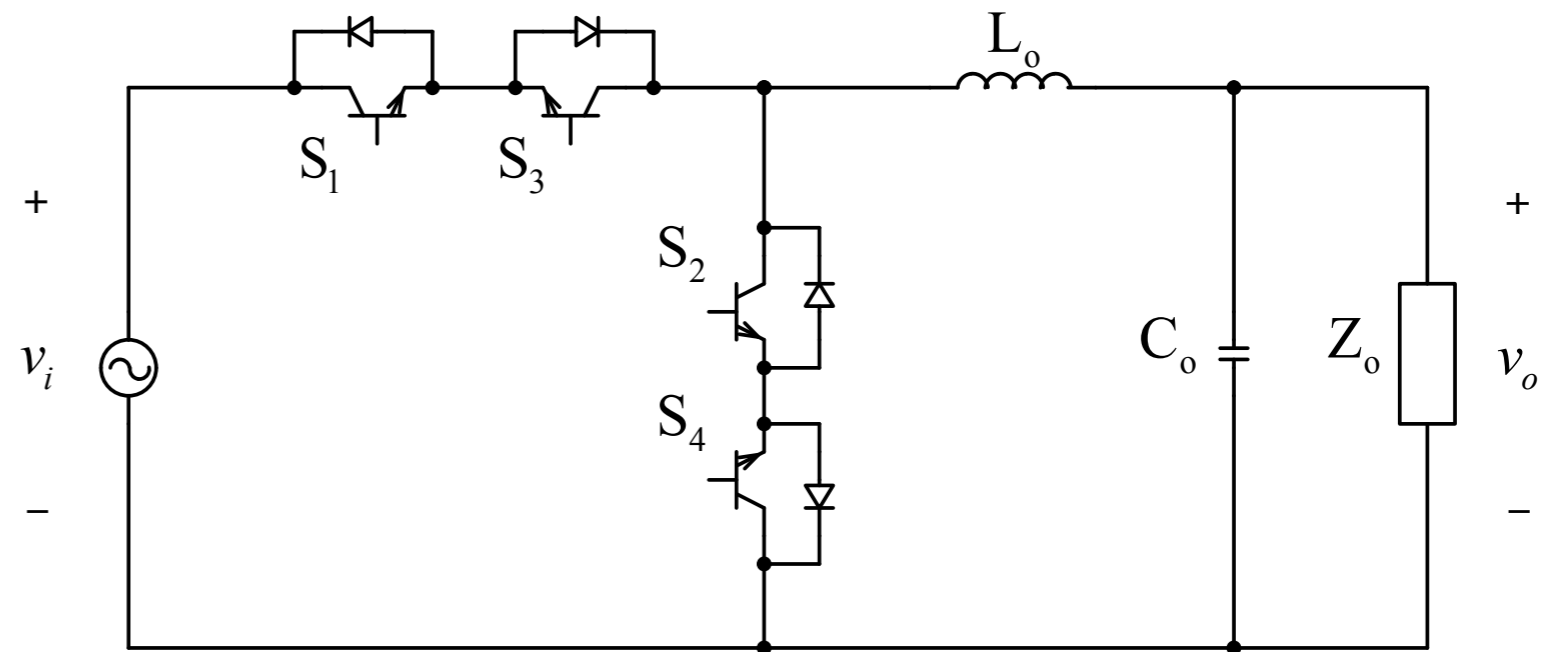


Trifásico

# Conversor CA-CA: Comando



Baixa frequência



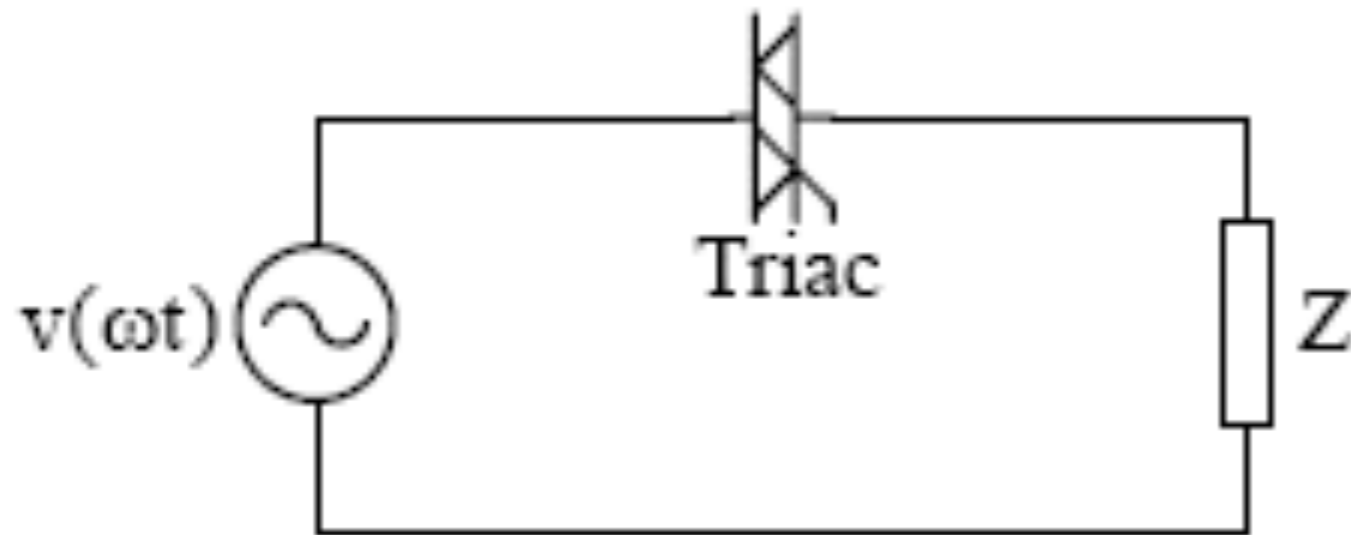
PWM alta frequência

# Aplicações dos Conversores CA-CA

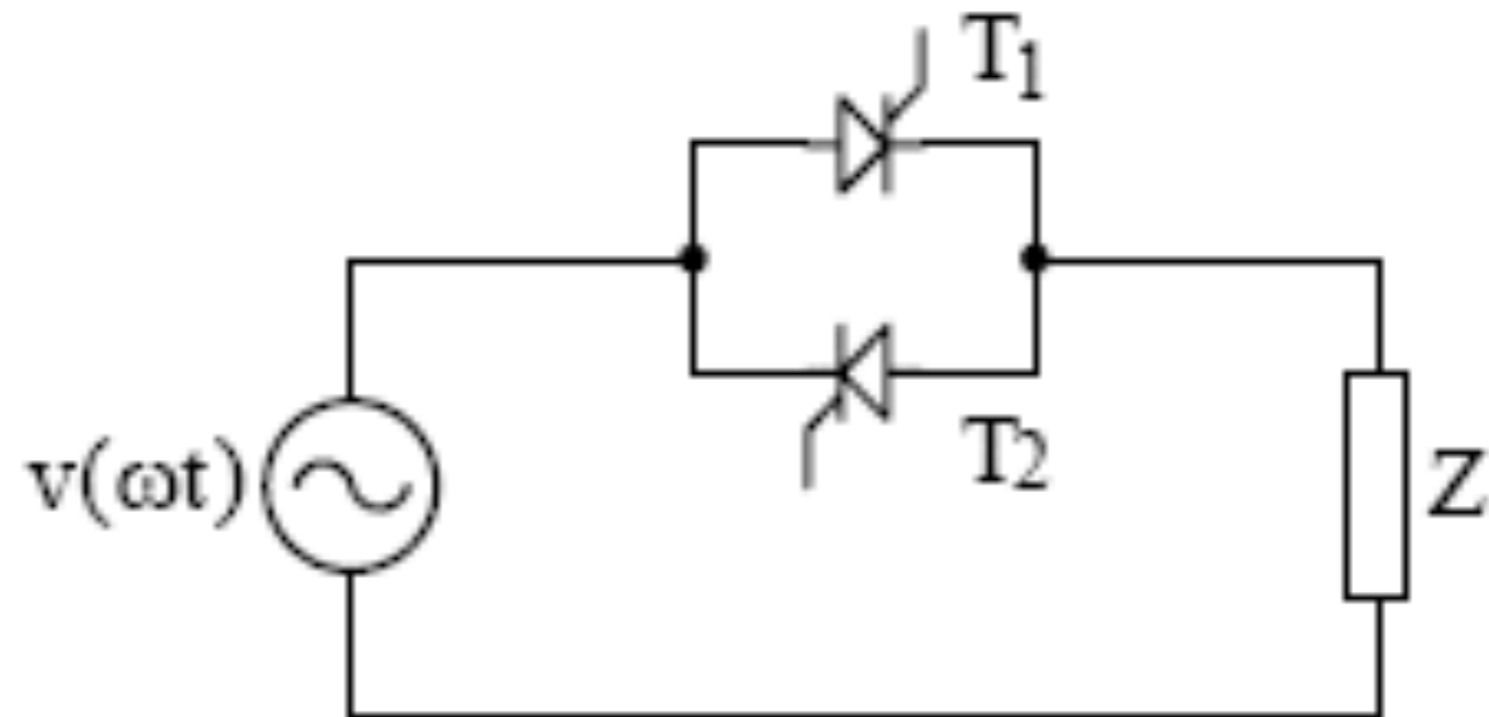
## Algumas aplicações:

1. Controle de intensidade luminosa;
2. Controle de temperatura;
3. Controle de velocidade de motores de indução;
4. Limitação da corrente de partida de motores de indução;
5. Estabilizadores de tensão;
6. Filtros ativos;
7. Pré-estabilização em fontes de alimentação e UPS;
8. Economia de energia;
9. Sistemas de potência;
10. Entre outras.

# Gradadores Monofásicos



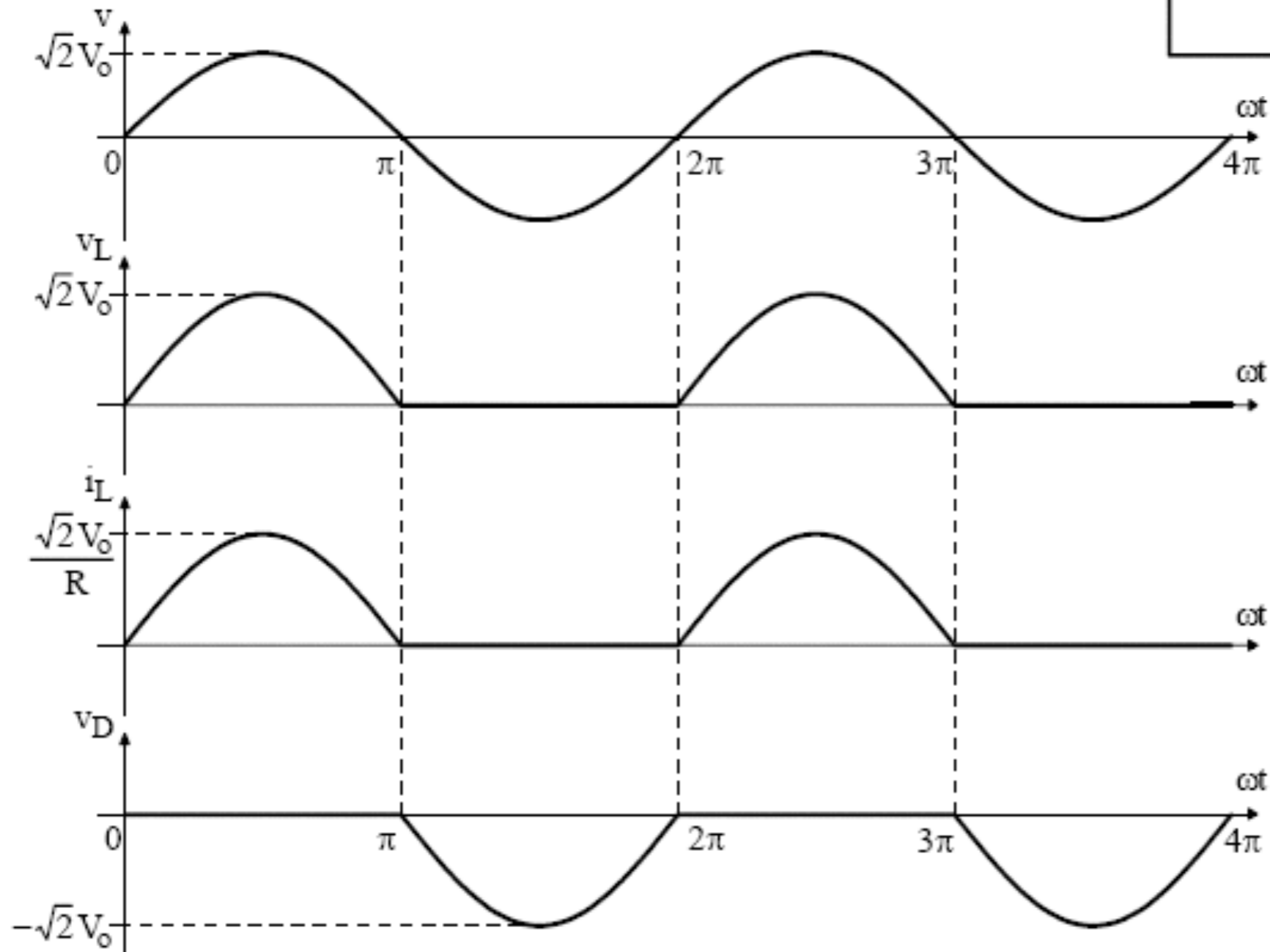
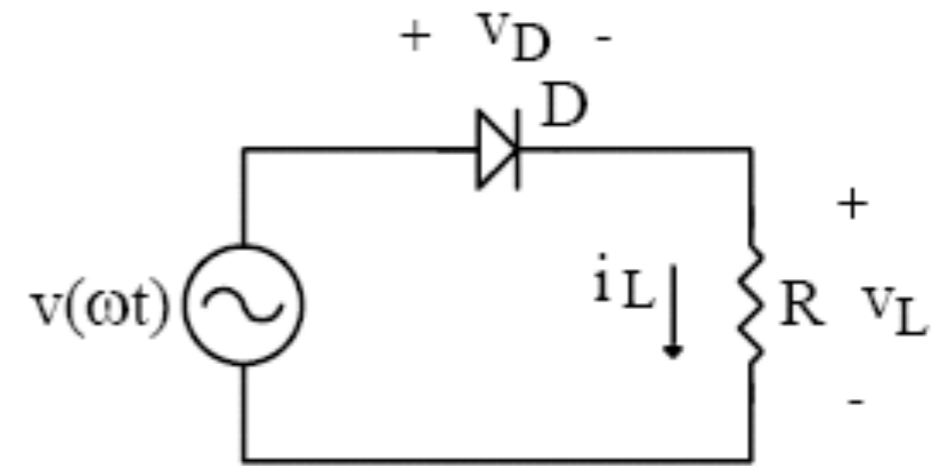
Gradador usando triac



