

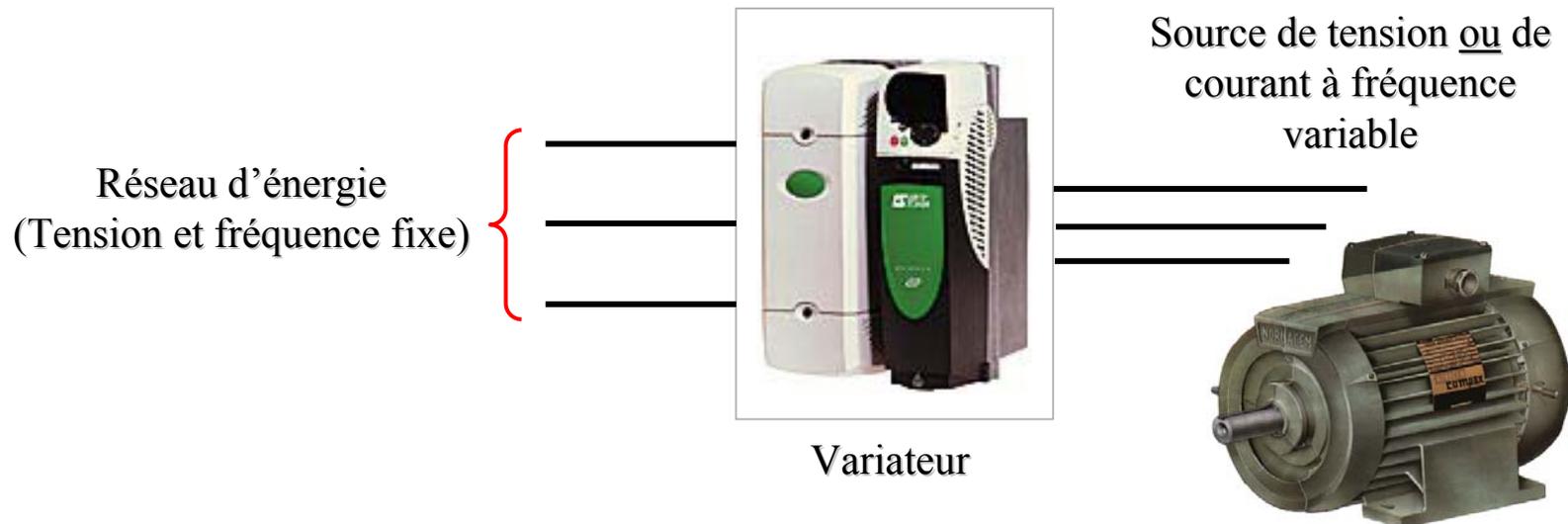
I

LES CONVERTISSEURS STATIQUES D'ENERGIE

I.1 Généralités

Adapter l'énergie électrique à l'application

- ✓ Fonctionnement en vitesse variable
- ✓ Freinage contrôlé et avec renvoi de l'énergie sur le réseau
- ✓ Fonctionnement à couple (effort moteur) contrôlé
- ✓ ...



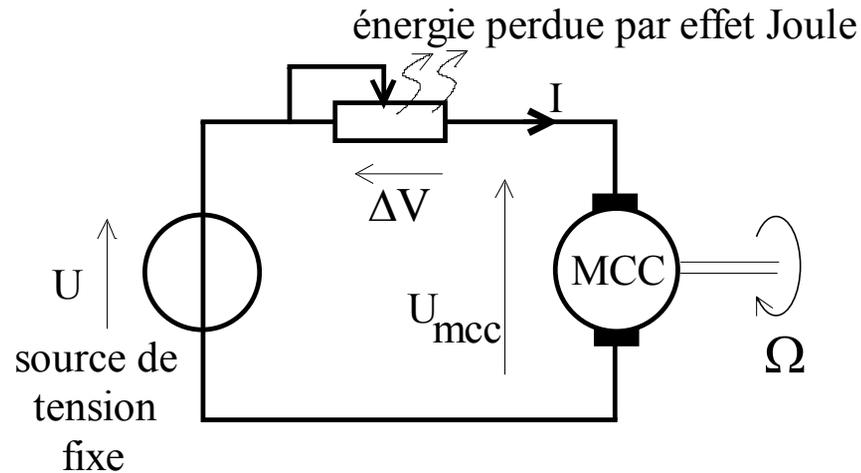
Exemple : Variation de vitesse en traction ferroviaire



TGV PSE (1981)
12 Moteurs à Courant Continu de 535 kW

Variation de vitesse d'une MCC \longrightarrow Variation de tension d'alimentation

■ Solution 1



Mauvais rendement
Contrôle difficile



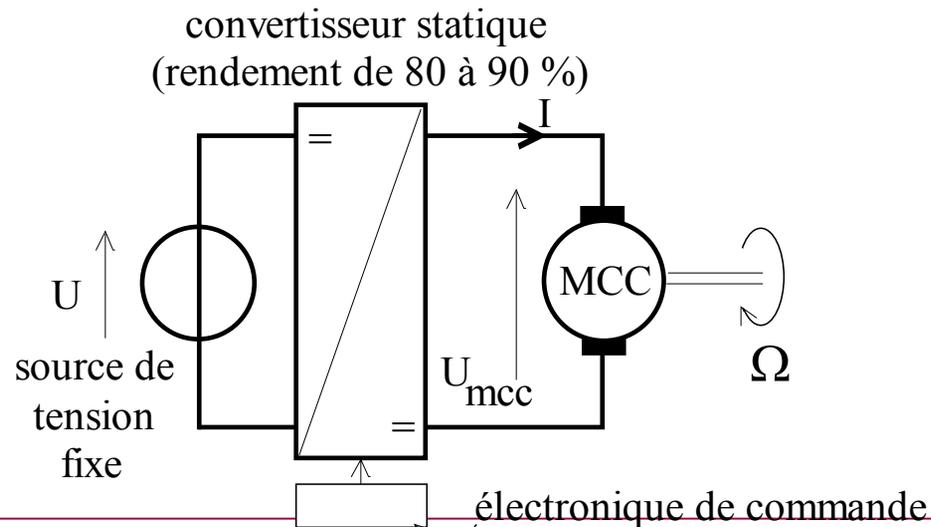
Exemple : Variation de vitesse en traction ferroviaire



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Variation de vitesse d'une MCC \longrightarrow Variation de tension d'alimentation

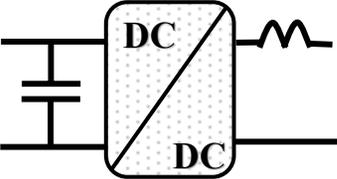
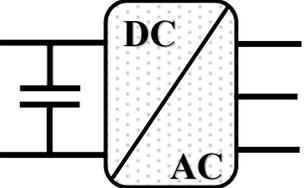
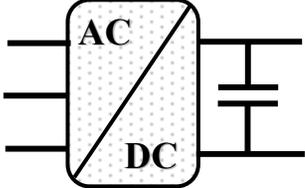
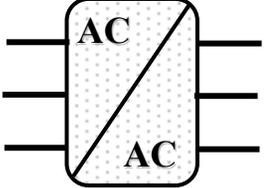
■ **Solution 2**



Bon rendement
Contrôle amélioré

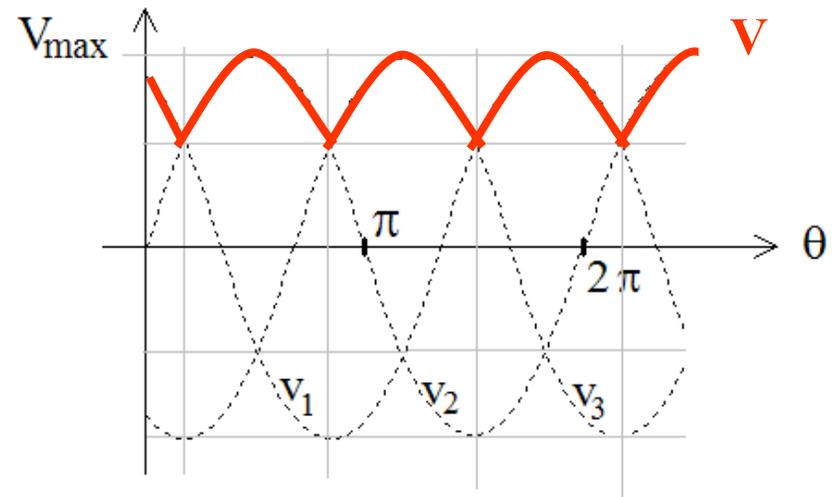
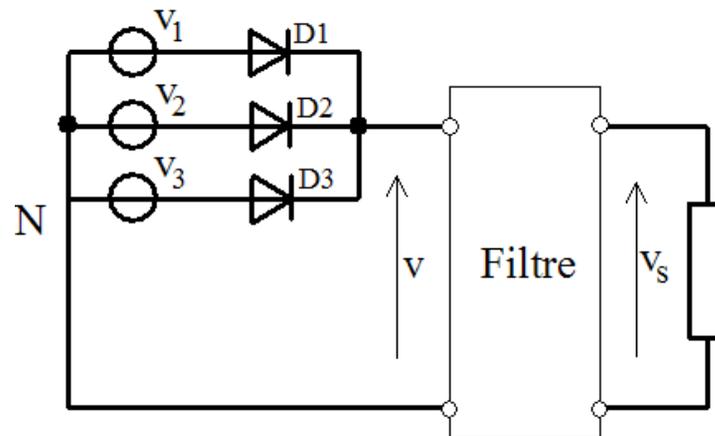


I.2 Les différentes familles de conversion

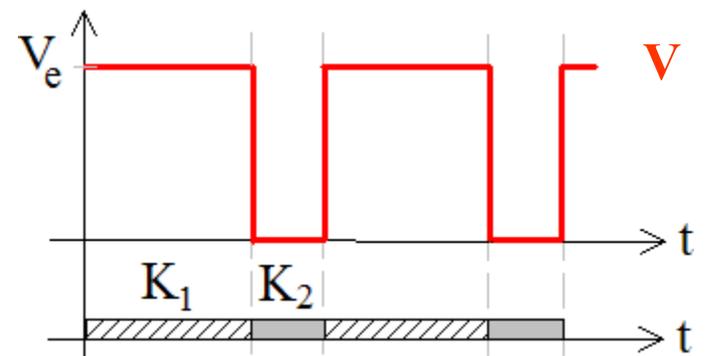
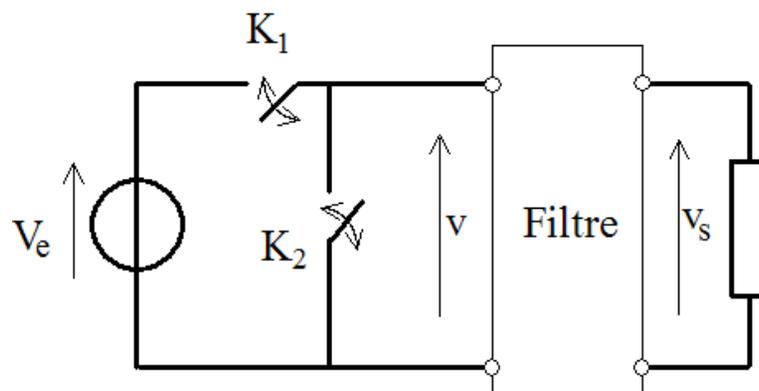
<i>Type de Conversion</i>	<i>Symbole</i>	<i>Montage</i>	<i>Applications</i>
<i>Continu/Continu</i>		HACHEUR	Machines à courant continu
<i>Continu/Alternatif</i>		ONDULEUR	Machines à courant alternatif Moteurs Pas à Pas
<i>Alternatif/Continu</i>		REDRESSEUR	Réalisation de la tension DC fixe pour l'alimentation de la plupart des machines
<i>Alternatif/Alternatif</i>		GRADATEUR	Quelques applications (Démarreurs...)

I.3 Principe de réalisation des sources d'alimentation

■ Les Redresseurs



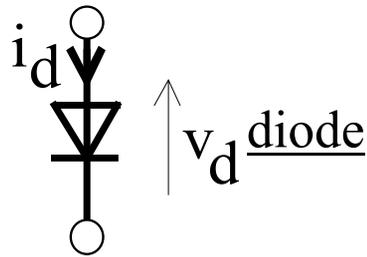
■ Les Convertisseurs à découpage



I.4 Les composants de l'électronique de puissance

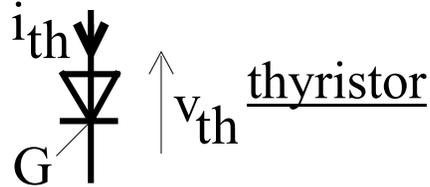
- Les composants non commandables

→ **DIODES**



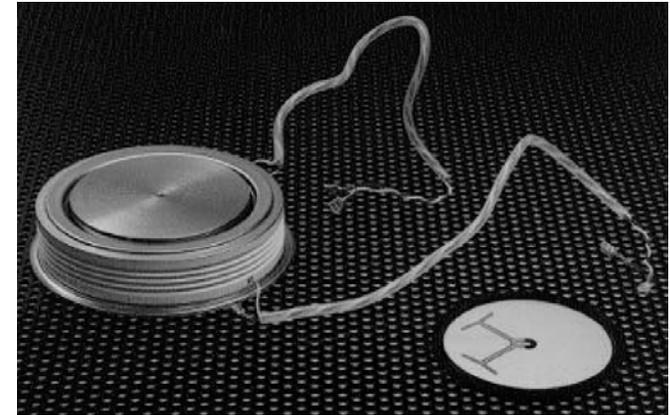
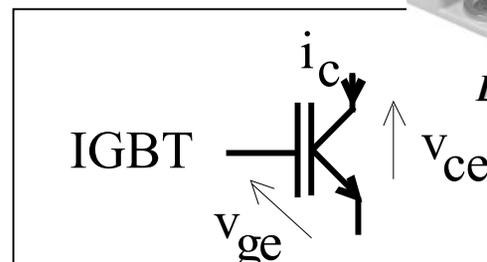
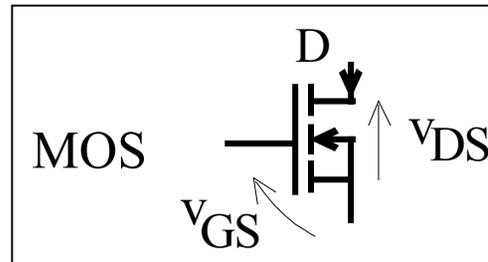
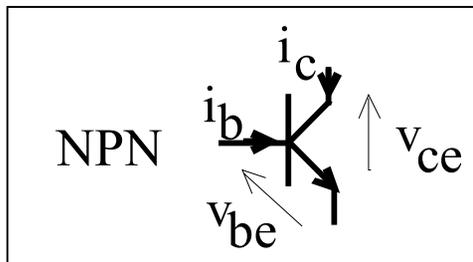
- Les composants commandables à la fermeture

→ **THYRISTORS**

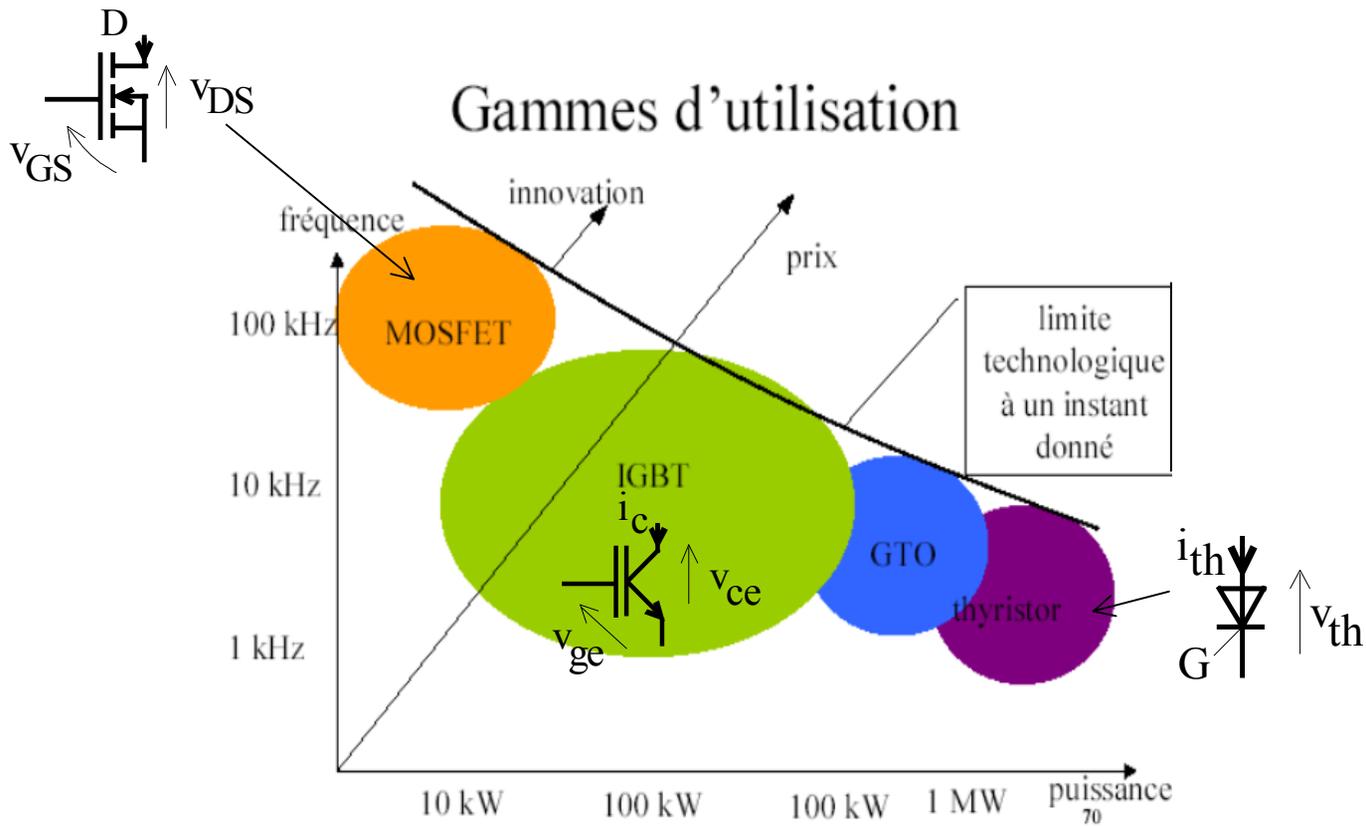


- Les composants commandables à la fermeture et à l'ouverture

→ **TRANSISTORS**

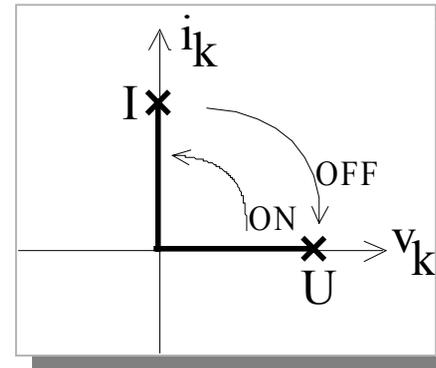
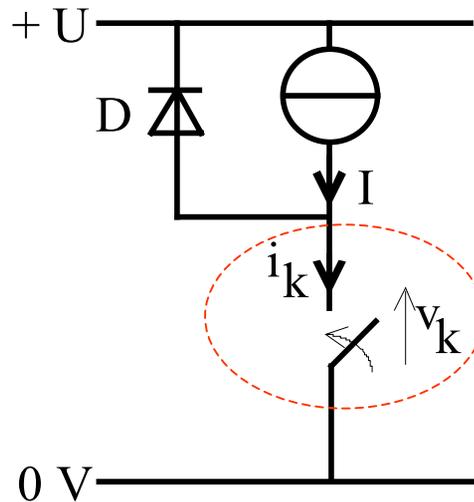


*Bras de Pont Semikron
(1200V – 60A)*



I.5 Principale caractéristique des composants

- Fonctionnement interrupteur \longrightarrow 2 états



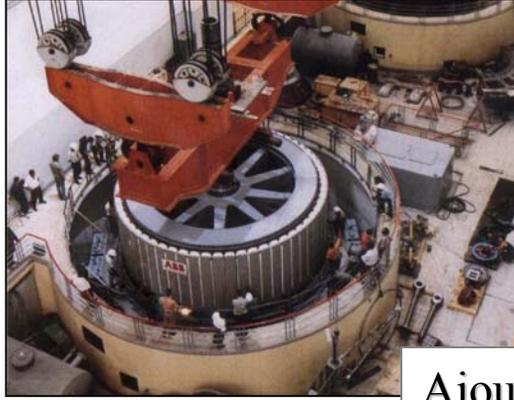
Cas d'un interrupteur parfait \rightarrow pertes nulles

I.6 Règle d'association des sources

- En commutation \longrightarrow Associer des sources de natures différentes

Exemples de sources de tension

→ Réseau EDF (tri ou mono sinus)



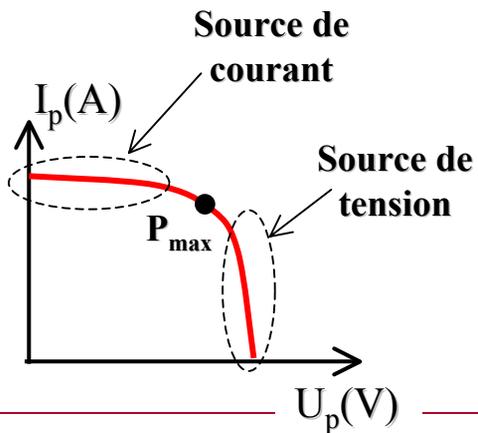
→ Batterie électrochimique (continue)



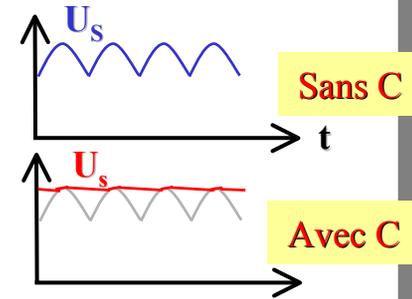
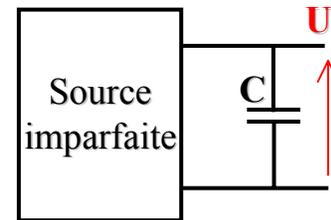
12 V DC

Une source particulière...

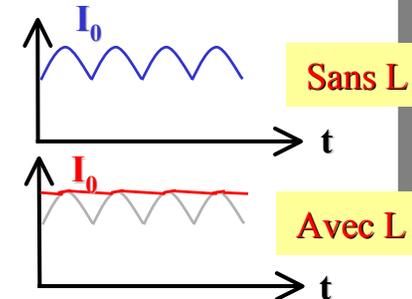
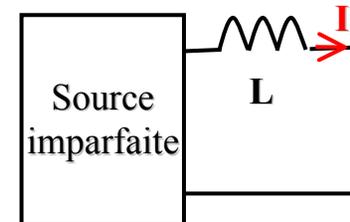
→ Panneau photovoltaïque



Ajouter une capacité...



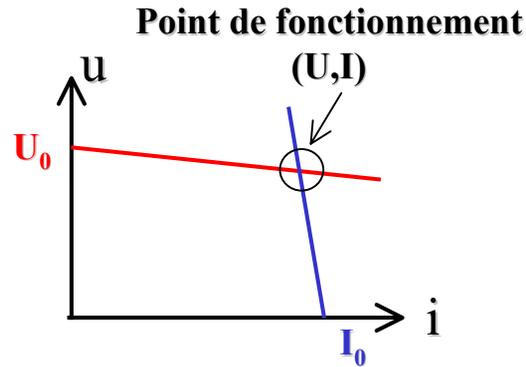
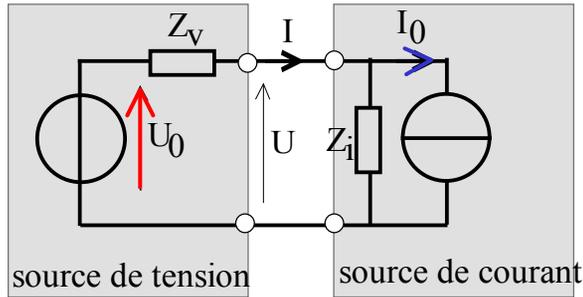
Ajouter une inductance...