Gradador usando tiristores

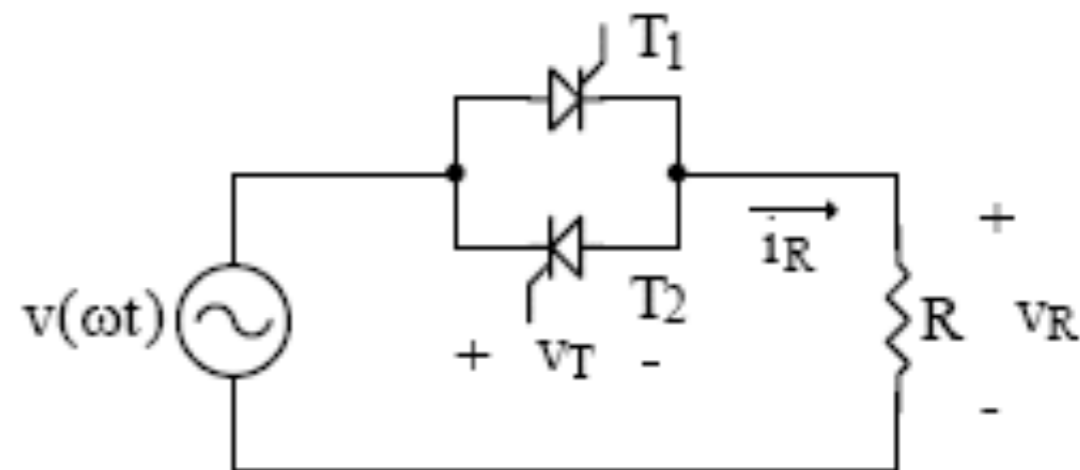
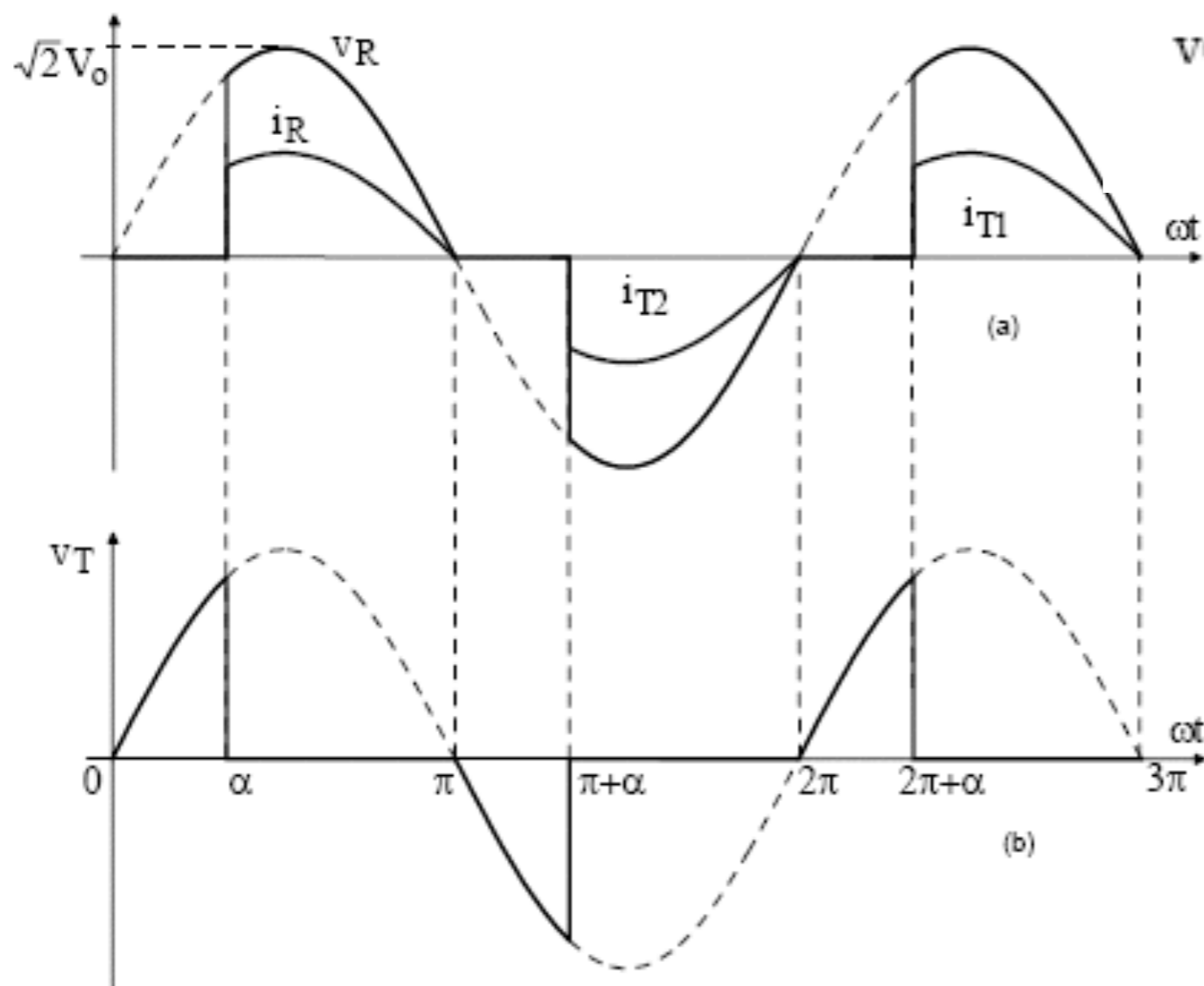
# Gradadores Monofásicos

Retificador com carga resistiva pura:



# Gradadores Monofásicos

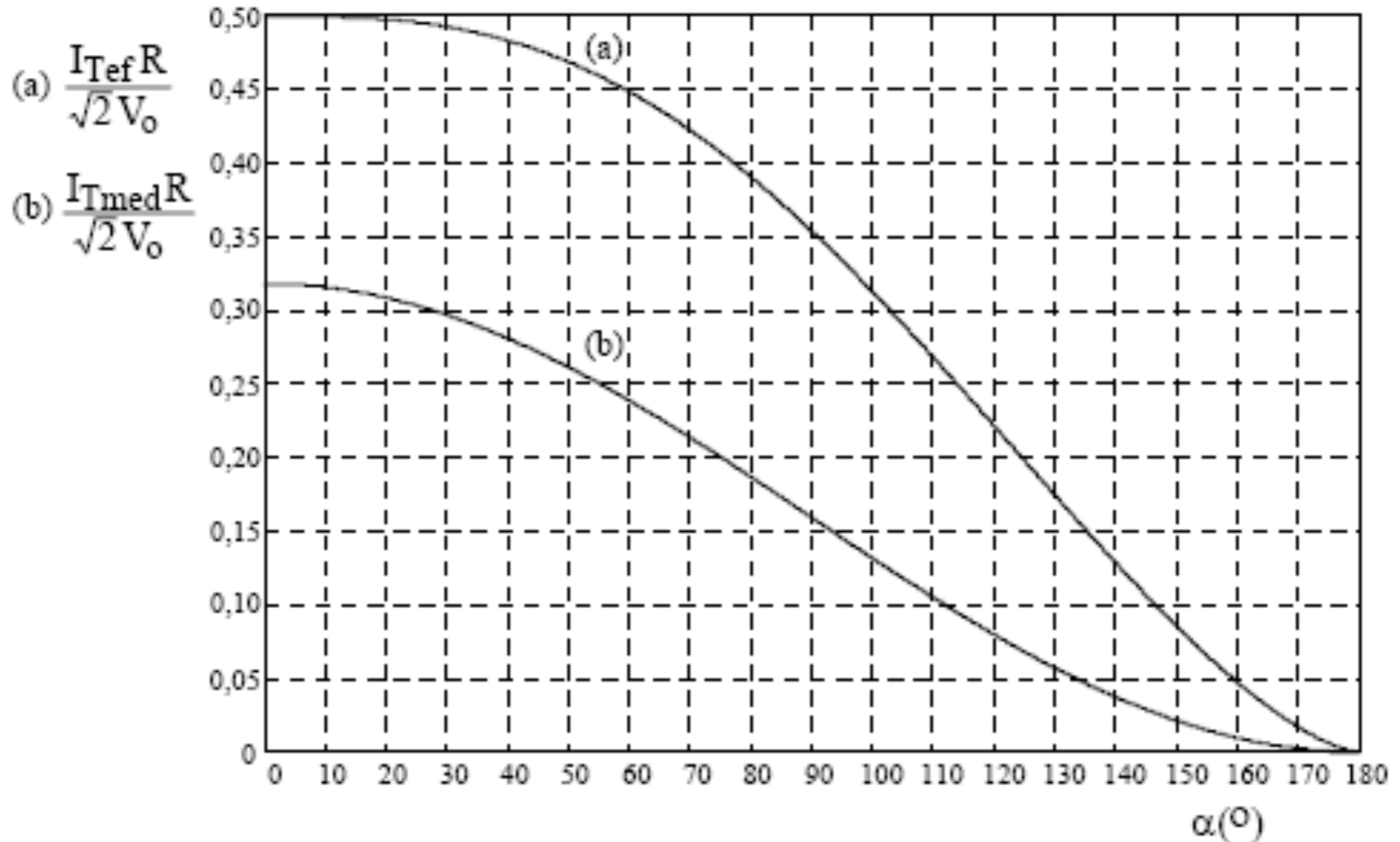
Gradador com carga resistiva pura:



$$V_o = V_i \cdot \sqrt{1 - \frac{\alpha}{\pi} + \frac{\text{sen}(2 \cdot \alpha)}{2 \cdot \pi}}$$

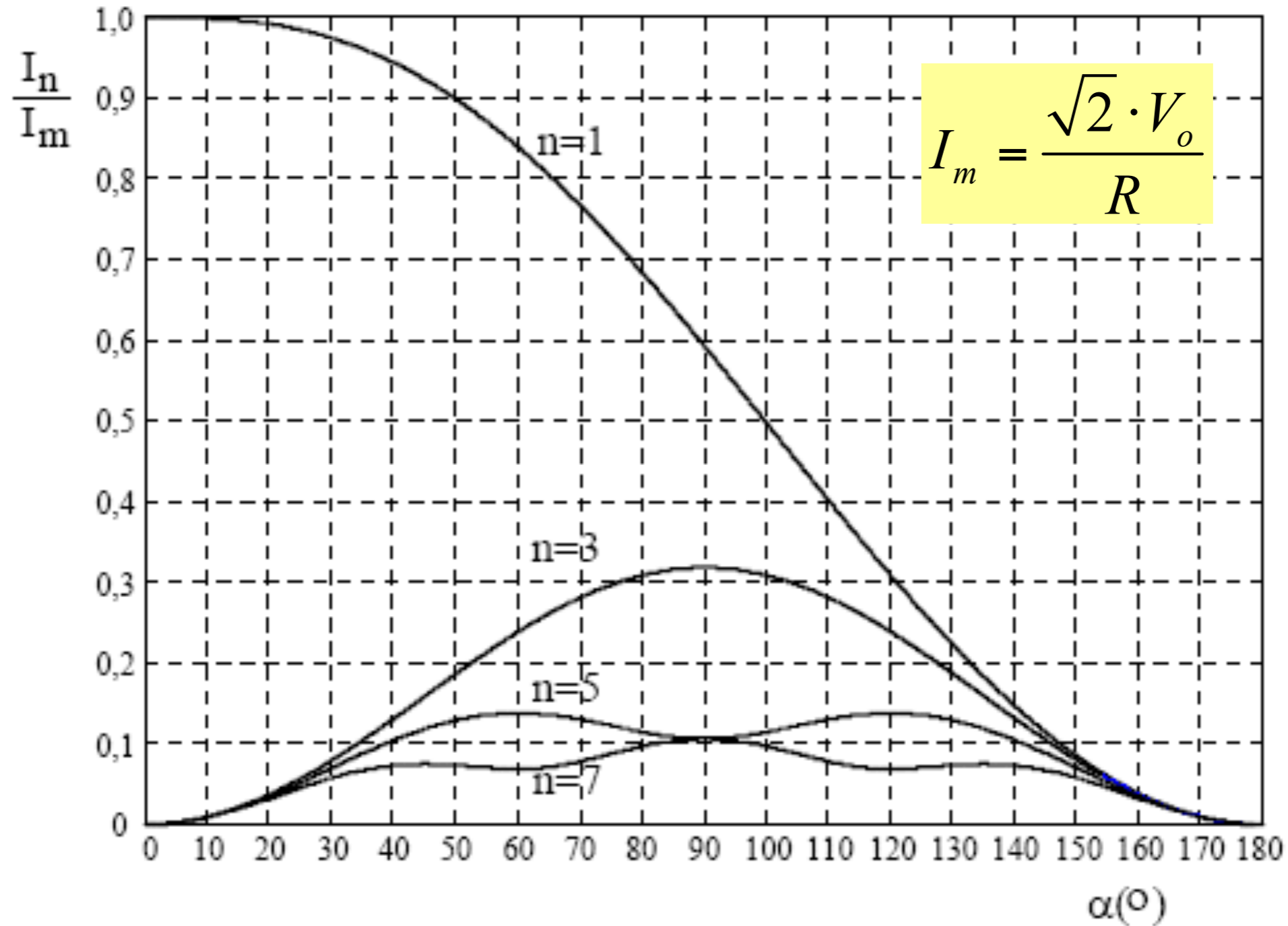
# Gradadores Monofásicos

Correntes média e eficaz na carga:



# Gradadores Monofásicos

Harmônicas da corrente de carga:



# Gradadores Monofásicos

Harmônicas da corrente de carga, exemplo:

$$V_o = 220V$$

$$P_o = 4800W$$

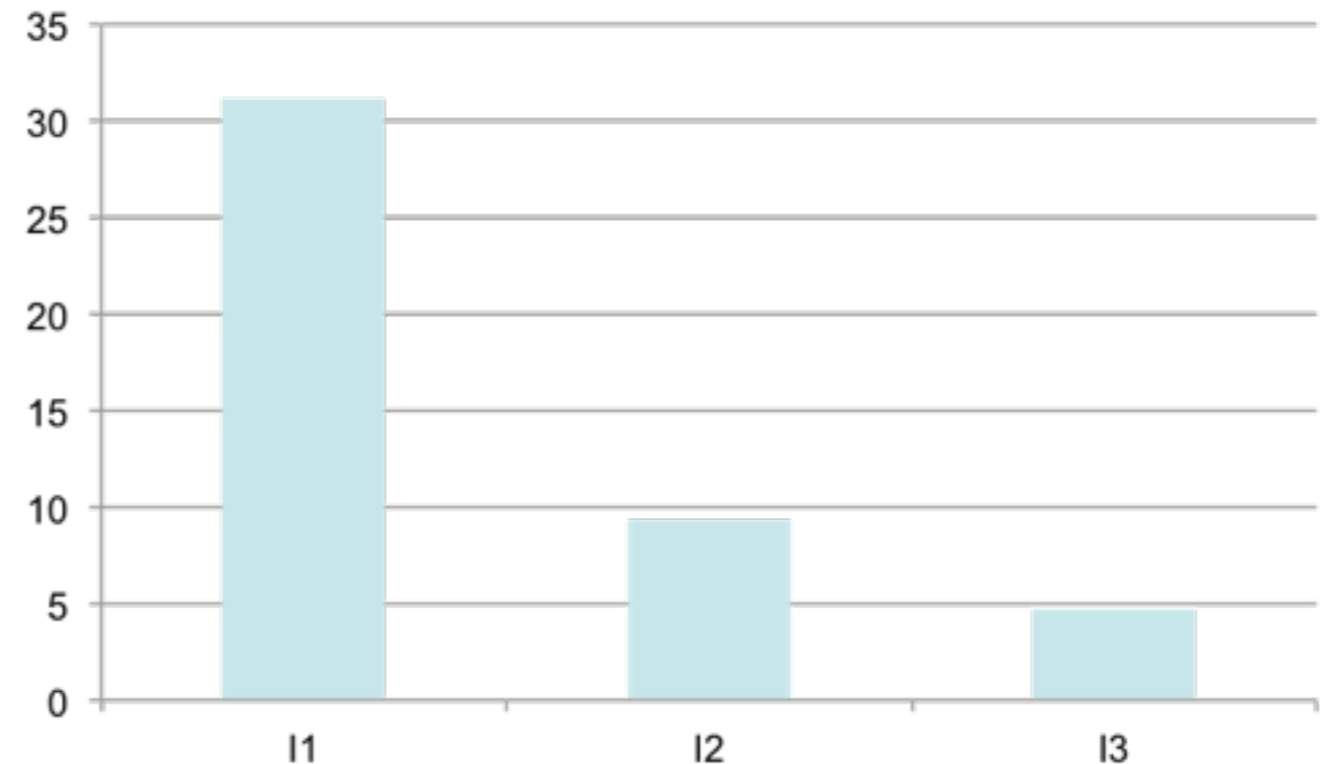
$$R = \frac{V_o^2}{P_o} = \frac{220^2}{4800} = 10\Omega$$

$$I_m = \frac{\sqrt{2} \cdot V_o}{R} = \frac{311}{10} = 31,1A$$

$$I_1 = 1 \cdot I_m = 31,1A$$

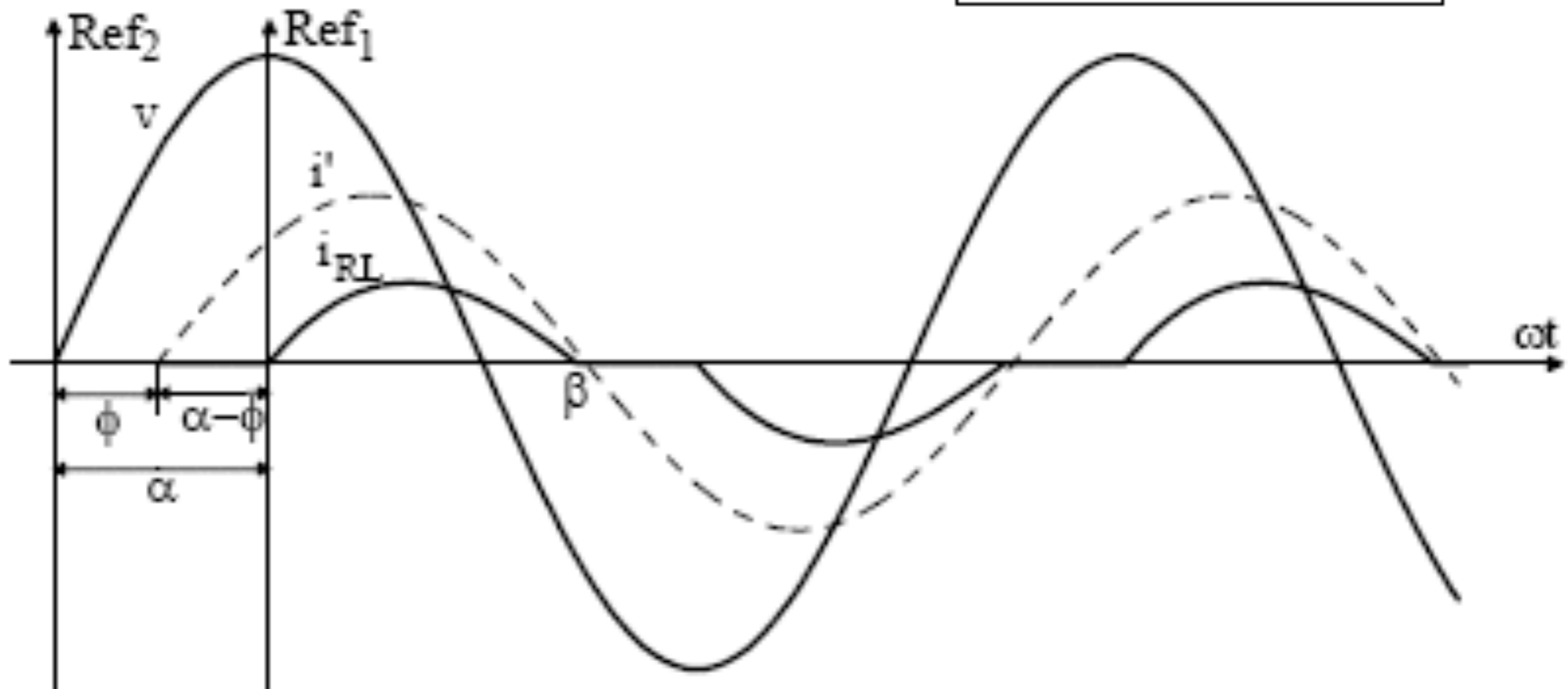
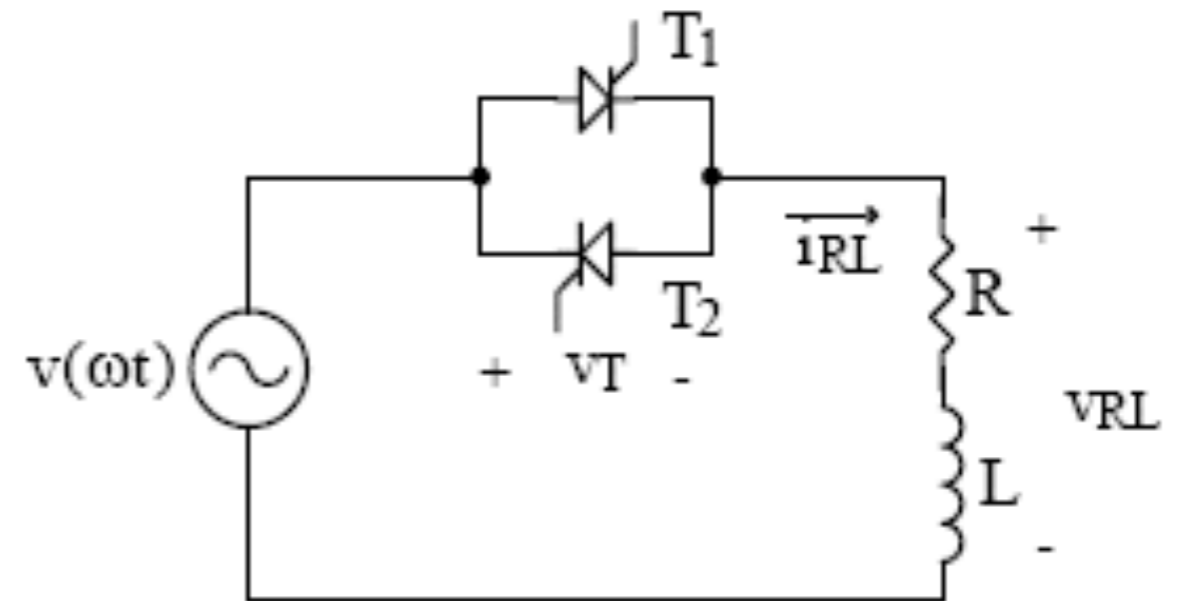
$$I_3 = 0,3 \cdot I_m = 9,33A$$

$$I_5 = 0,15 \cdot I_m = 4,66A$$



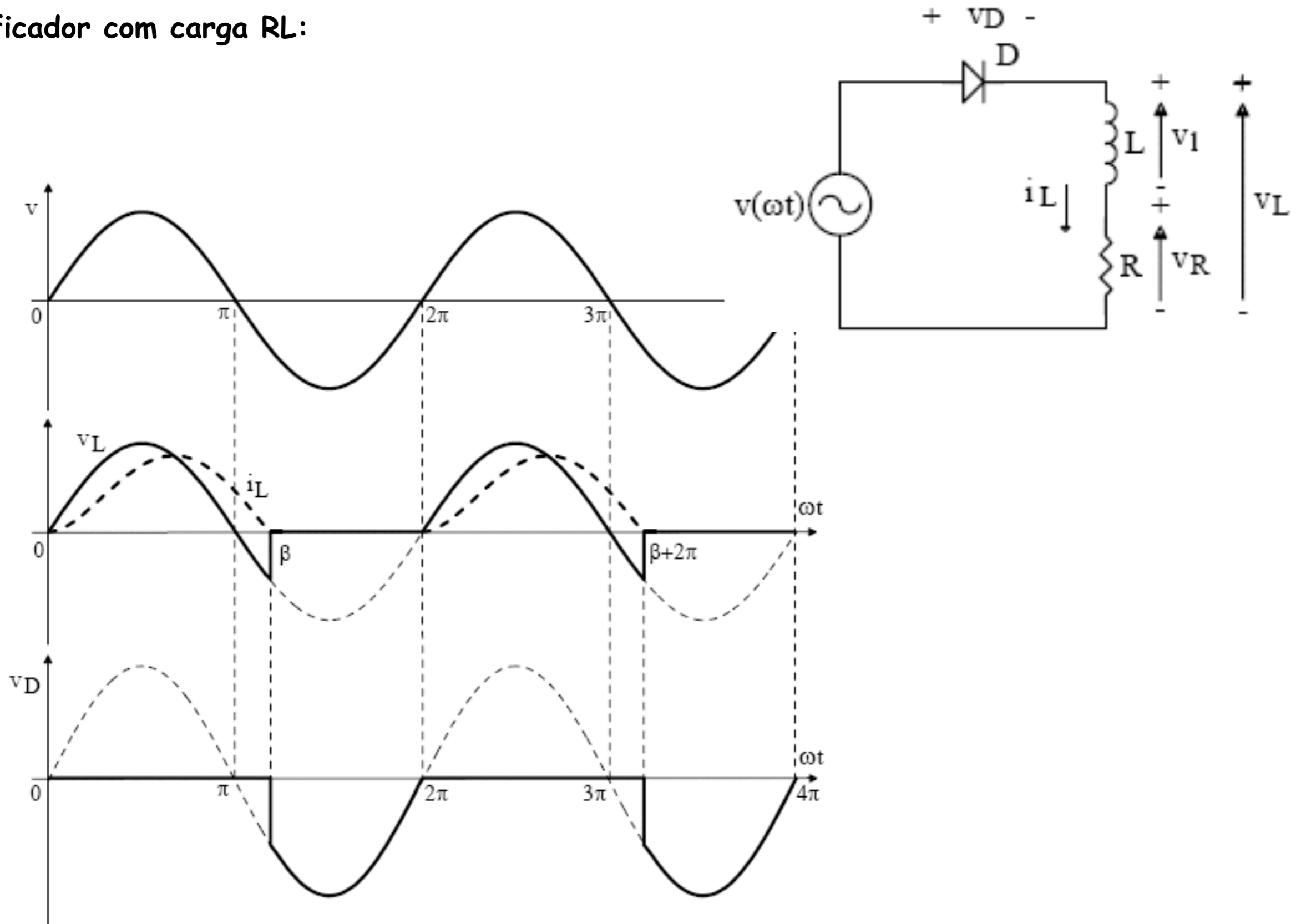
# Gradadores Monofásicos

Retificador com carga RL:



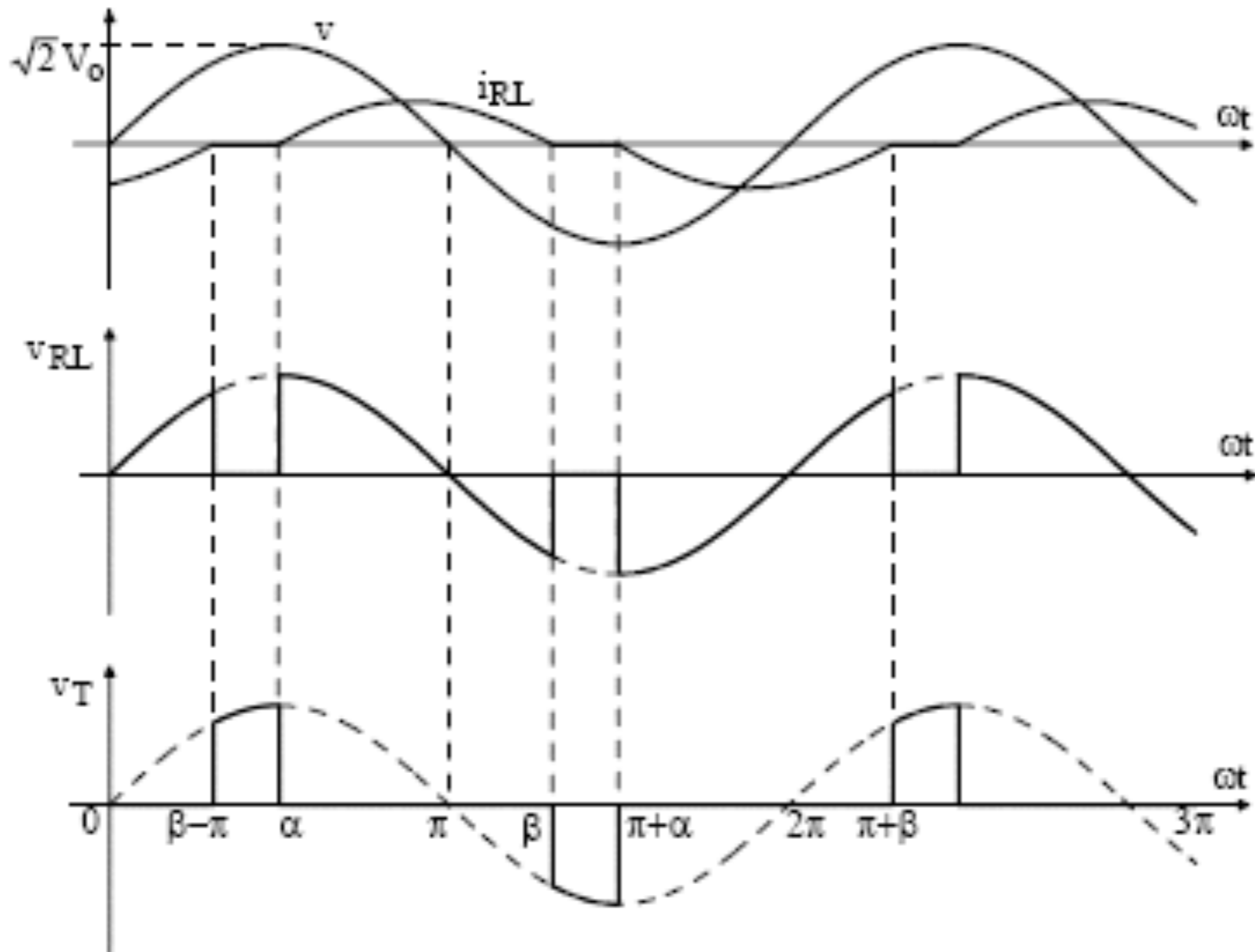
# Gradadores Monofásicos

Retificador com carga RL:

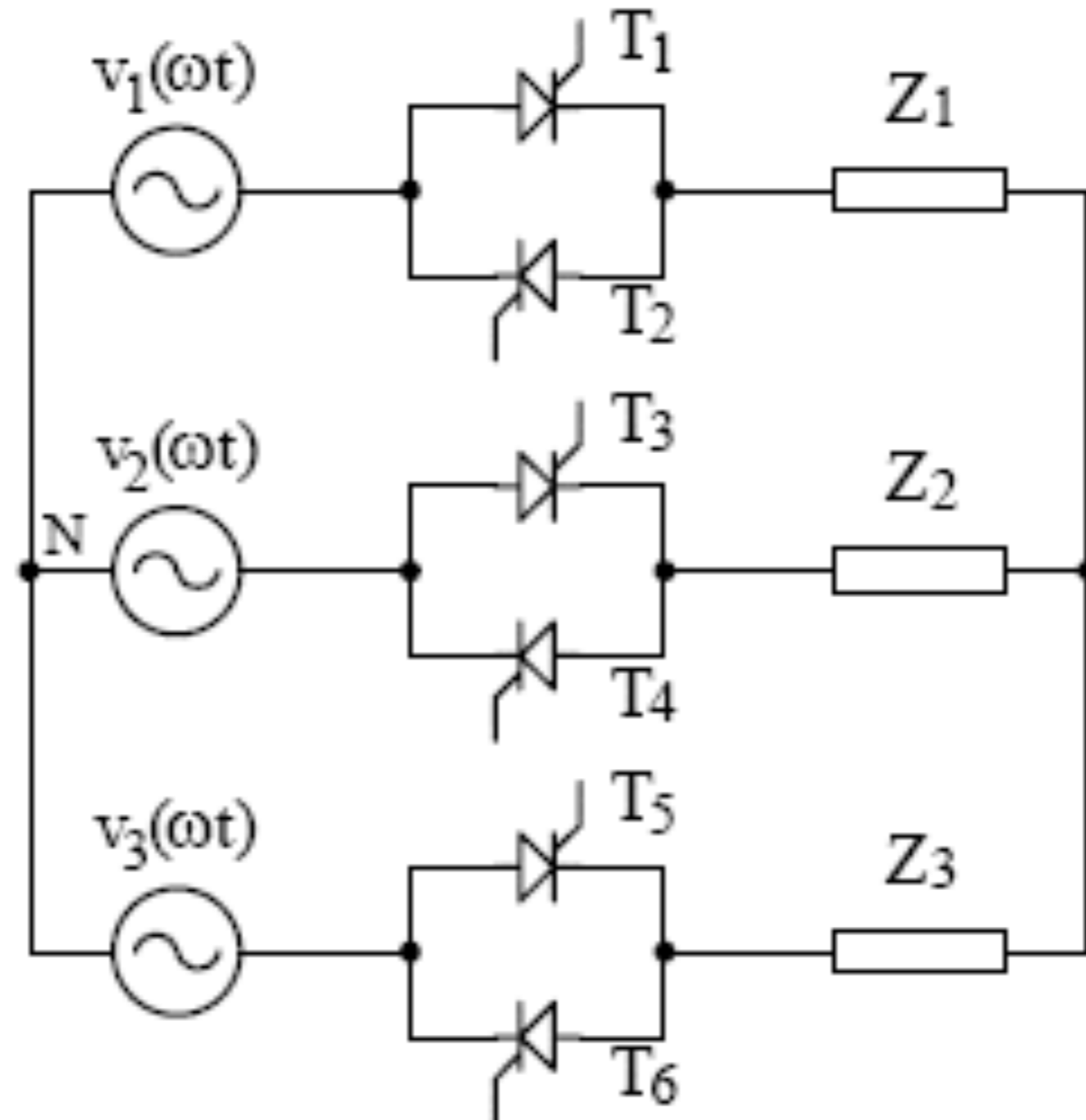


# Gradadores Monofásicos

Gradador com carga RL:

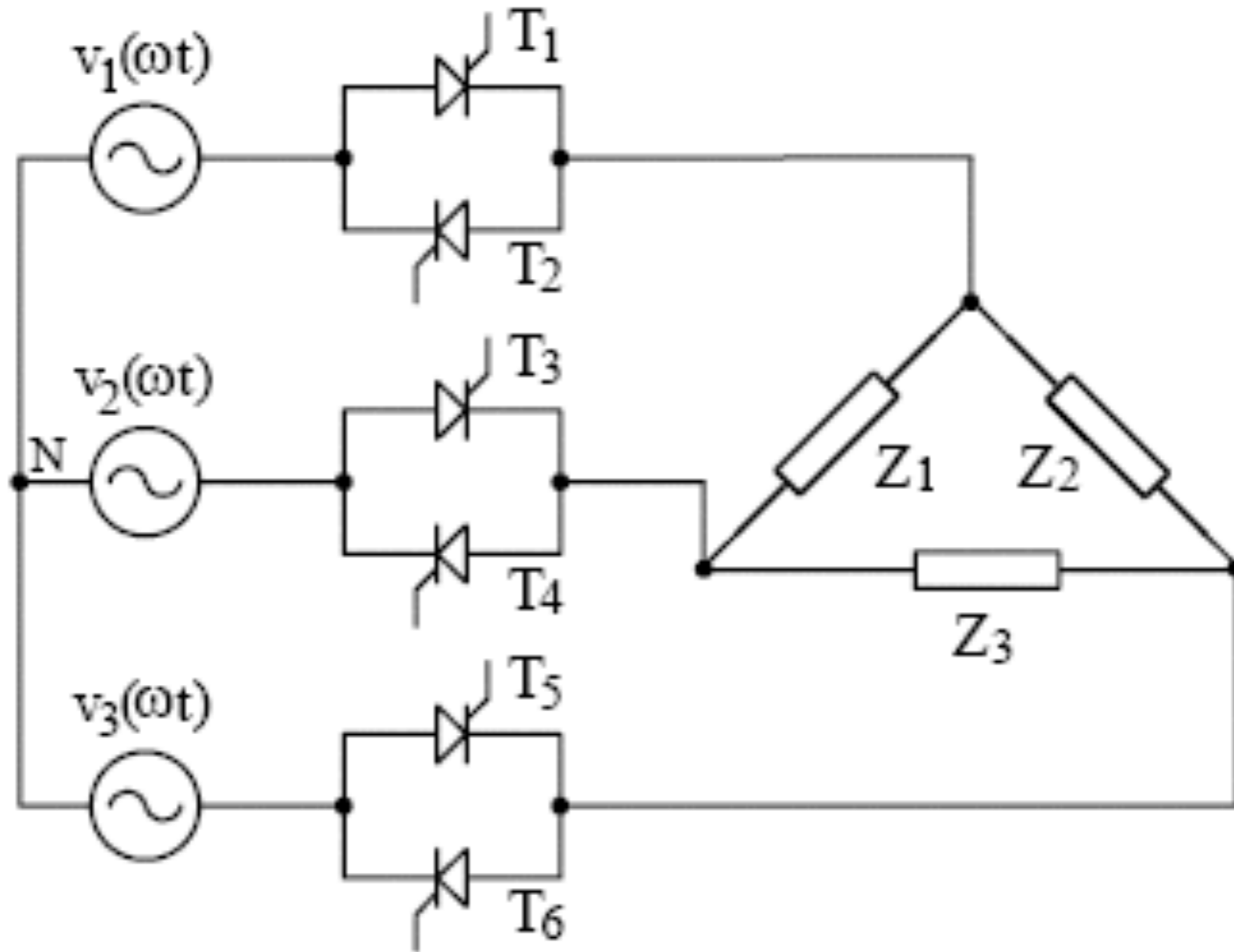


# Gradadores Trifásicos



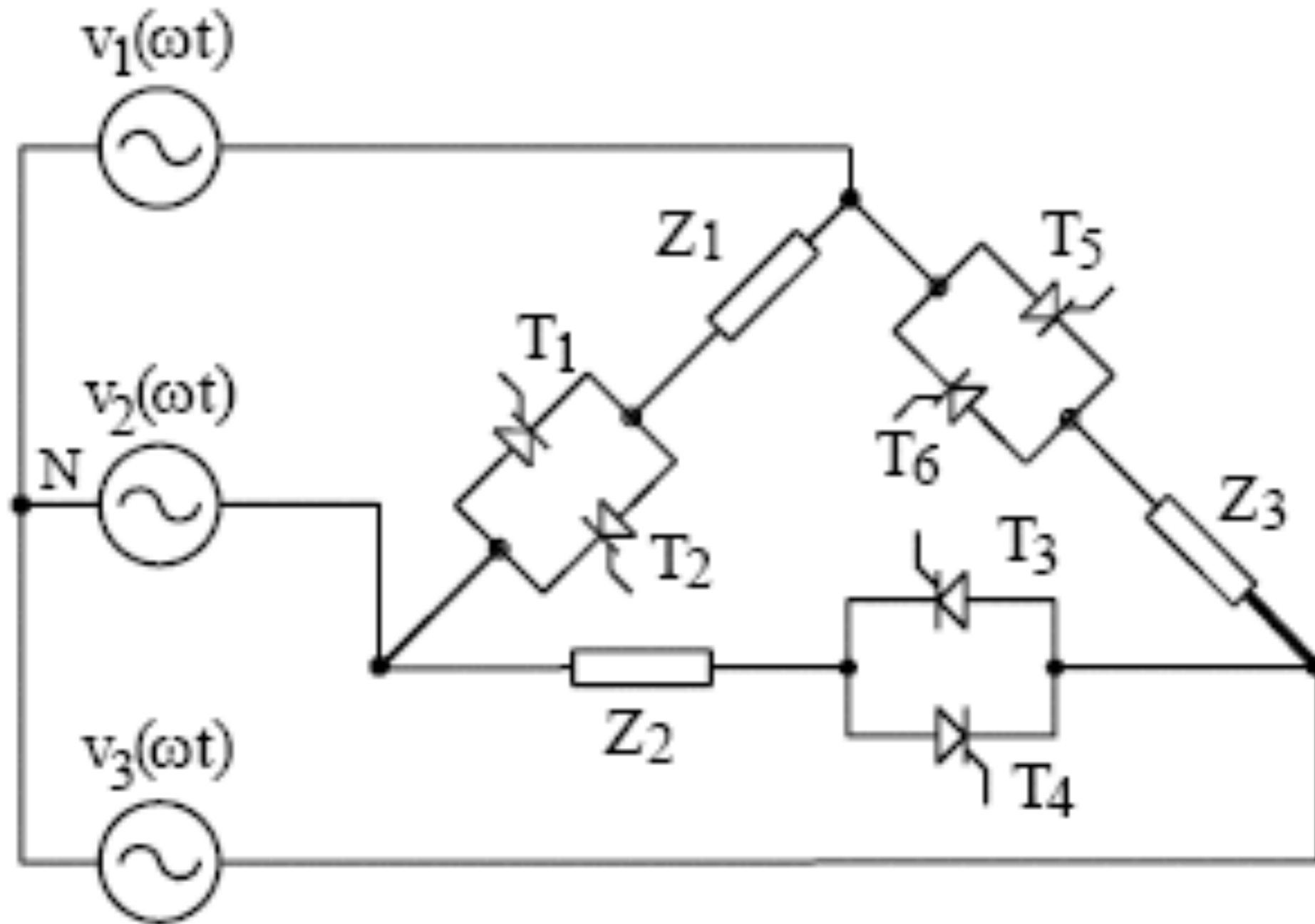
Carga conectada em estrela (Y)

# Gradadores Trifásicos



Carga conectada em delta ( $\Delta$ )

# Gradadores Trifásicos



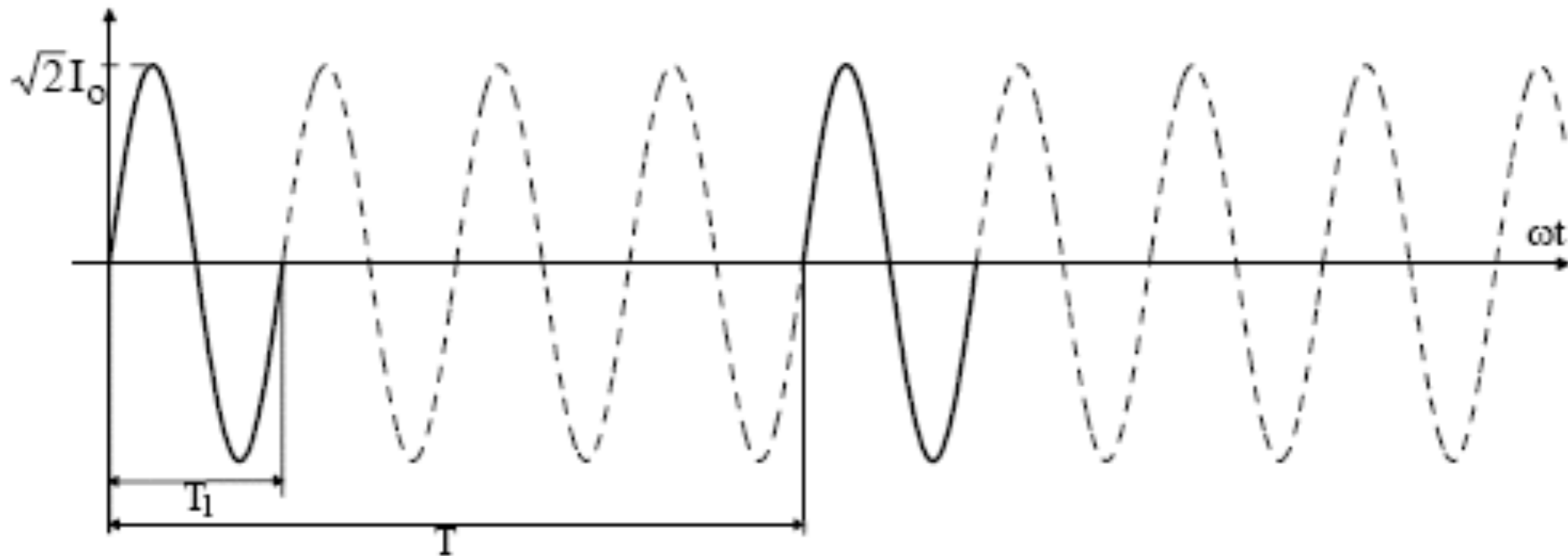
Carga conectada em delta ( $\Delta$ )