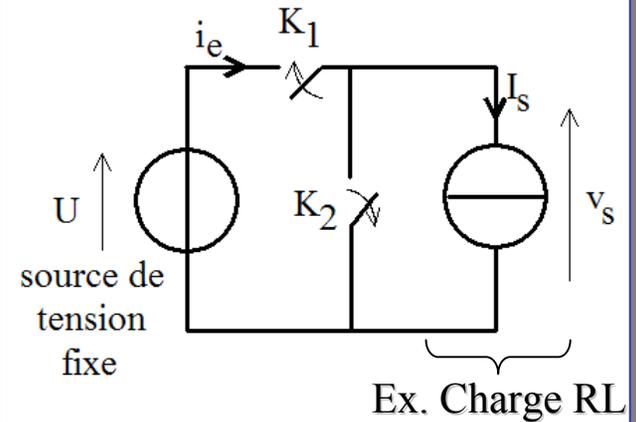
Association des sources

Règle à respecter \longrightarrow Associer des sources de natures différentes

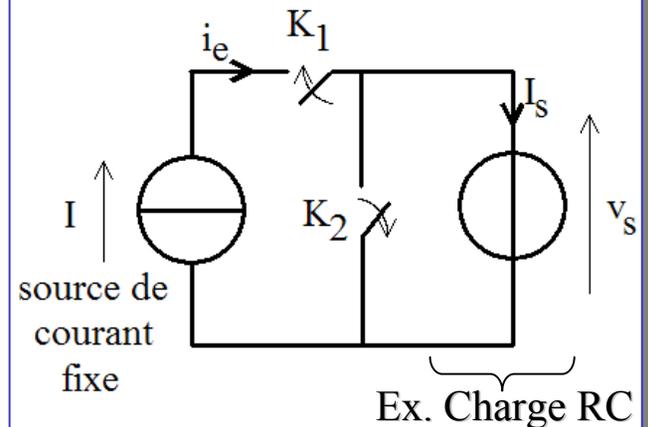
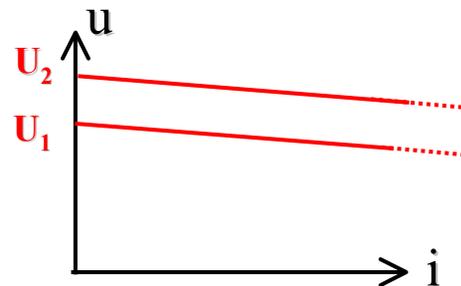
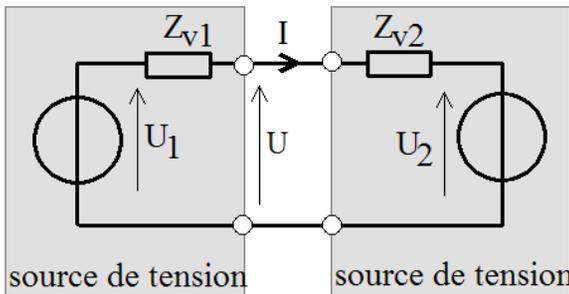
😊 Source de natures différentes = point de fonctionnement « naturel »



On rencontrera par exemple



☹ Source de natures identiques = point de fonctionnement à l'infini



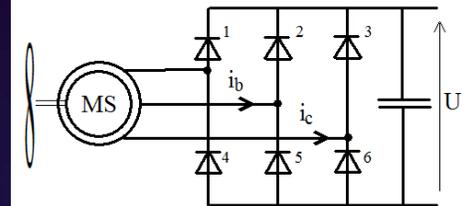
II LES REDRESSEURS (Convertisseurs lents)

Fonction

- ✓ Réalisation de sources continues de puissance à partir d'une tension sinusoïdale

Applications

- ✓ Blocs d'alimentations (PC, TV, ...)
- ✓ Étage d'entrée des variateurs de vitesse industriels pour moteurs
- ✓ Traction ferroviaire et propulsion navale
- ✓ Chaîne de conversion d'énergie pour éolienne
- ✓ ...



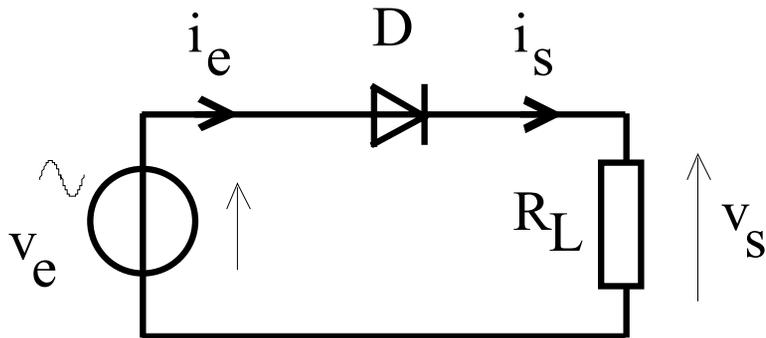
Tendance

- ✓ De moins en moins utilisés au profit des convertisseurs à découpage

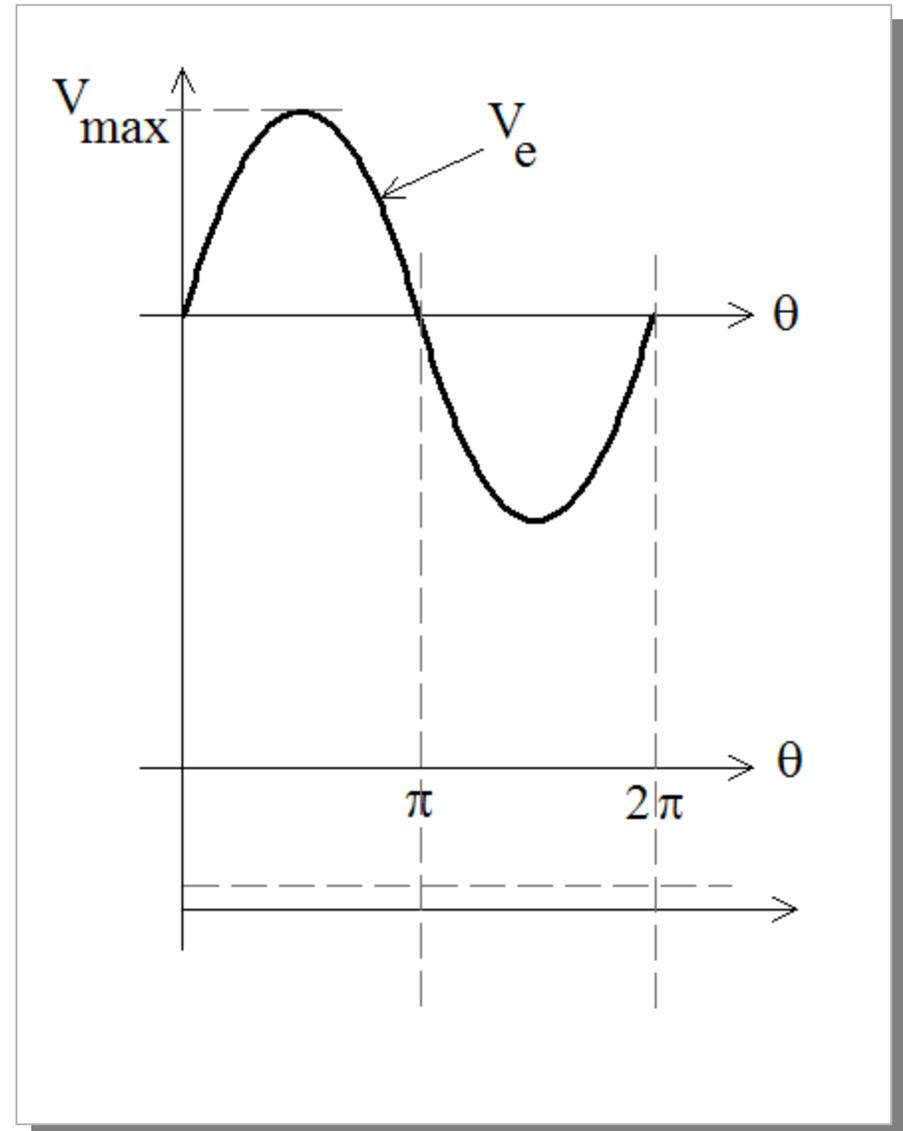
II.1 Redressement monophasé non commandé

→ Ponts à Diodes

a. Redressement simple alternance



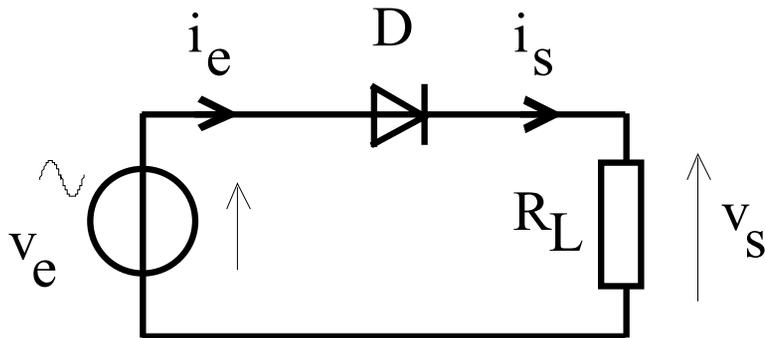
$$v_e = V_{\max} \cdot \sin(\theta)$$



II.1 Redressement monophasé non commandé

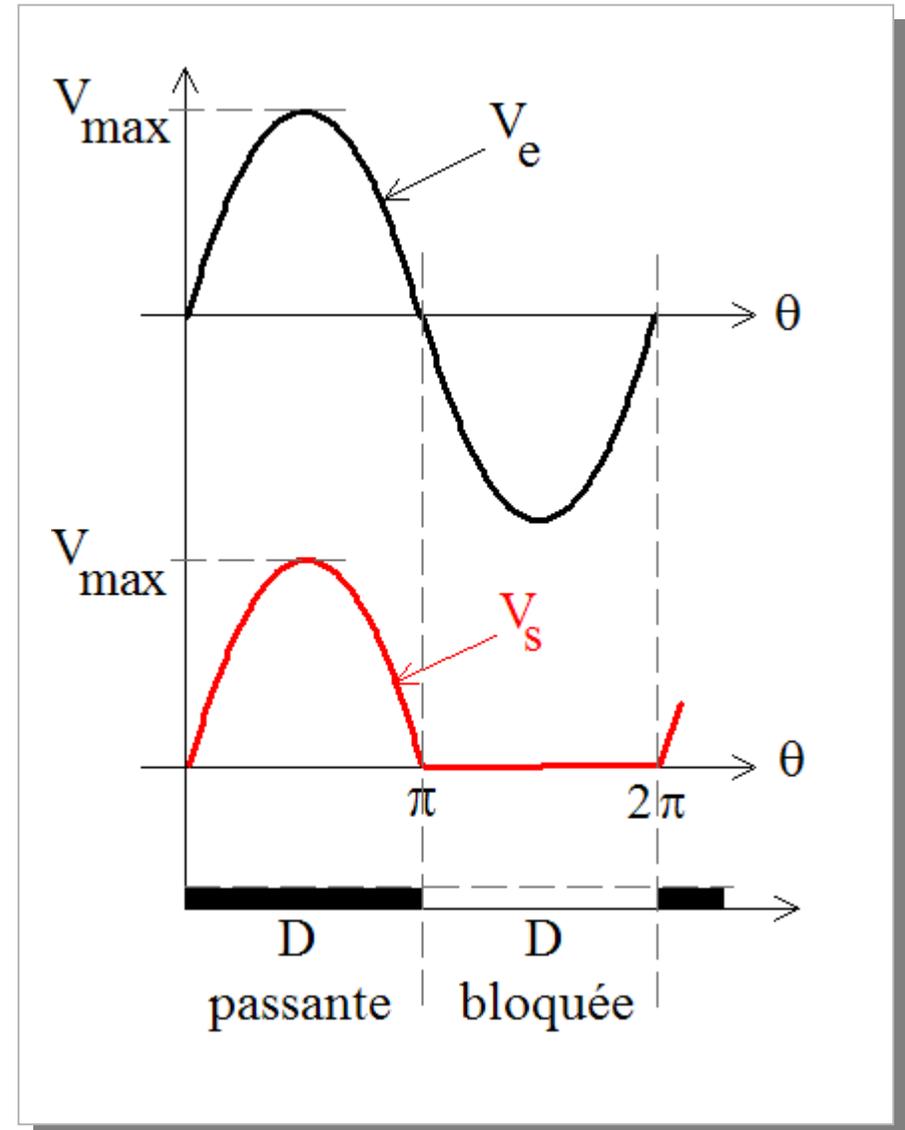
➔ Ponts à Diodes

a. Redressement simple alternance



$$v_e = V_{\max} \cdot \sin(\theta)$$

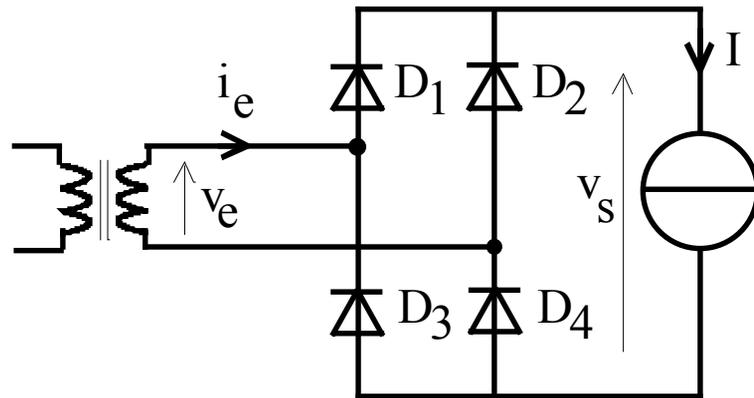
➔
$$V_s \text{ moyen} = \frac{V_{\max}}{\pi}$$



II.1 Redressement monophasé non commandé

→ Ponts à Diodes

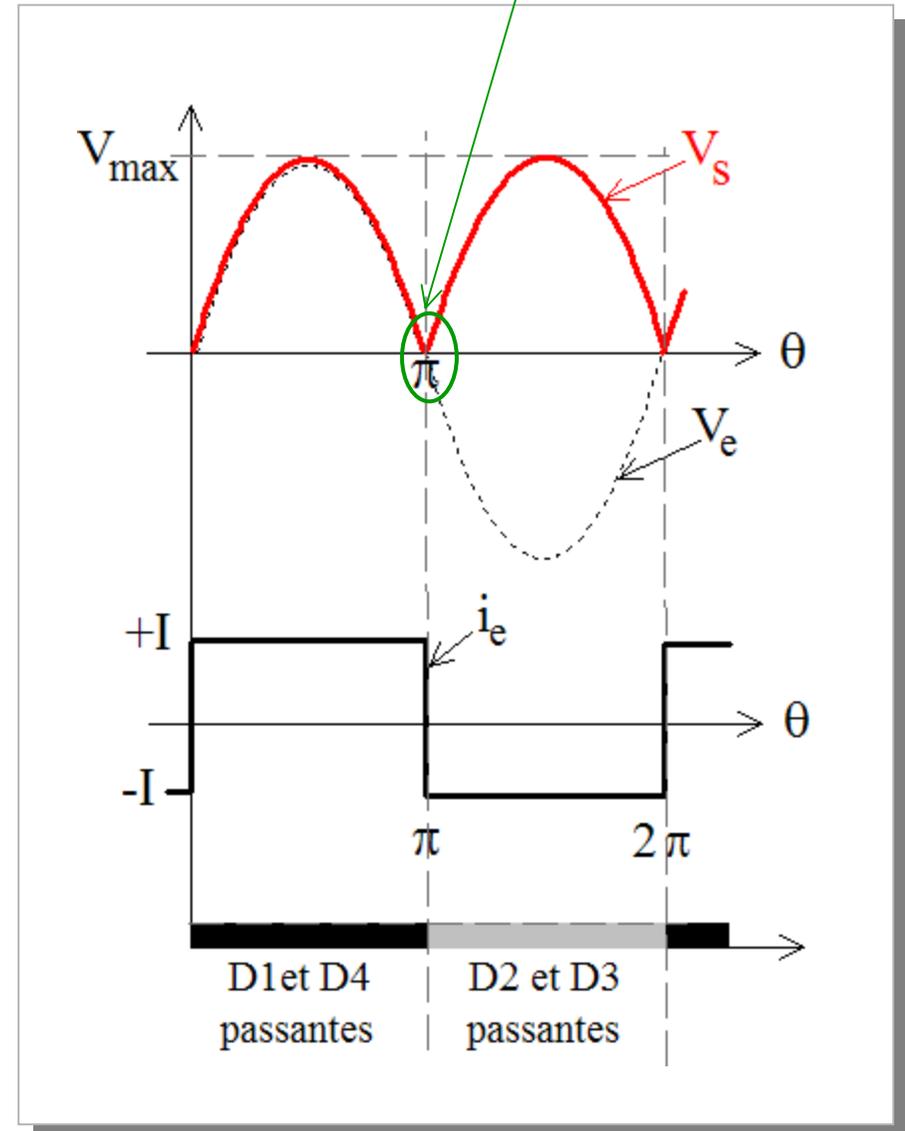
b. Redressement double alternance



$$v_e = V_{\max} \cdot \sin(\theta)$$

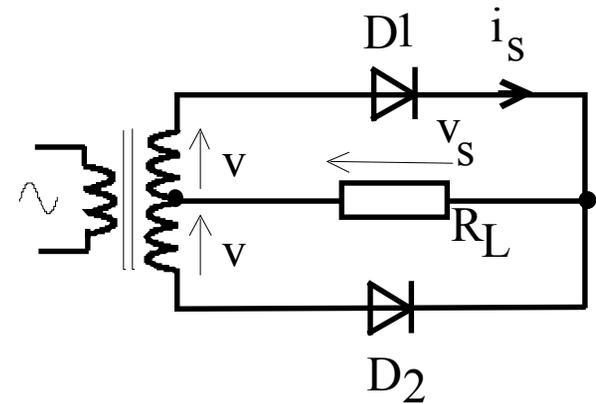
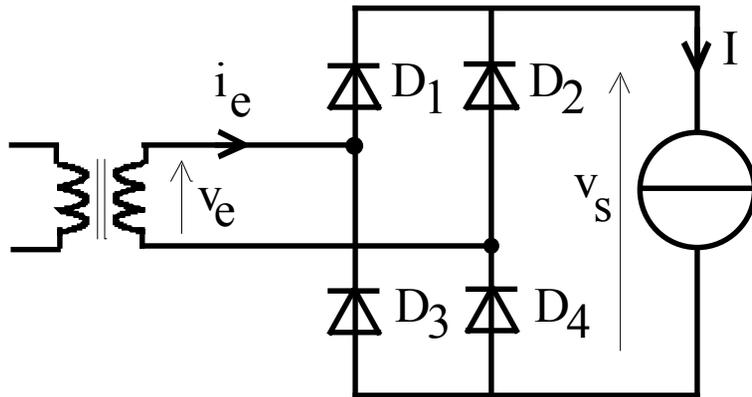
→
$$V_s \text{ moyen} = \frac{2 \cdot V_{\max}}{\pi}$$

Instant de commutation naturelle



II.1 Redressement monophasé non commandé

2 montages équivalents

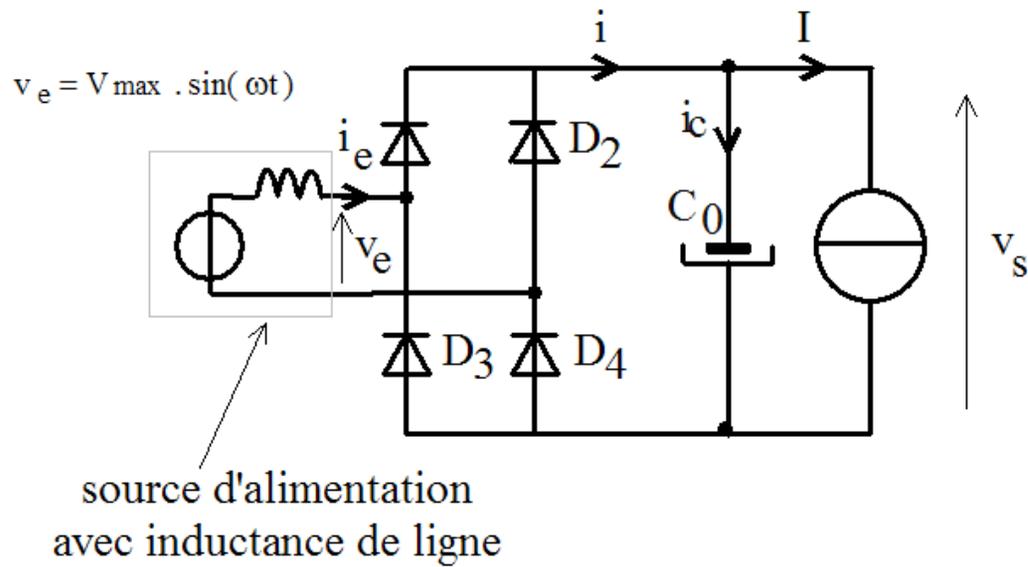


II.1 Redressement monophasé non commandé

c. Le filtrage

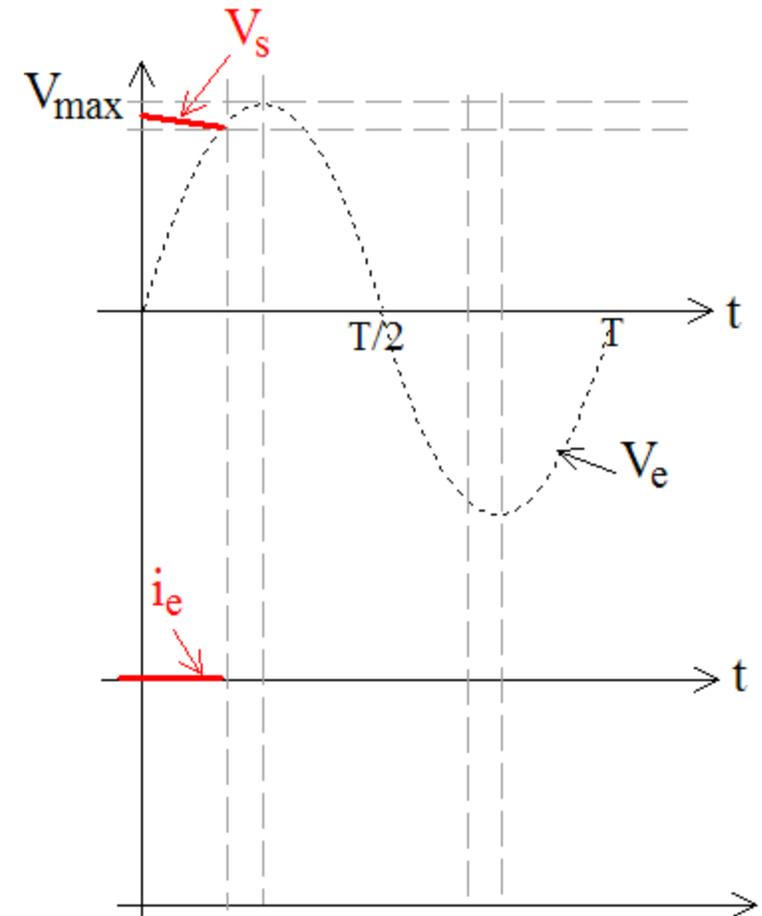
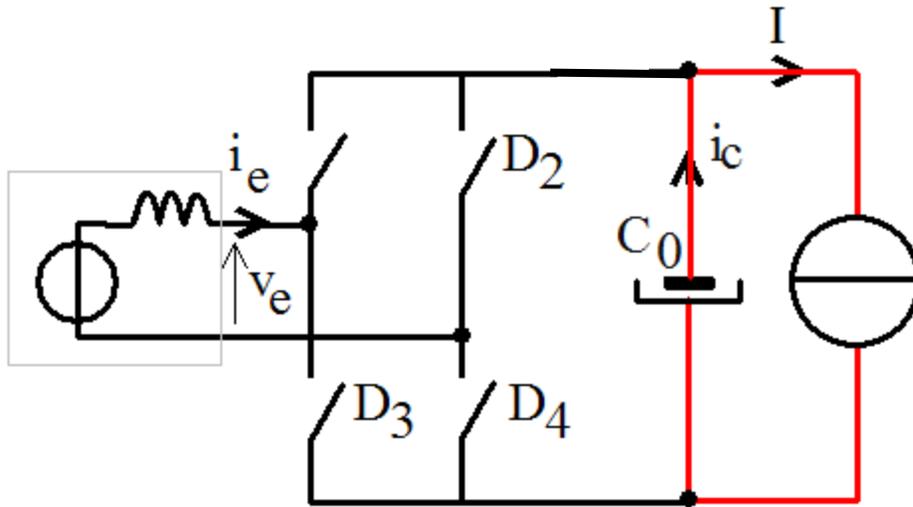
→ *Lissage de la tension ou du courant*