# Controle por Ciclos Inteiros

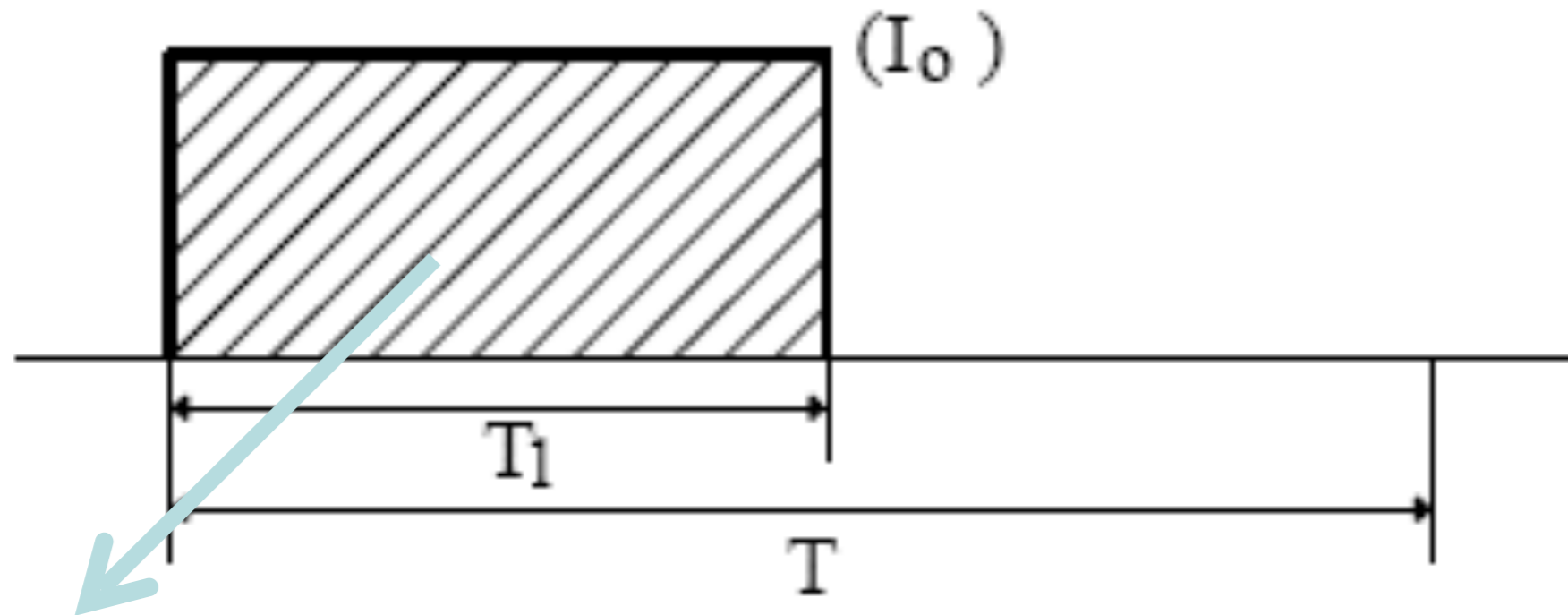
## Deficiências dos gradadores:

1. Introduzem harmônicas significativas de corrente na rede;
2. Para ângulos de disparo ( $\alpha$ ) elevados o fator de potência é baixo.

## Controle por ciclos inteiros:



# Controle por Ciclos Inteiros



$$W_1 = R \cdot I_o^2 \cdot T_1$$

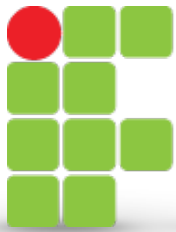
$$W_2 = R \cdot I^2 \cdot T$$

$m$  = número de ciclos aplicados à carga;  
 $M$  = número de ciclos da rede.

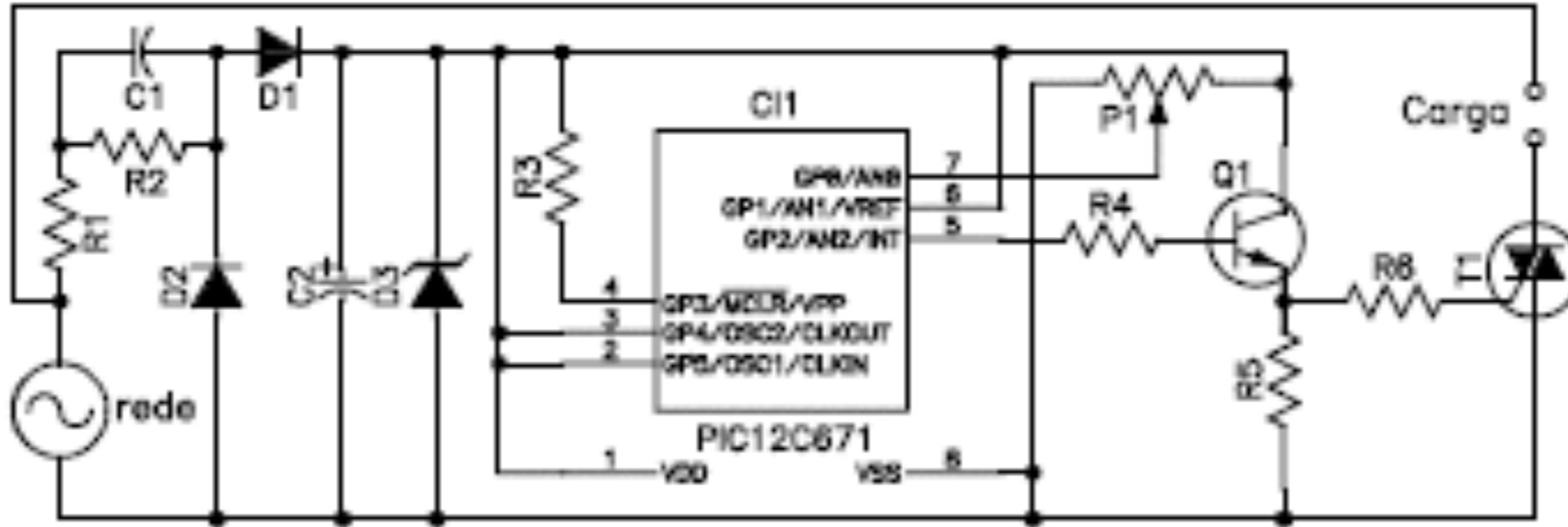
$$W_1 = W_2$$

$$R \cdot I_o^2 \cdot T_1 = R \cdot I^2 \cdot T$$

$$I = \sqrt{\frac{T_1}{T}} \cdot I_o = \sqrt{\frac{m}{M}} \cdot I_o$$



# Controle por Ciclos Inteiros



**A New Topology for Power Control of AC Load Using AC-AC Converter**

Paulo Sérgio dos Santos, Fábio de Oliveira, Osvaldo de Lencastre

1998

Abstract: This work describes the design of a new topology for power control of AC loads using AC-AC converters. The proposed topology is based on a full-bridge inverter and a diode bridge rectifier. The proposed topology is based on a full-bridge inverter and a diode bridge rectifier. The proposed topology is based on a full-bridge inverter and a diode bridge rectifier.