1^{er} type → Filtrage capacitif

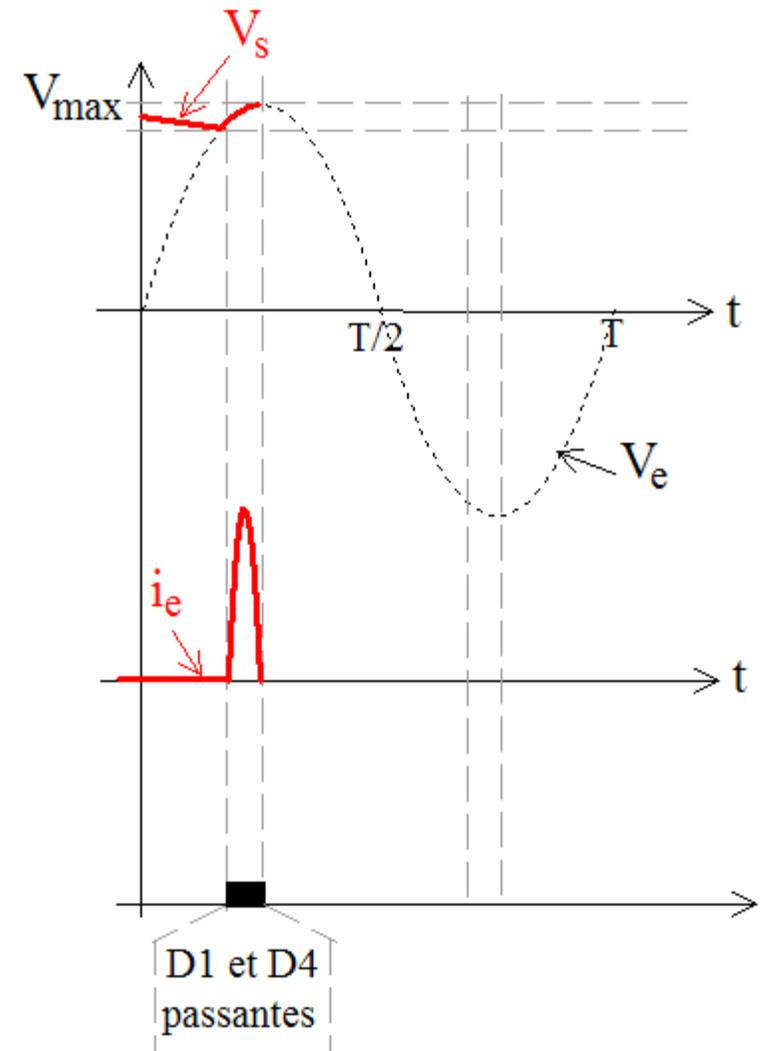
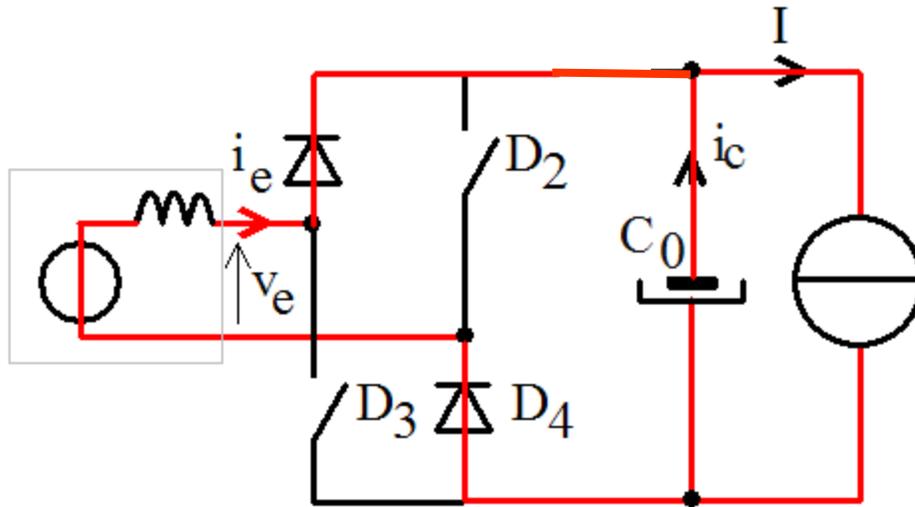


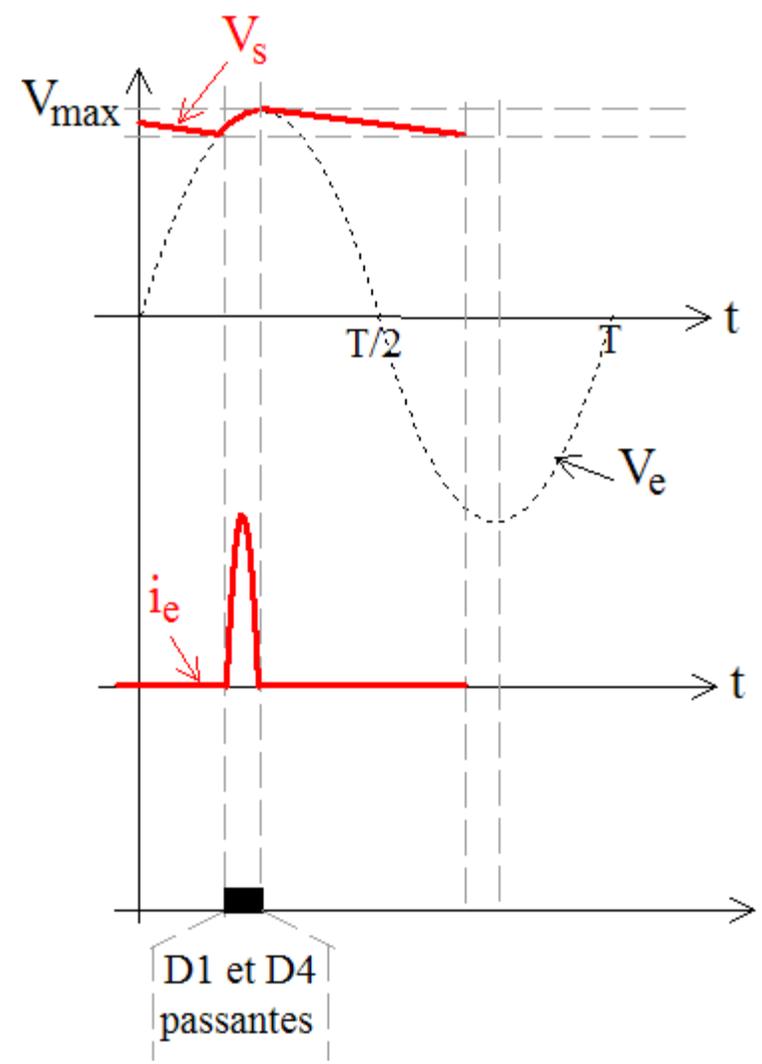
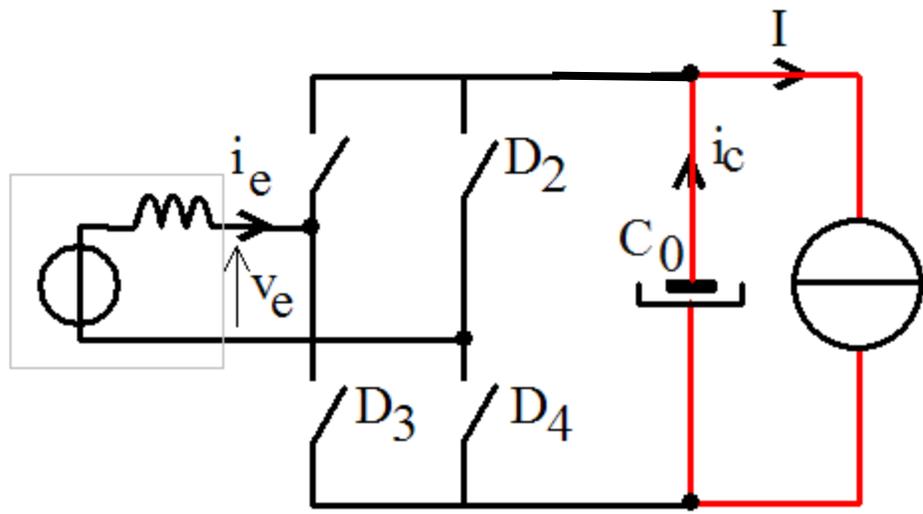
**Règle d'association des sources
non respectée**

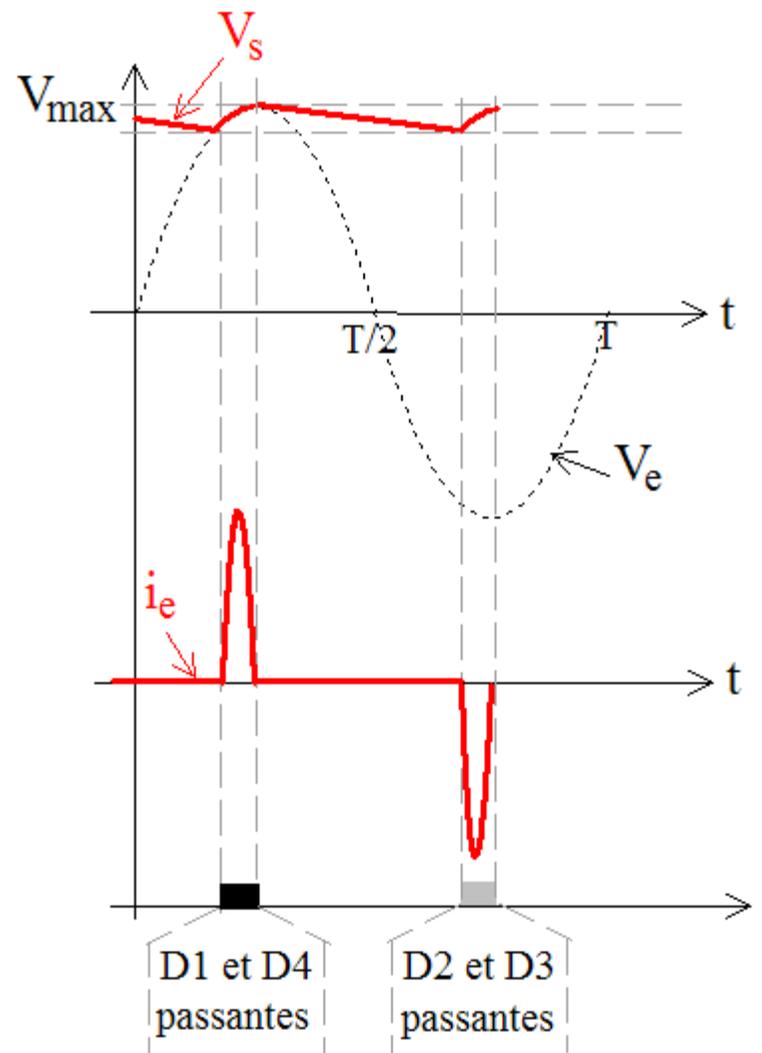
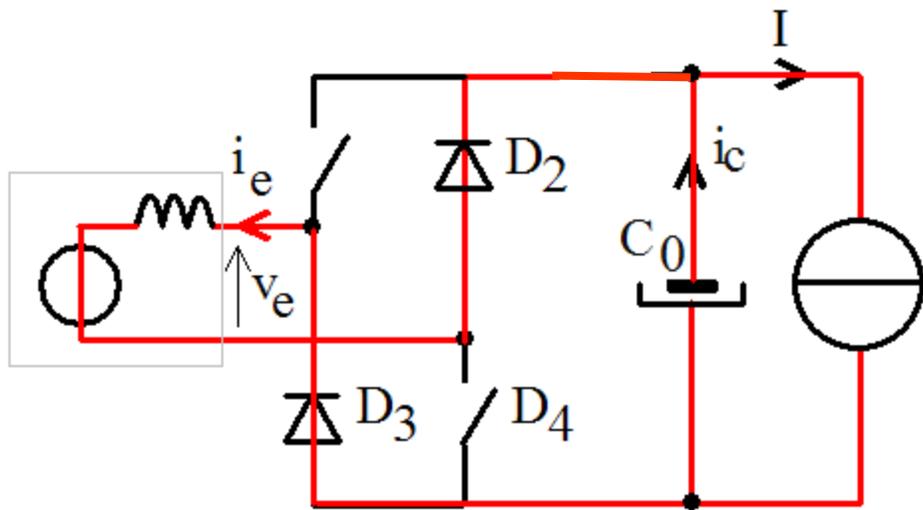
Si tension de sortie > Tension d'entrée \longrightarrow Pont bloqué (diodes ouvertes)

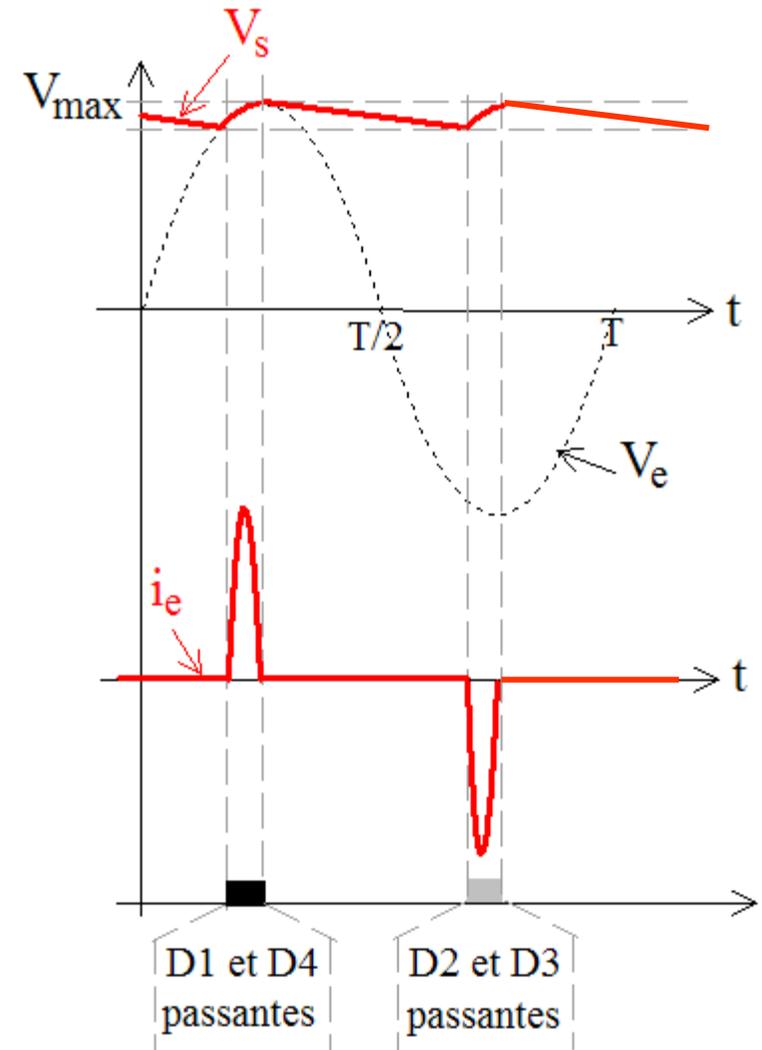
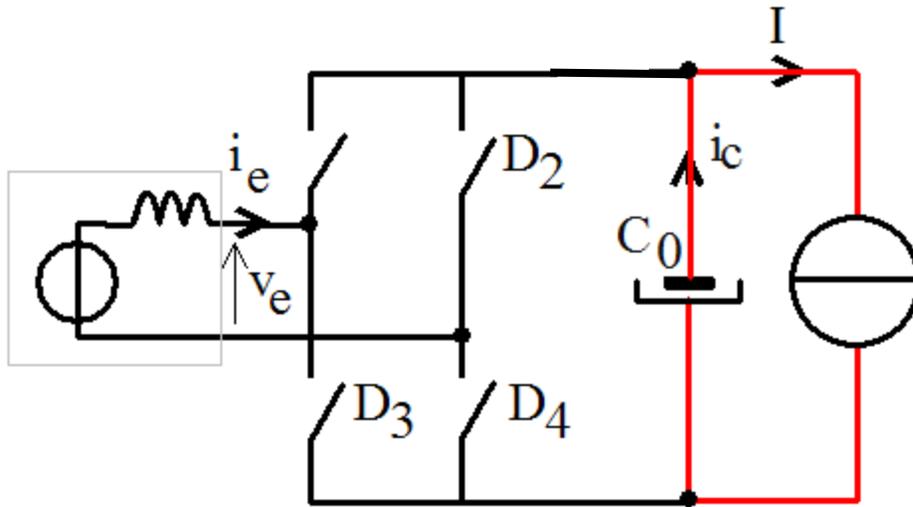


Si tension de sortie < Tension d'entrée \longrightarrow Pont débloqué (diodes passantes)







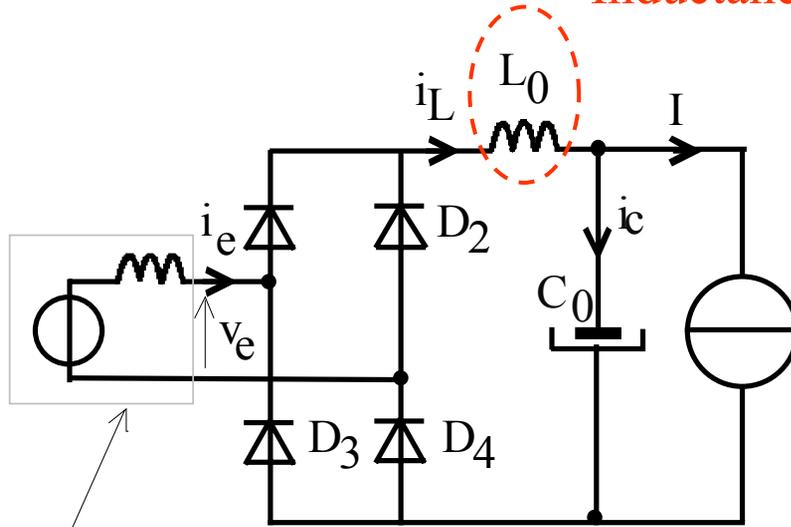


Ondulation de tension de sortie

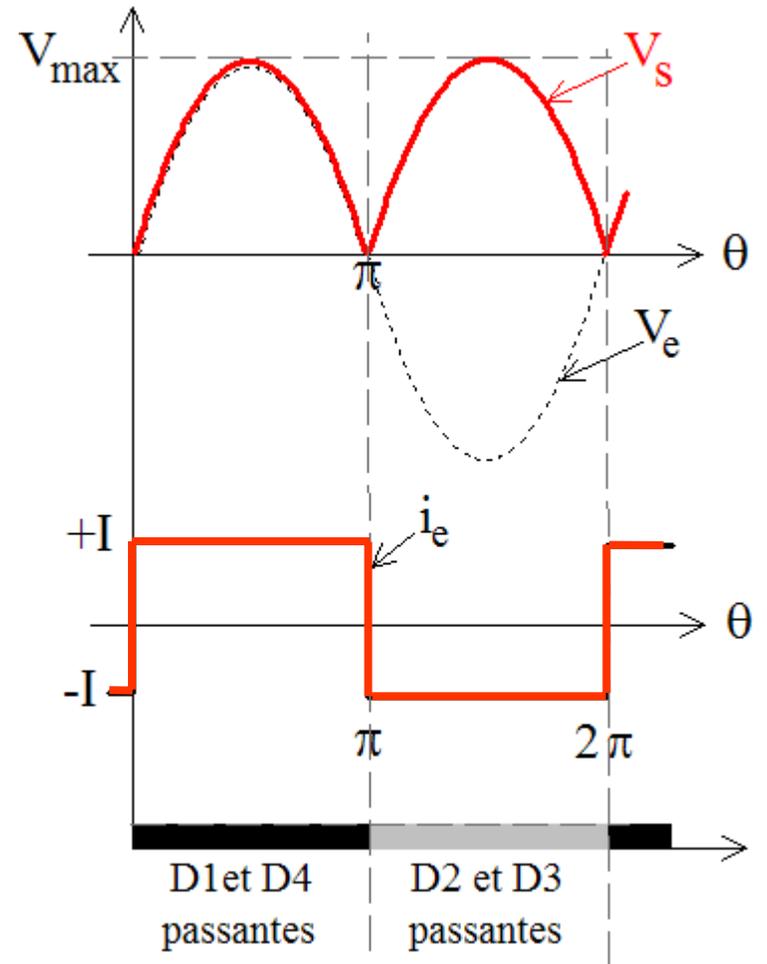
$$\Delta V_s = \frac{I \cdot T}{2 \cdot C_0} = \frac{I}{2 \cdot C_0 \cdot f}$$

2^{ème} type → LC

Inductance de lissage du courant



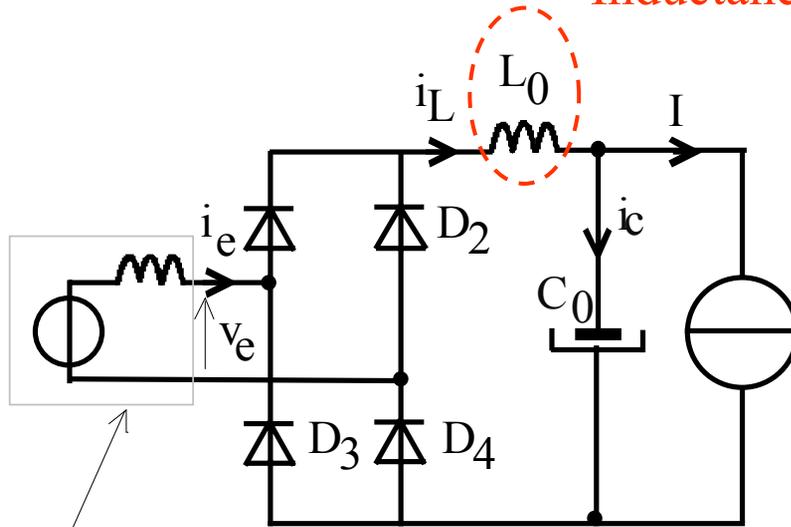
source d'alimentation avec inductance de ligne



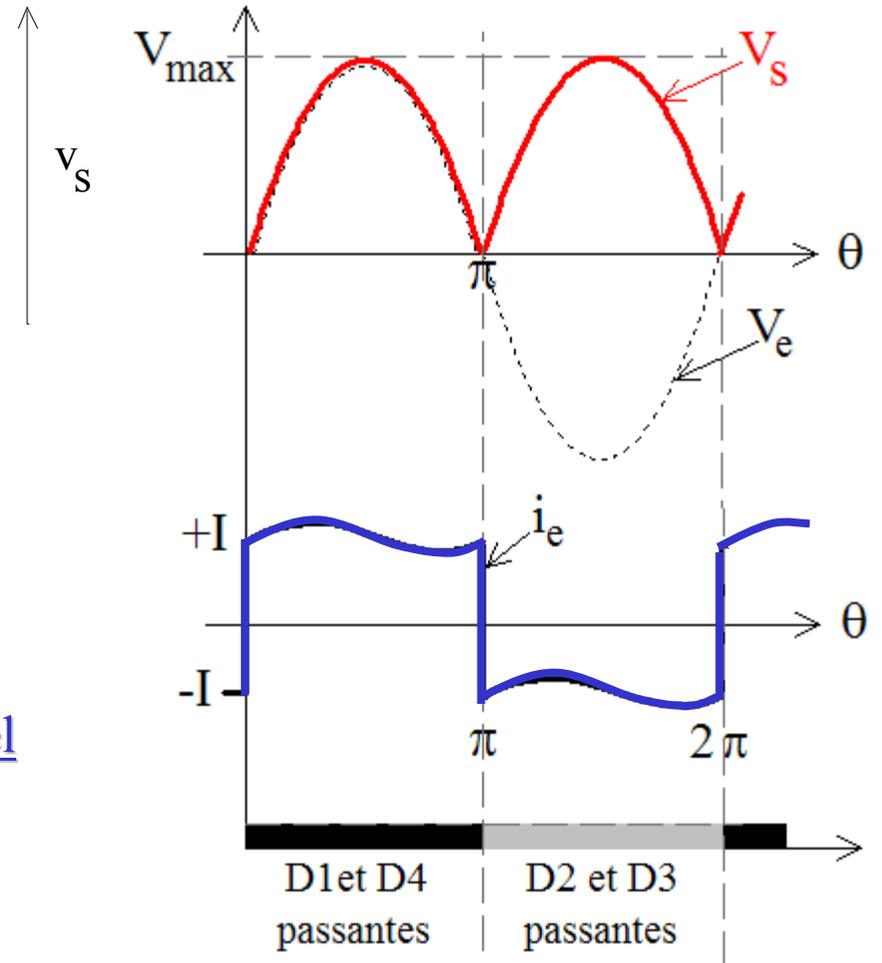
Lissage parfait

2^{ème} type → LC

Inductance de lissage du courant



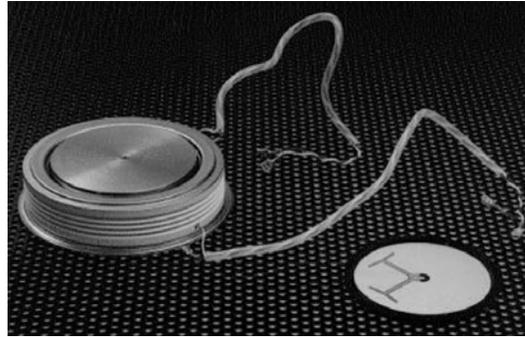
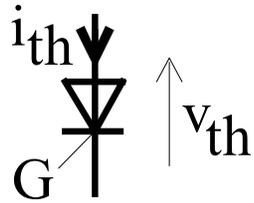
source d'alimentation avec inductance de ligne