1. INTRODUÇÃO

2. O PROBLEMA DE CONTROLE DE POTÊNCIA

3. O PROBLEMA DE CONTROLE DE POTÊNCIA

4. O PROBLEMA DE CONTROLE DE POTÊNCIA

5. O PROBLEMA DE CONTROLE DE POTÊNCIA

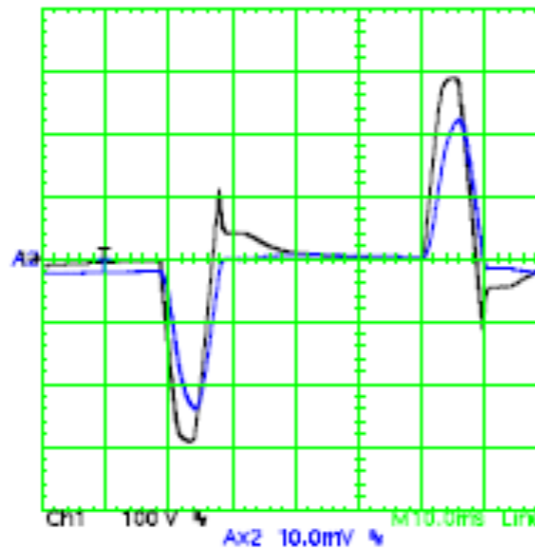
6. O PROBLEMA DE CONTROLE DE POTÊNCIA

7. O PROBLEMA DE CONTROLE DE POTÊNCIA

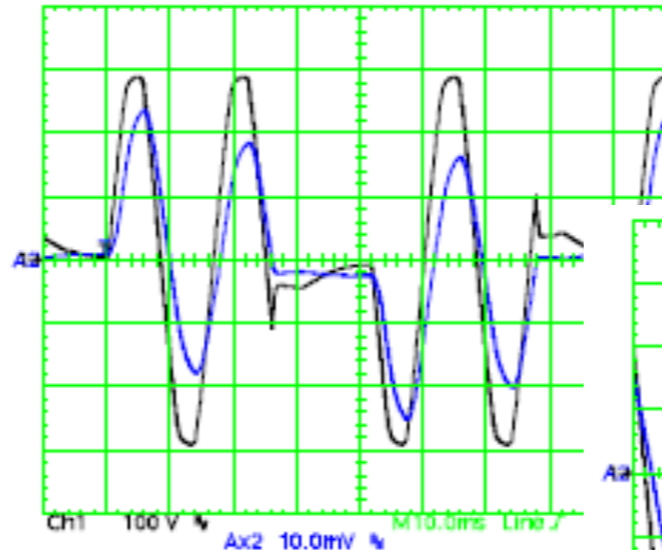
8. O PROBLEMA DE CONTROLE DE POTÊNCIA

9. O PROBLEMA DE CONTROLE DE POTÊNCIA

10. O PROBLEMA DE CONTROLE DE POTÊNCIA

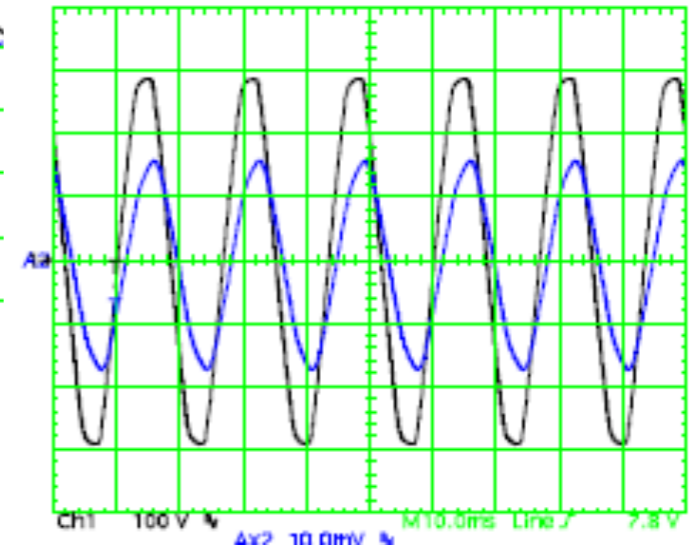


$$\frac{m}{M} = \frac{1}{5}$$

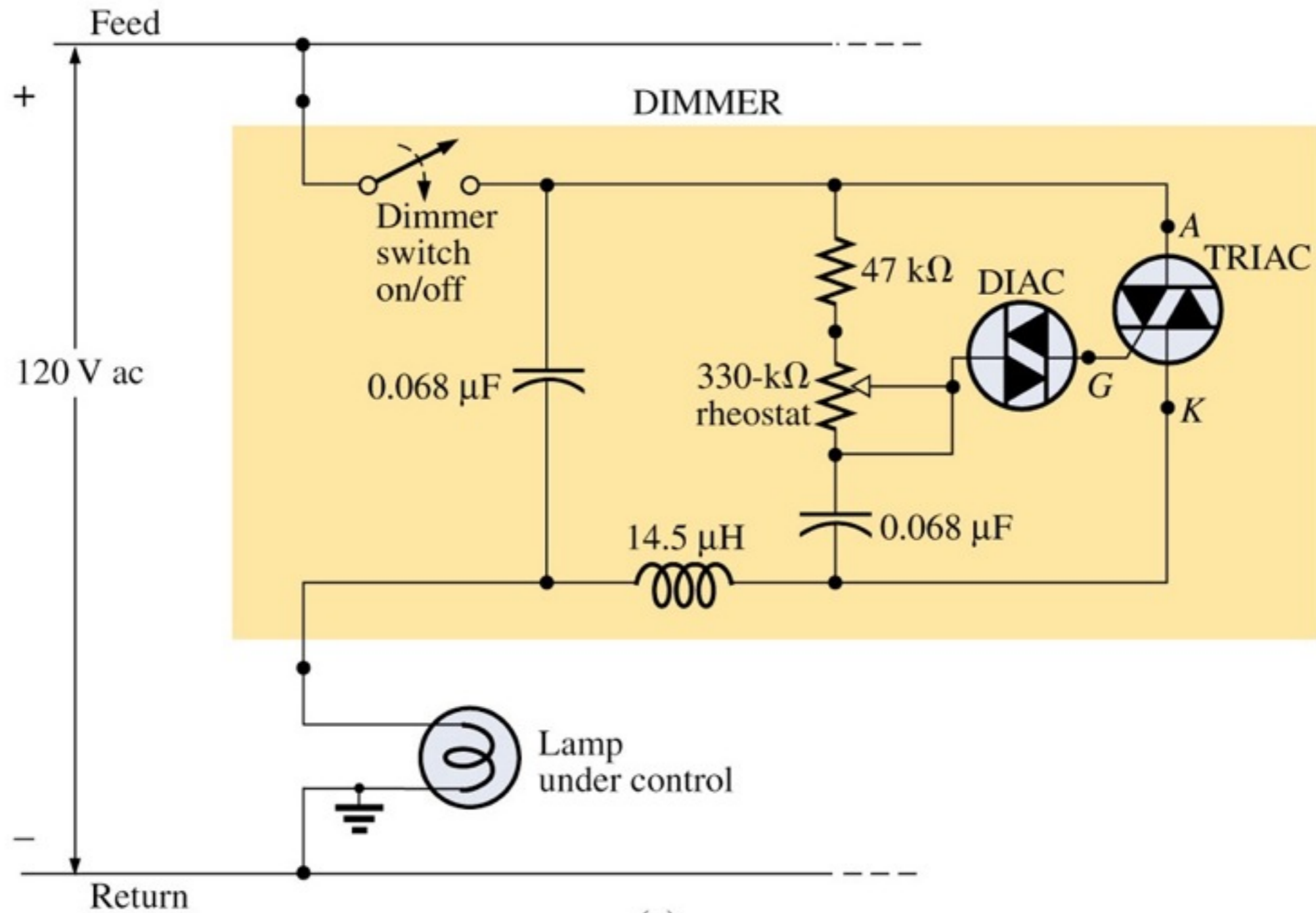


$$\frac{m}{M} = \frac{3}{5}$$

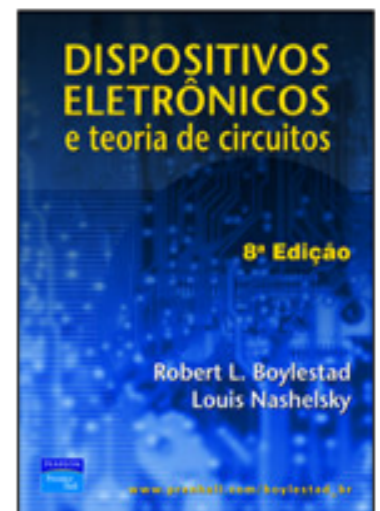
$$\frac{m}{M} = \frac{5}{5}$$



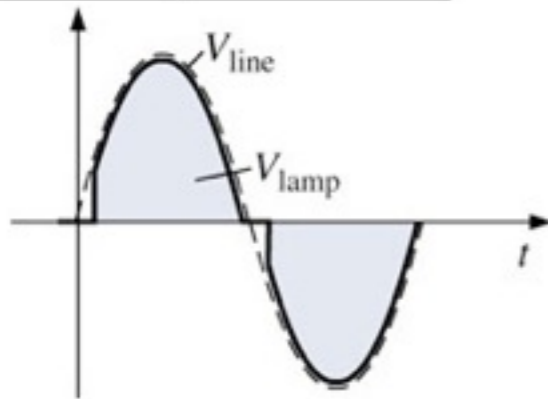
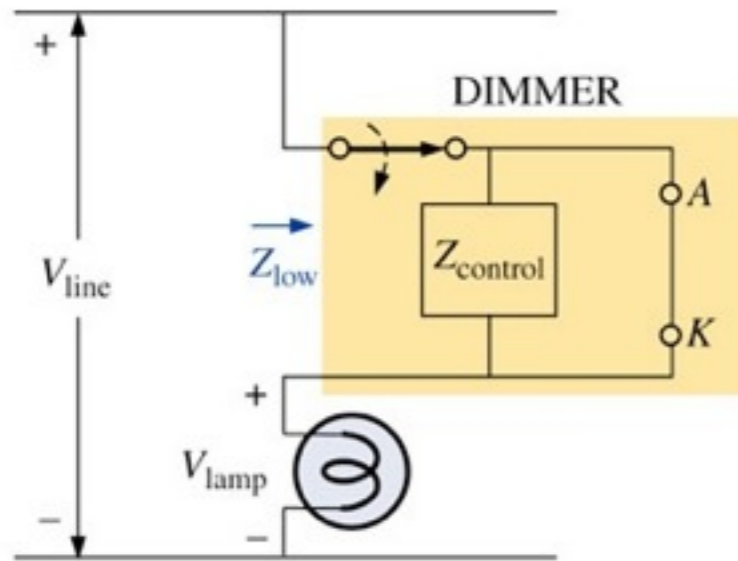
# Implementação do gradador monofásico (dimmer)



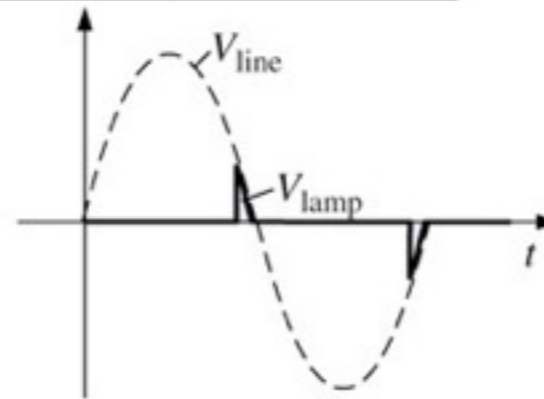
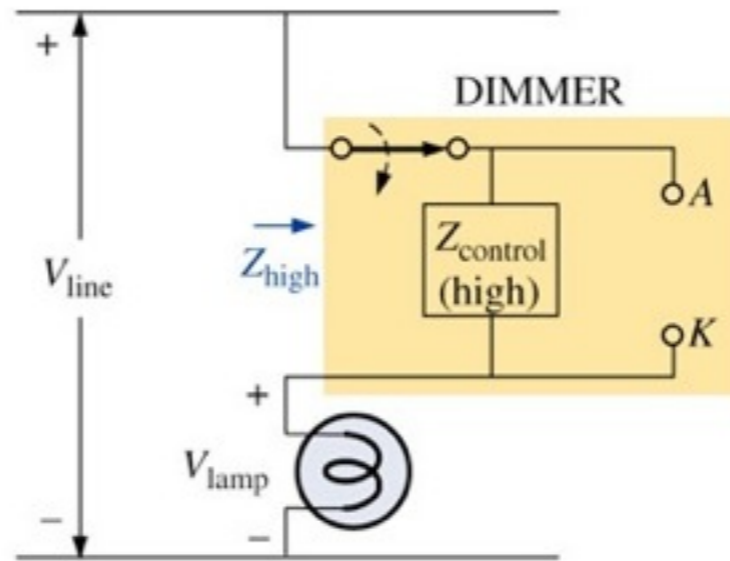
(c)



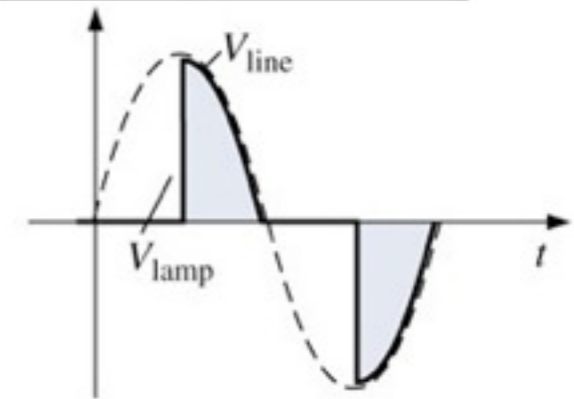
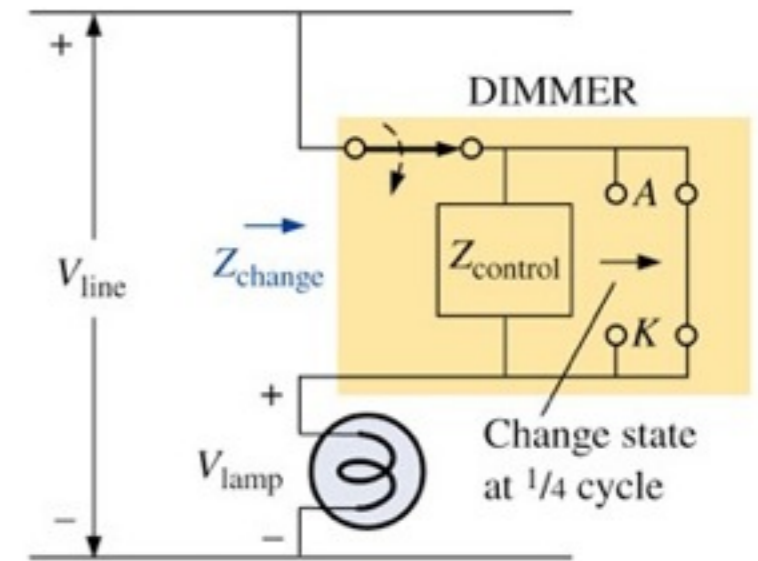
# Implementação do gradador monofásico (dimmer)



(a)

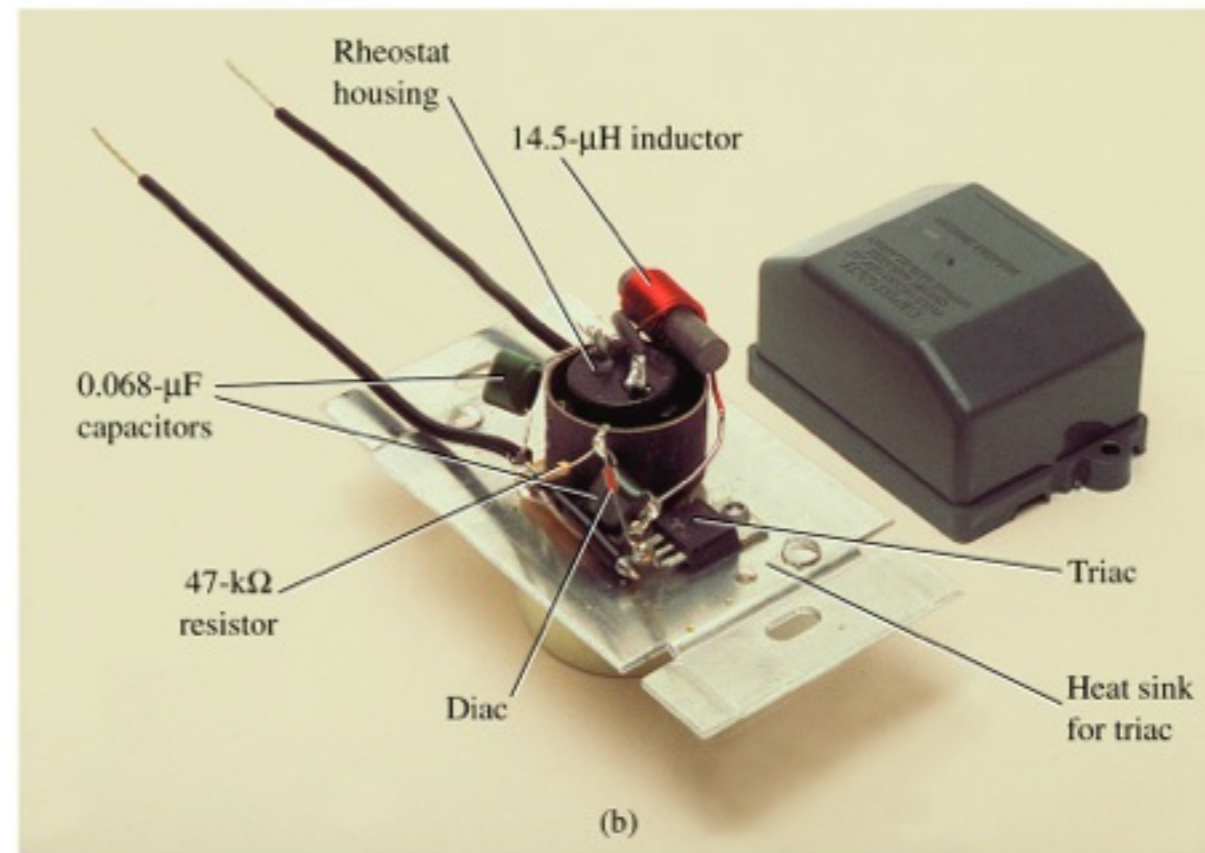


(b)



(c)