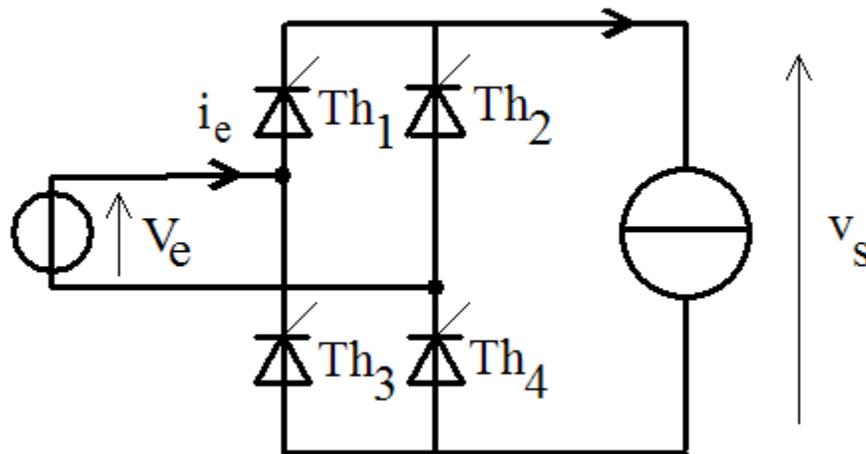
Lissage réel

II.1 Redressement monophasé commandé en pont complet

→ Ponts à Thyristors

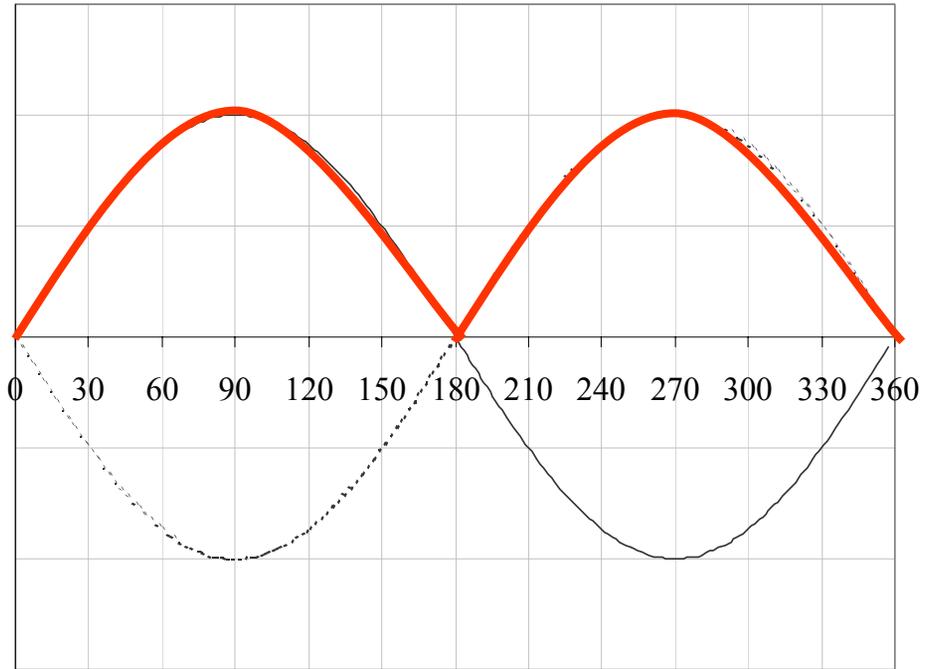
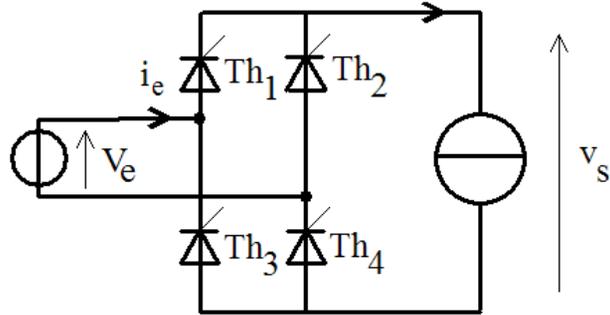


a. Montage

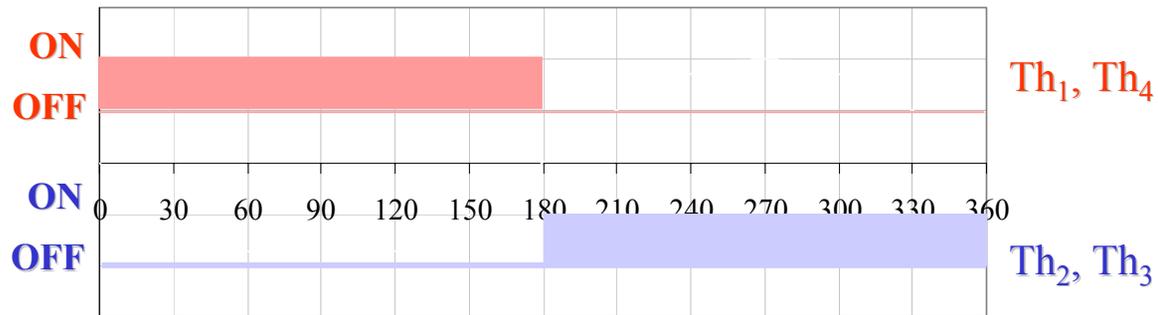


Amorçage des thyristors : définit par rapport aux instants de commutation naturelle

Tension de sortie

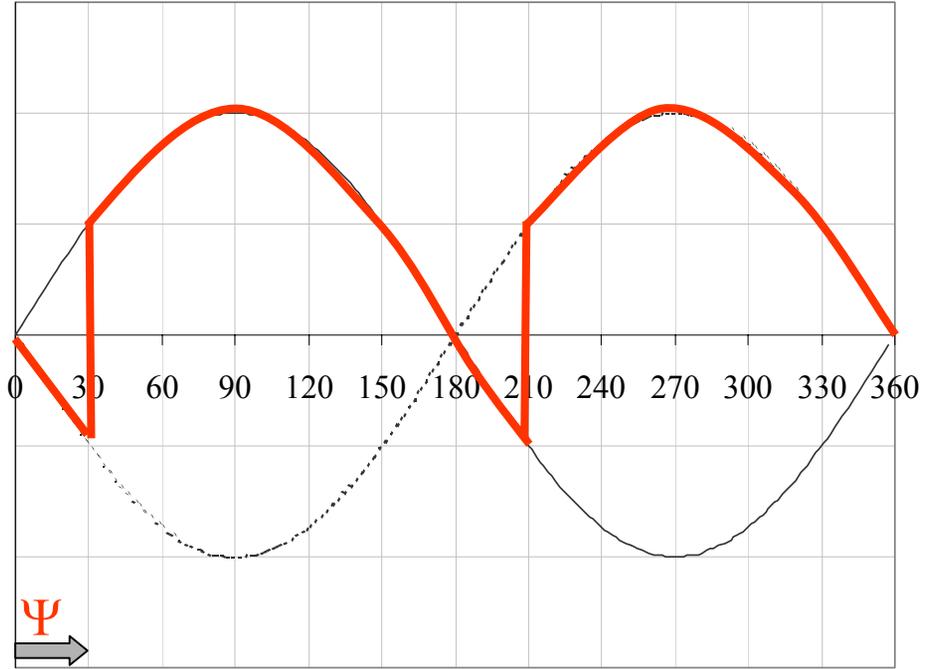
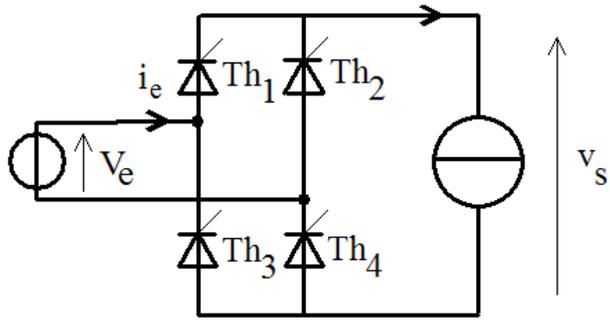


Commande des thyristors



$\Psi = 0$

Tension de sortie

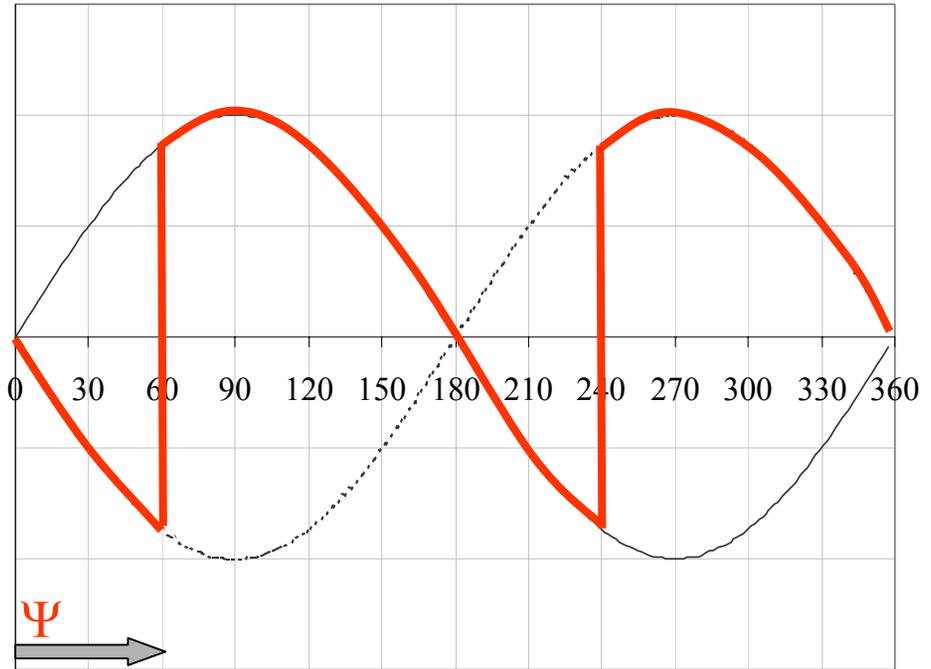
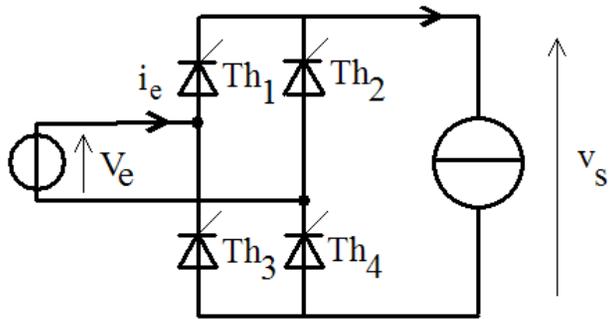


Commande des thyristors



$\Psi = 30^\circ$

Tension de sortie

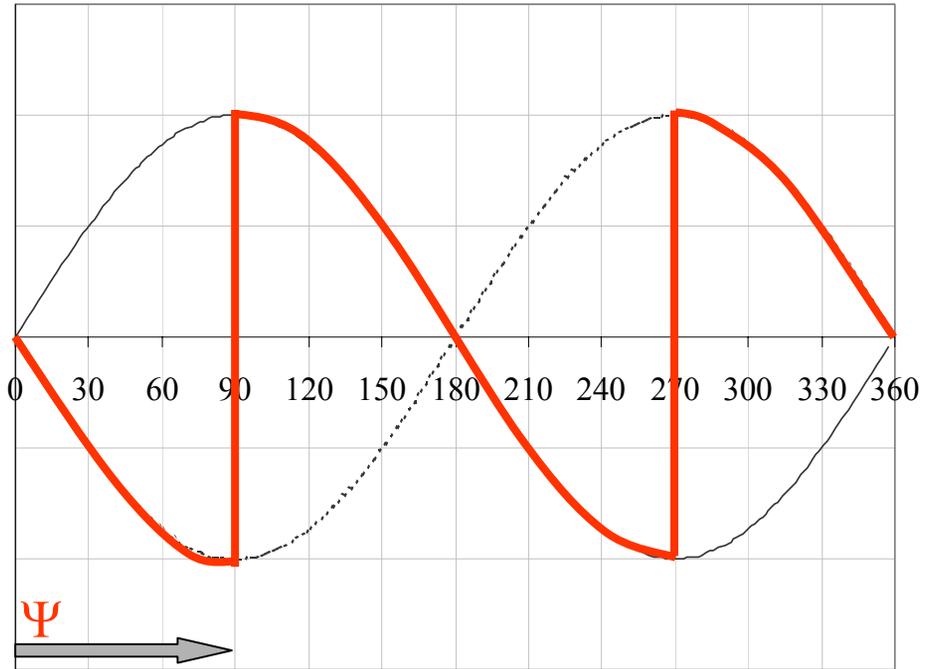
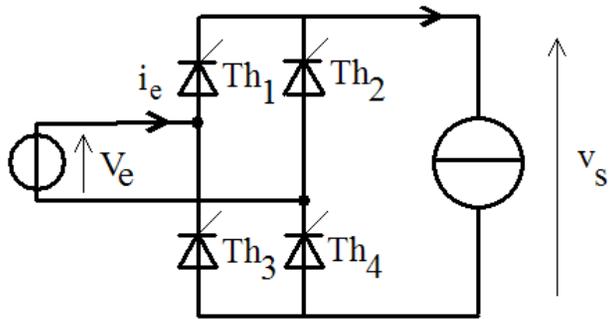