# Implementação do gradador monofásico (dimmer)

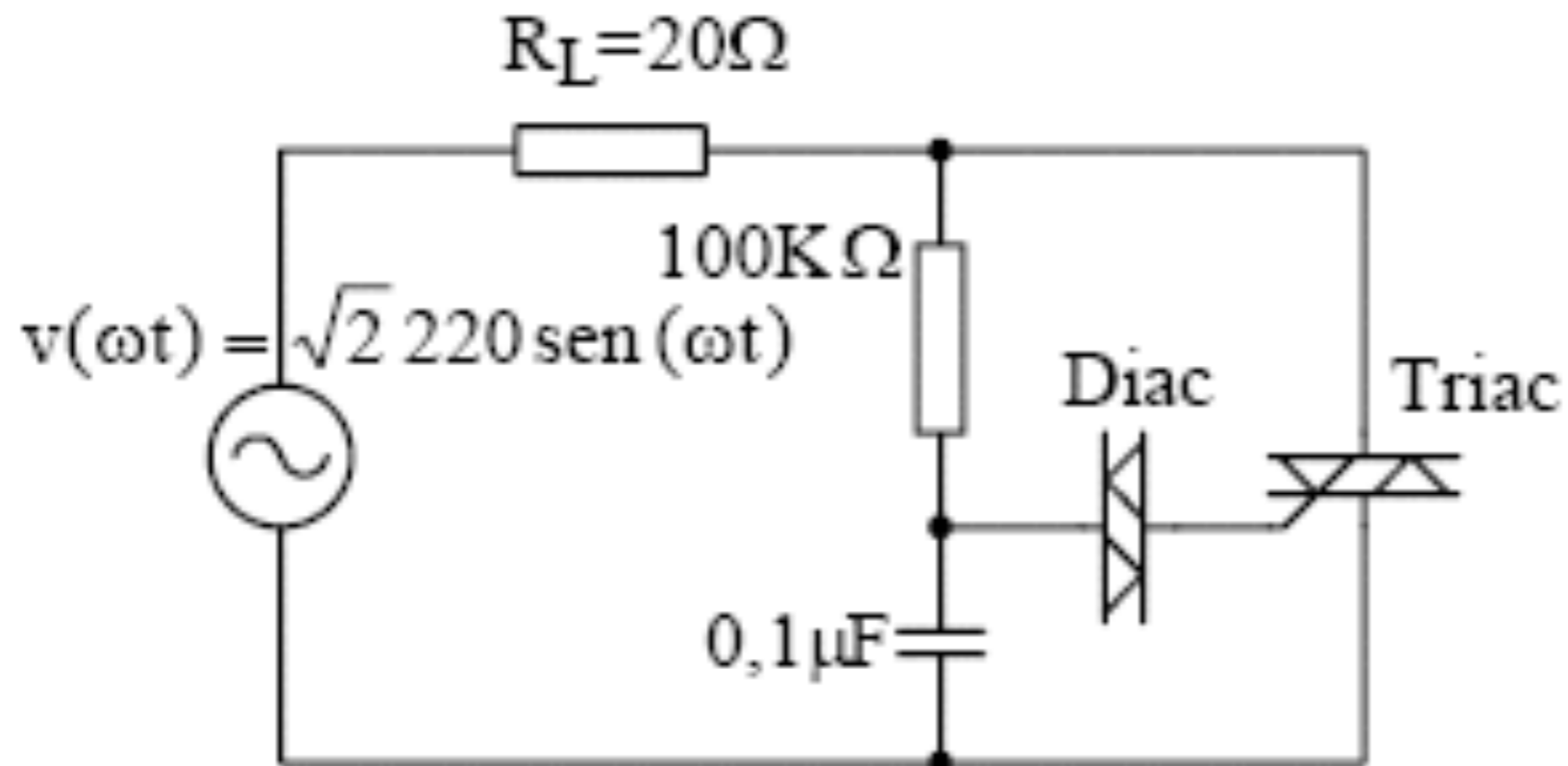


# Implementação do gradador monofásico (dimmer)

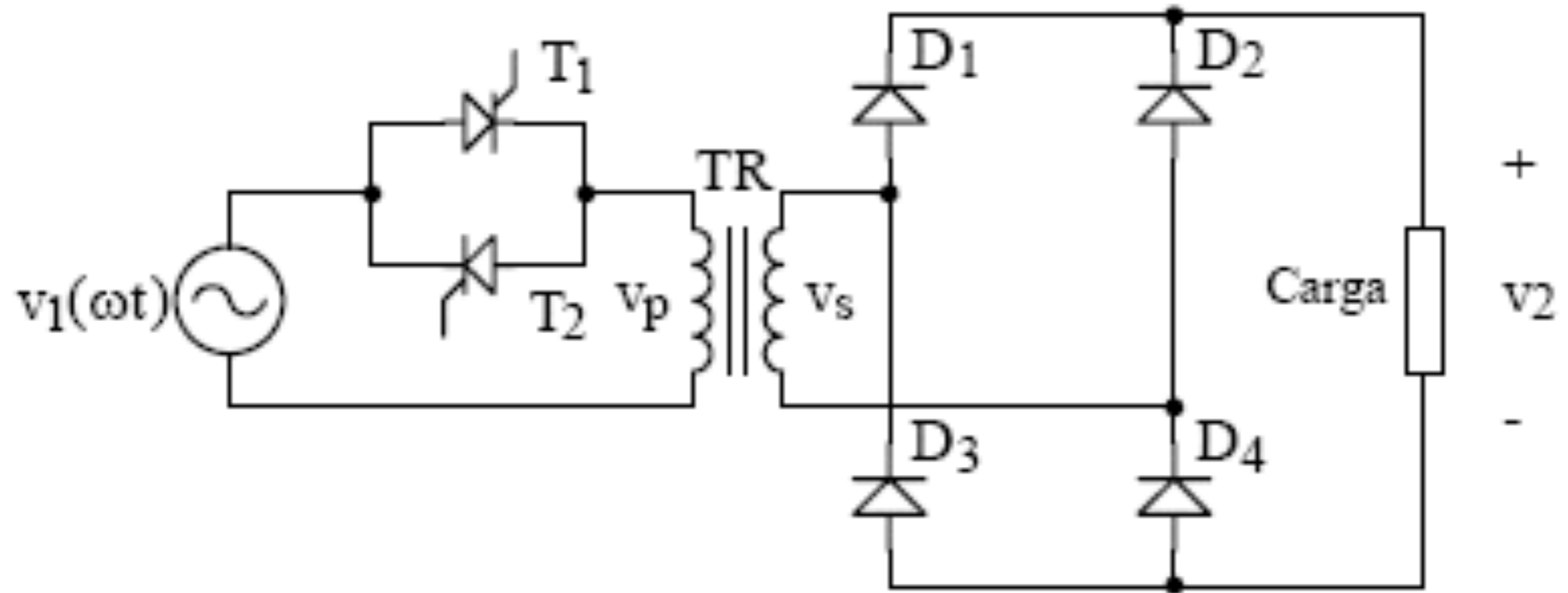
## Tarefa:

Estudar o exercício 6, do  
Capítulo 7 - Gradadores.

Diac de  $\pm 42$  V.



# Partida de Cargas com Gradadores



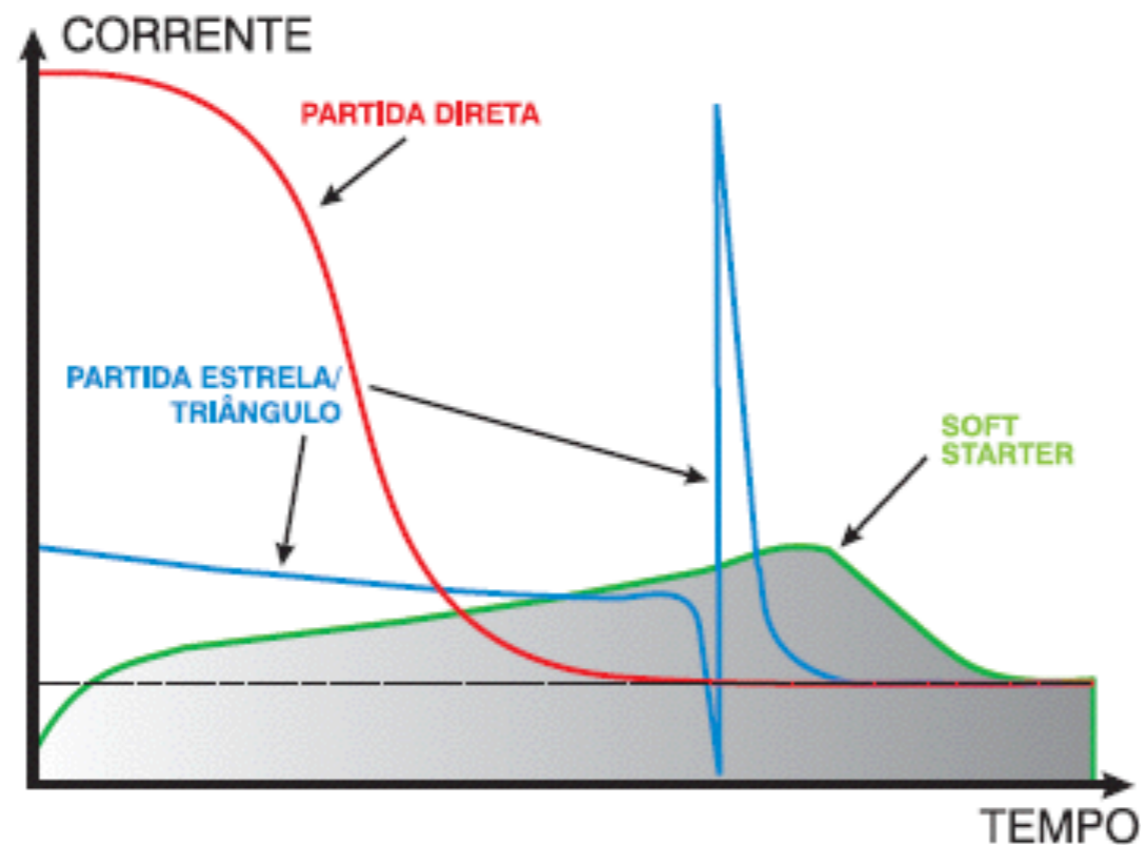
Controle da tensão de saída do retificador pelo gradador

# Partida de Cargas com Gradadores



**SSW 05**  
SOFT-STARTER  
*Plus*

- Potência : 0,75 a 75cv
- Tensão : 220 a 575 V
- By-pass incorporado
- Controle com DSP
- HMI remota (opcional)
- Proteções do motor incorporadas
- Operação em ambientes de até 55°



[www.weg.com.br](http://www.weg.com.br)

Controle da corrente de partida de motores usando gradadores

# Disparo dos Tiristores

## MKP1V120 Series

Preferred Device

### Sidac High Voltage

#### Bidirectional Triggers

Bidirectional devices designed for direct interface with the ac power line. Upon reaching the breakover voltage in each direction, the device switches from a blocking state to a low voltage on-state. Conduction will continue like a Triac until the main terminal current drops below the holding current. The plastic axial lead package provides high pulse current capability at low cost. Glass passivation insures reliable operation.

#### Features

- High Pressure Sodium Vapor Lighting
- Strobes and Flashers
- Igniters
- High Voltage Regulators
- Pulse Generators
- Used to Trigger Gates of SCR's and Triacs
- $\Phi$  Indicates UL Registered — File #E116110
- These are Pb-Free Devices\*

#### MAXIMUM RATINGS ( $T_J = 25^\circ\text{C}$ unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Repetitive Off-State Voltage (Sine Wave, 50 to 60 Hz, $T_J = -40$ to $125^\circ\text{C}$ ) MKP1V120, MKP1V130, MKP1V180 MKP1V240	$V_{DRM}$ $V_{DRM}$	$\pm 90$ $\pm 180$	V
On-State Current RMS ( $T_J = 80^\circ\text{C}$ , Lead Length = $3/8"$ , All Conduction Angles)	$I_{TRM(S)}$	$\pm 0.9$	A
Peak Non-repetitive Surge Current (80 Hz One Cycle Sine Wave, $T_J = 125^\circ\text{C}$ )	$I_{TSM}$	$\pm 4.0$	A
Operating Junction Temperature Range	$T_J$	$-40$ to $+125$	$^\circ\text{C}$
Storage Temperature Range	$T_{stg}$	$-40$ to $+150$	$^\circ\text{C}$

#### THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction-to-Lead Lead Length = $3/8"$	$R_{\theta JL}$	40	$^\circ\text{C/W}$
Lead Solder Temperature (Lead Length $\geq 1/16"$ from Case, 10 s Max)	$T_L$	260	$^\circ\text{C}$

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

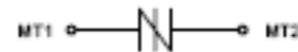
\*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.



ON Semiconductor®

http://onsemi.com

SIDACS( $\Phi$ )  
0.9 AMPERES RMS  
120 - 240 VOLTS



#### MARKING DIAGRAM

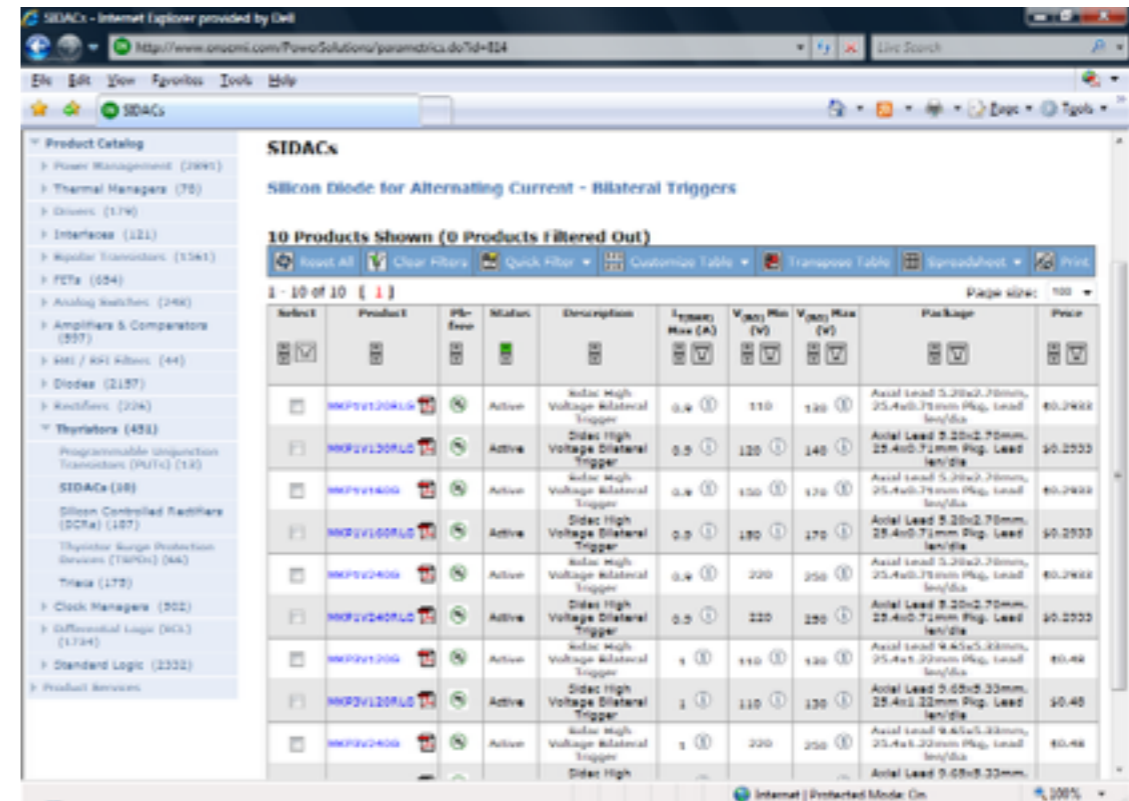


A = Assembly Location  
MKP1Vxxx0 = Device Number  
xx = 12, 13, 15 or 24  
YY = Year  
WW = Work Week  
• = Pb-Free Package  
(Note: Microdot may be in either location)

#### ORDERING INFORMATION

See detailed ordering and shipping information on page 2 of this data sheet.

Preferred devices are recommended choices for future use and best overall value.



SIDACs - Internet Explorer provided by Dell  
http://www.onsemi.com/PowerSolutions/parametrics.do?td=524

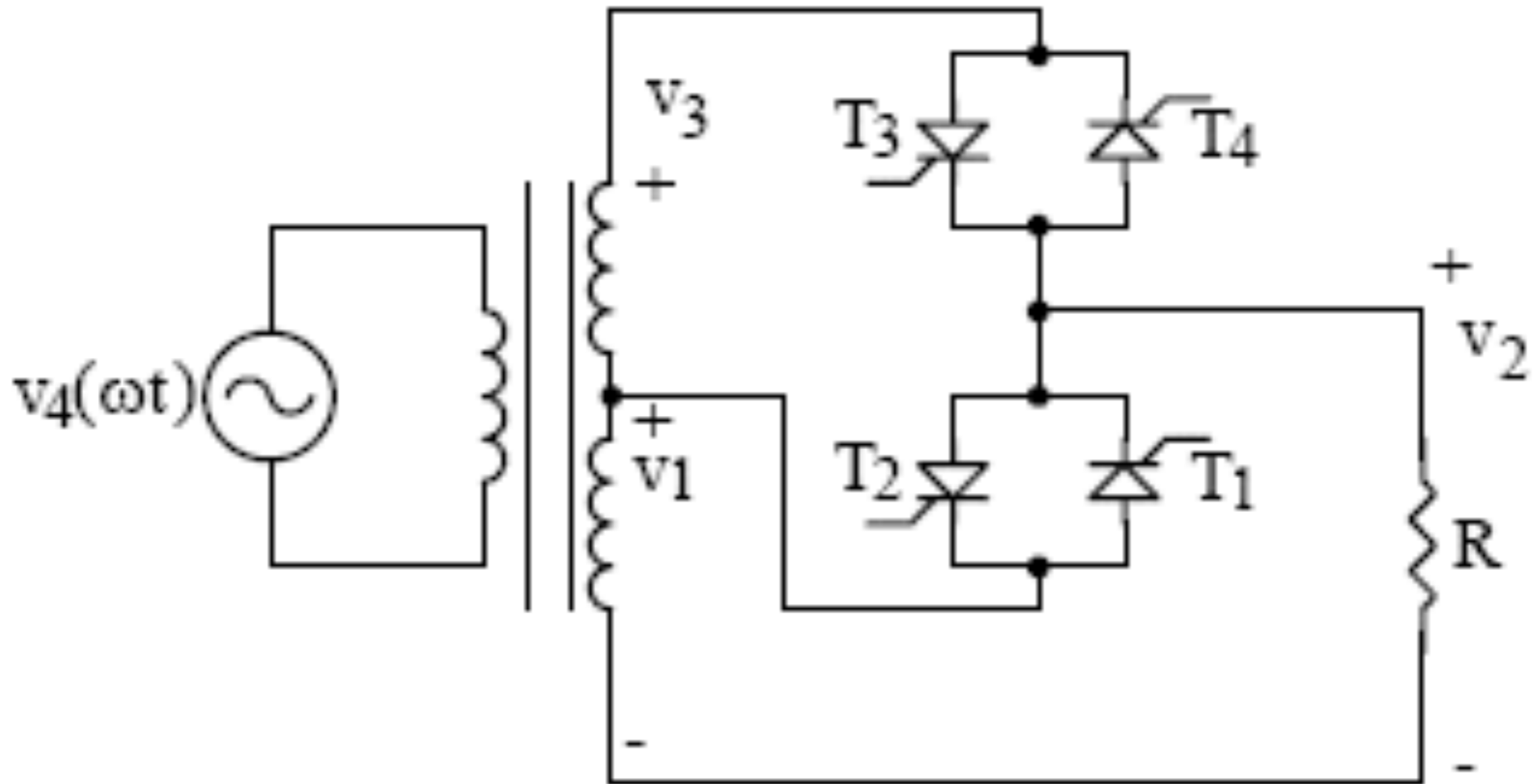
SIDACs  
Silicon Diode for Alternating Current - Bilateral Triggers

10 Products Shown (0 Products Filtered Out)

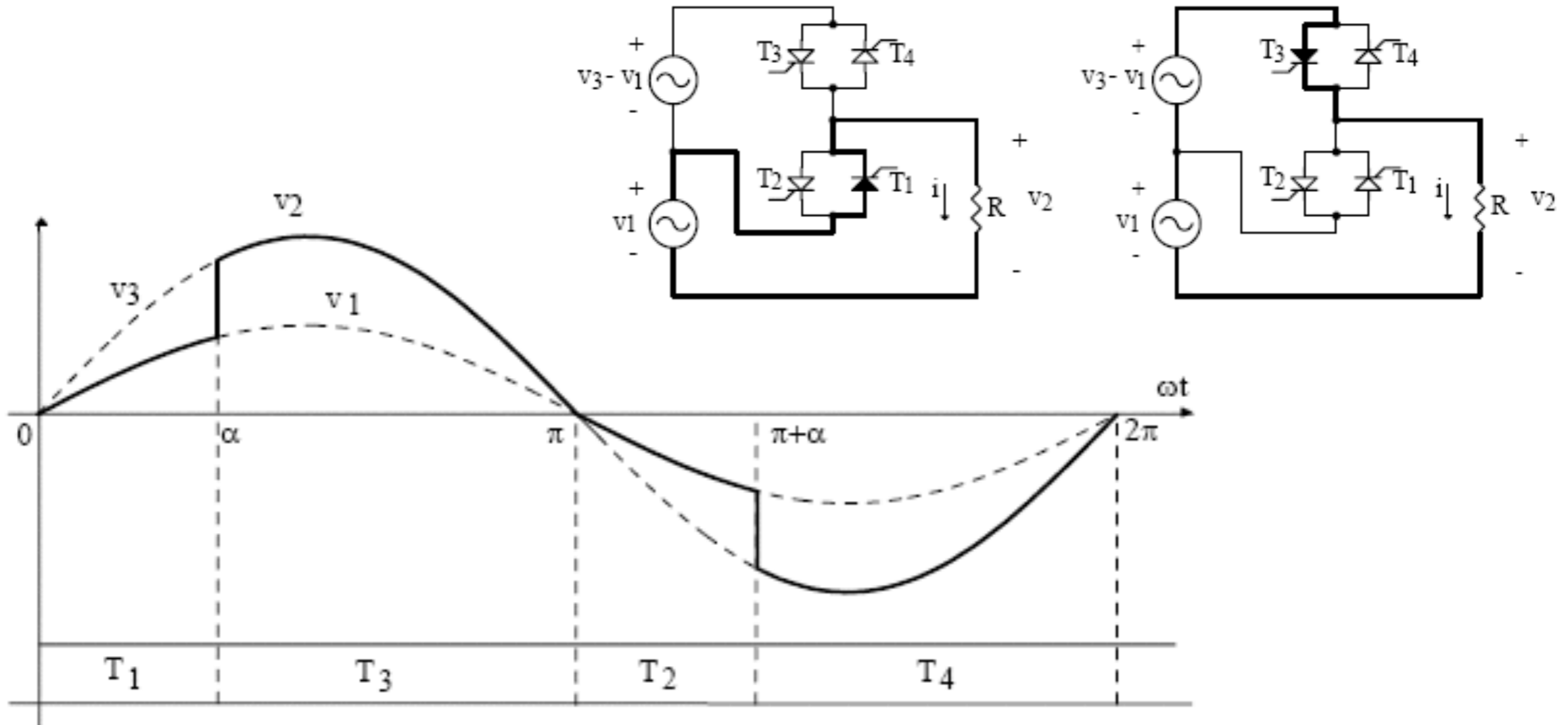
Select	Product	Pb-Free	Status	Description	$I_{TRM(S)}$ Max (A)	$V_{DRM}$ Min (V)	$V_{DRM}$ Max (V)	Package	Price
<input type="checkbox"/>	MKP1V120ALD	$\Phi$	Active	Sidac High Voltage Bilateral Trigger	0.9	110	120	Axial Lead 5.20x2.70mm, 25.4x1.27mm Pig. Lead Sn/Pb	\$0.2600
<input type="checkbox"/>	MKP1V120FLD	$\Phi$	Active	Sidac High Voltage Diateral Trigger	0.9	120	140	Axial Lead 5.20x2.70mm, 25.4x1.27mm Pig. Lead Sn/Pb	\$0.2500
<input type="checkbox"/>	MKP1V140L	$\Phi$	Active	Sidac High Voltage Bilateral Trigger	0.9	150	170	Axial Lead 5.20x2.70mm, 25.4x1.27mm Pig. Lead Sn/Pb	\$0.2600
<input type="checkbox"/>	MKP1V140FLD	$\Phi$	Active	Sidac High Voltage Diateral Trigger	0.9	180	170	Axial Lead 5.20x2.70mm, 25.4x1.27mm Pig. Lead Sn/Pb	\$0.2500
<input type="checkbox"/>	MKP1V240L	$\Phi$	Active	Sidac High Voltage Bilateral Trigger	0.9	200	250	Axial Lead 5.20x2.70mm, 25.4x1.27mm Pig. Lead Sn/Pb	\$0.2600
<input type="checkbox"/>	MKP1V240FLD	$\Phi$	Active	Sidac High Voltage Diateral Trigger	0.9	220	250	Axial Lead 5.20x2.70mm, 25.4x1.27mm Pig. Lead Sn/Pb	\$0.2500
<input type="checkbox"/>	MKP1V120L	$\Phi$	Active	Sidac High Voltage Bilateral Trigger	1	110	120	Axial Lead 9.65x5.33mm, 25.4x1.27mm Pig. Lead Sn/Pb	\$0.40
<input type="checkbox"/>	MKP1V120FLD	$\Phi$	Active	Sidac High Voltage Diateral Trigger	1	110	130	Axial Lead 9.65x5.33mm, 25.4x1.27mm Pig. Lead Sn/Pb	\$0.40
<input type="checkbox"/>	MKP1V240L	$\Phi$	Active	Sidac High Voltage Bilateral Trigger	1	200	250	Axial Lead 9.65x5.33mm, 25.4x1.27mm Pig. Lead Sn/Pb	\$0.40
<input type="checkbox"/>	MKP1V240FLD	$\Phi$	Active	Sidac High Voltage Diateral Trigger	1	200	250	Axial Lead 9.65x5.33mm, 25.4x1.27mm Pig. Lead Sn/Pb	\$0.40

[www.onsemi.com.br](http://www.onsemi.com.br)

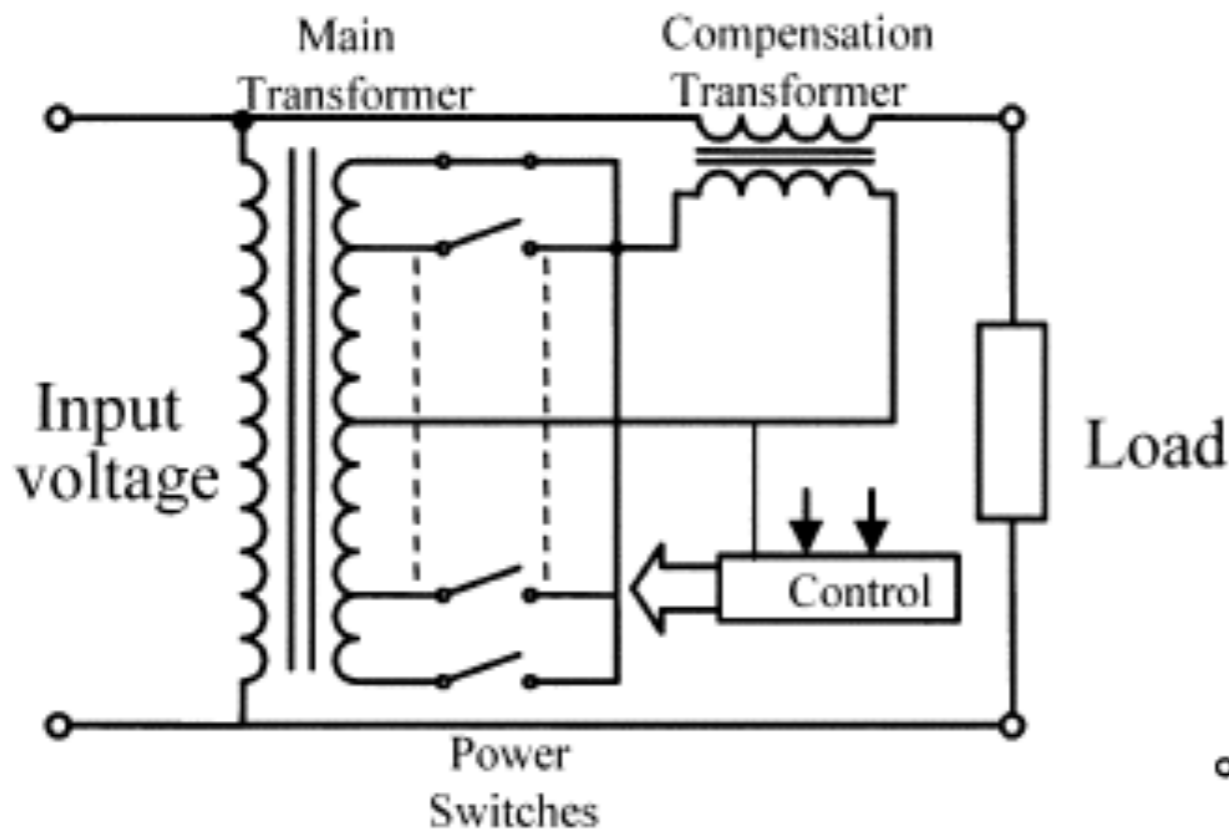
# Estabilizador em Derivação (tap variável)



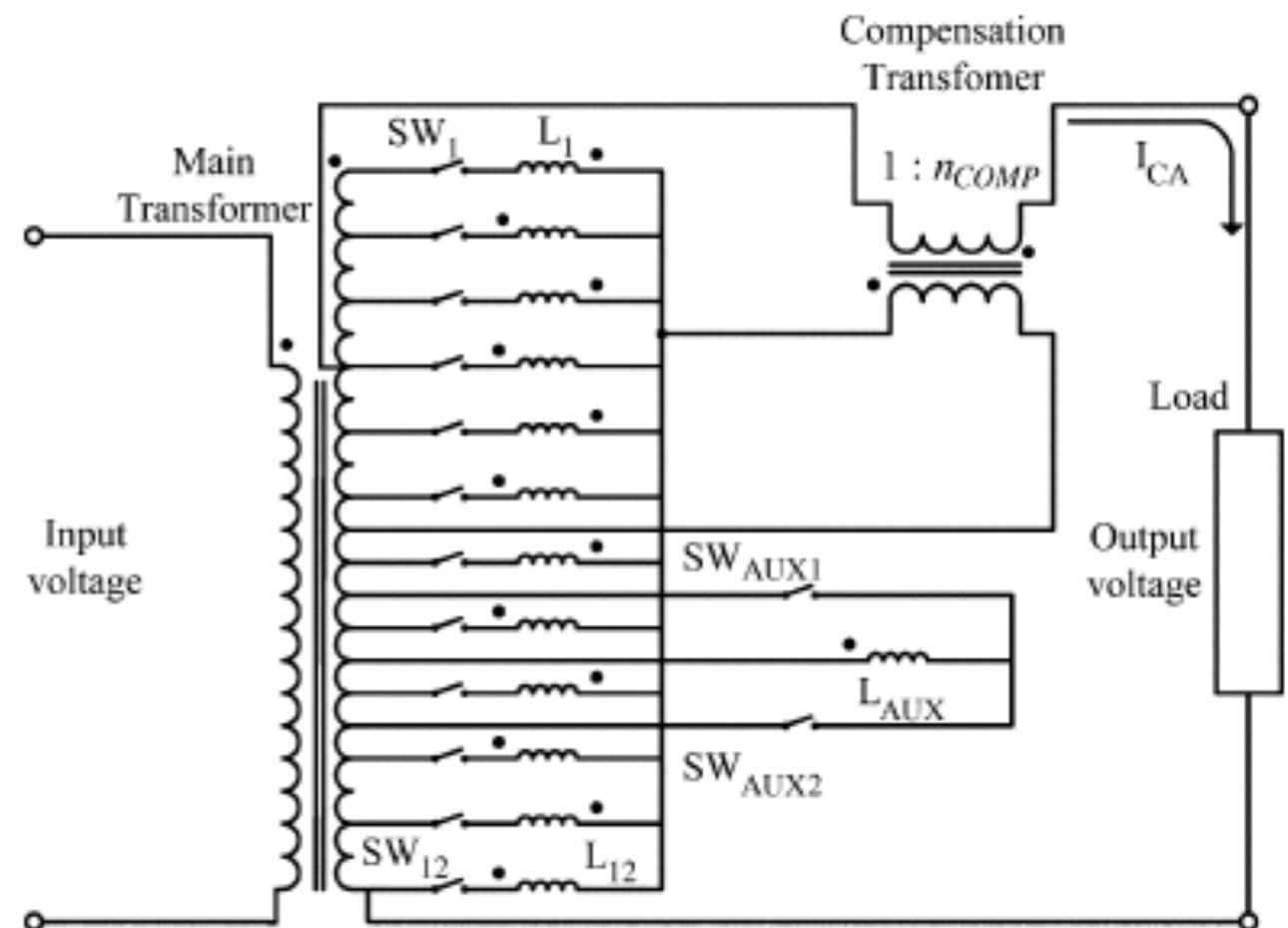
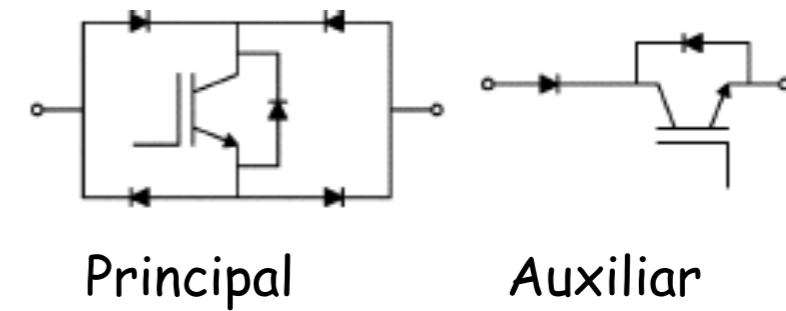
# Estabilizador em Derivação (tap variável)



# Estabilizador em Derivação (tap variável)



Echavarría et al, 2007.



## Conversores ca-ca:

- Estabilizadores de tensão.