Commande des thyristors

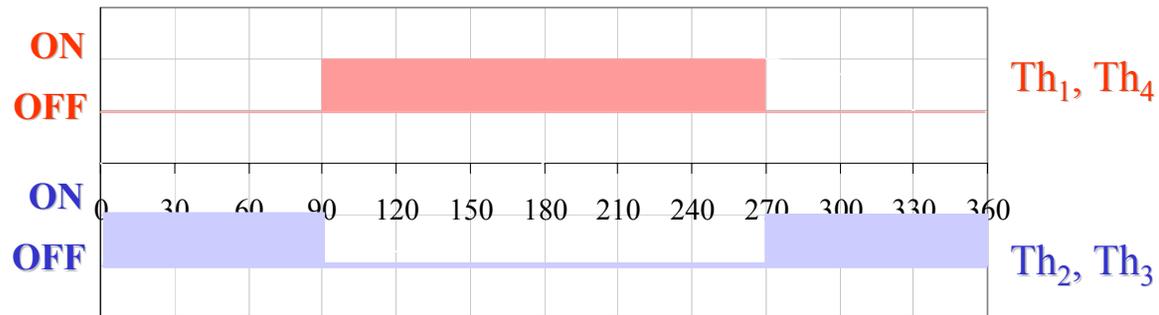


$\Psi = 60^\circ$

Tension de sortie

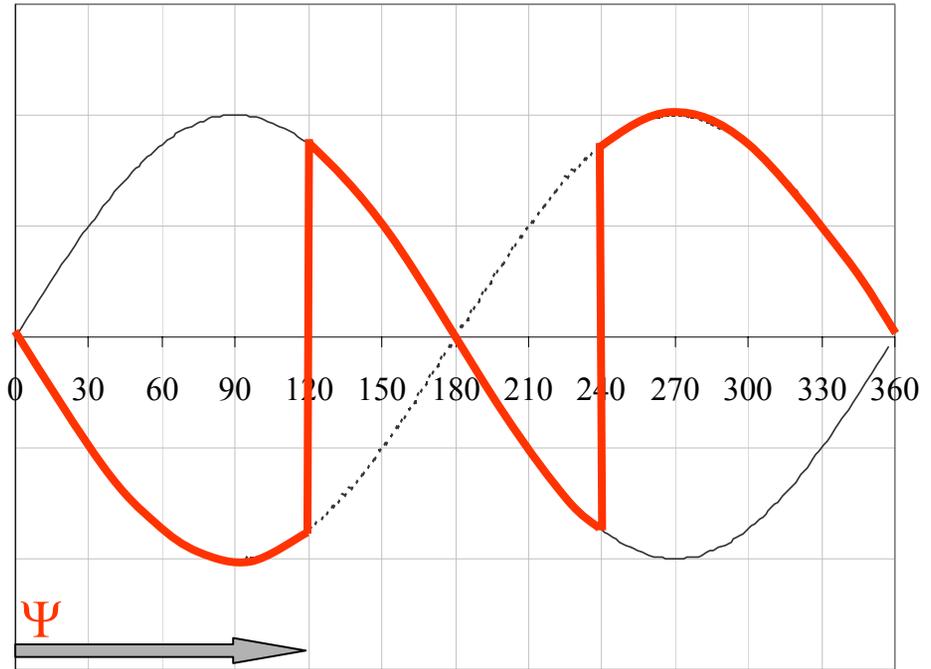
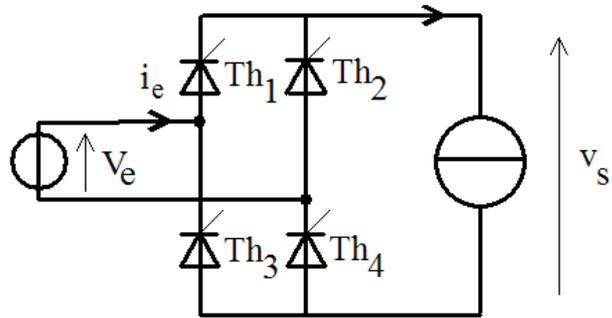


Commande des thyristors

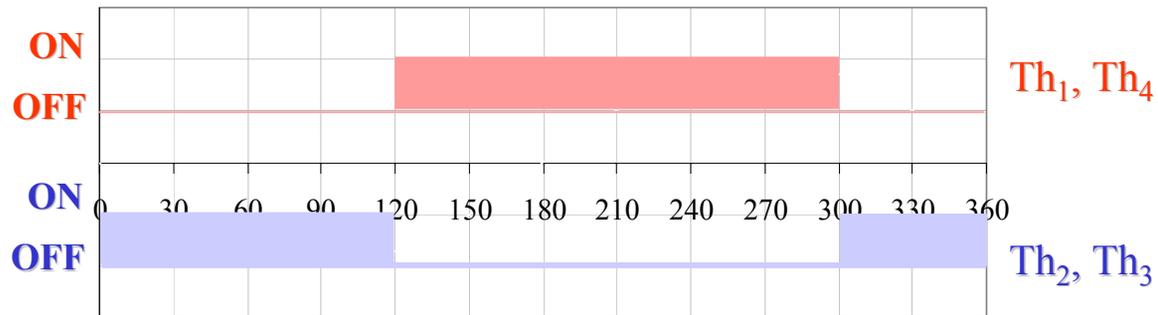


$\Psi = 90^\circ$

Tension de sortie

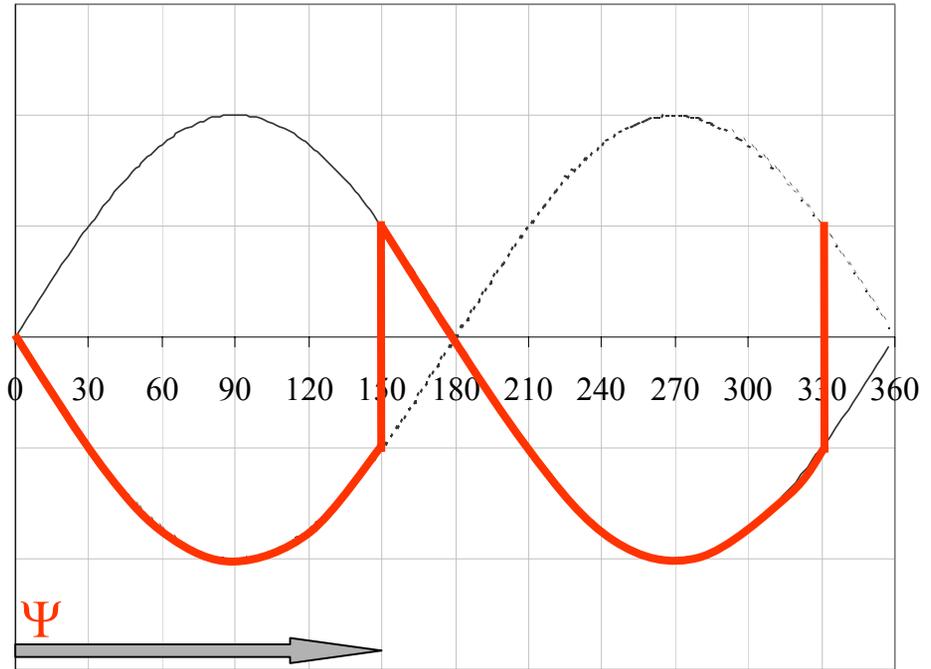
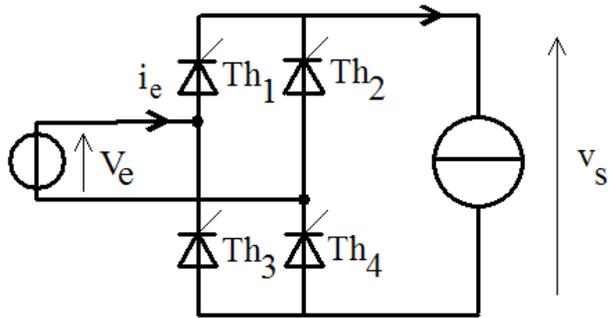


Commande des thyristors



$\Psi = 120^\circ$

Tension de sortie

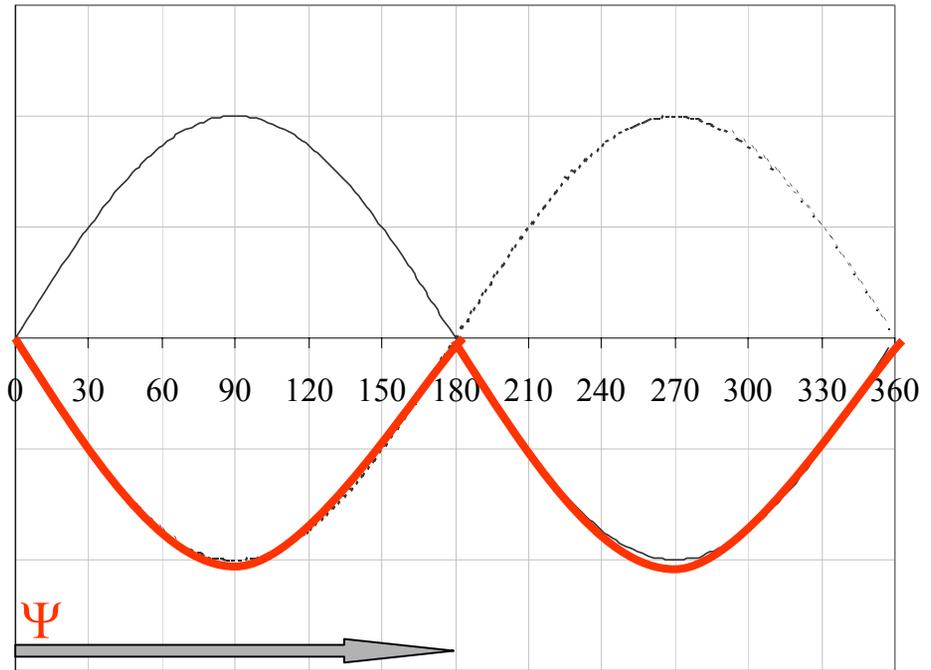
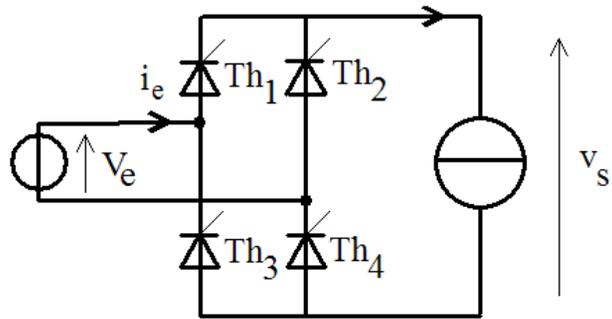


Commande des thyristors

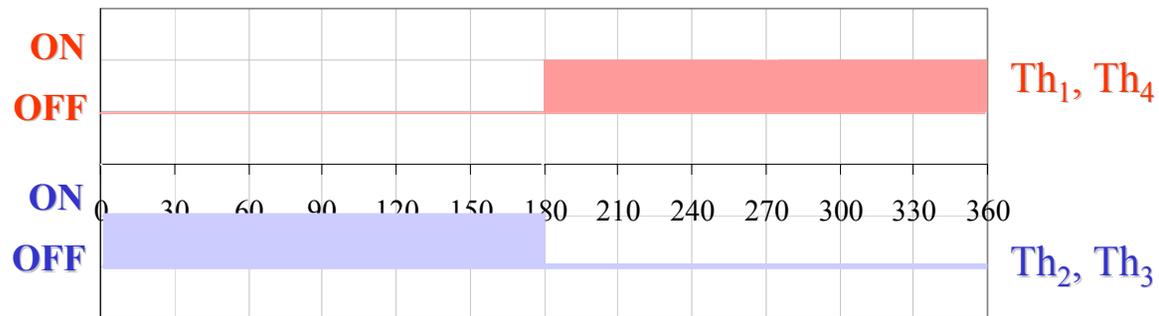


$\Psi = 150^\circ$

Tension de sortie



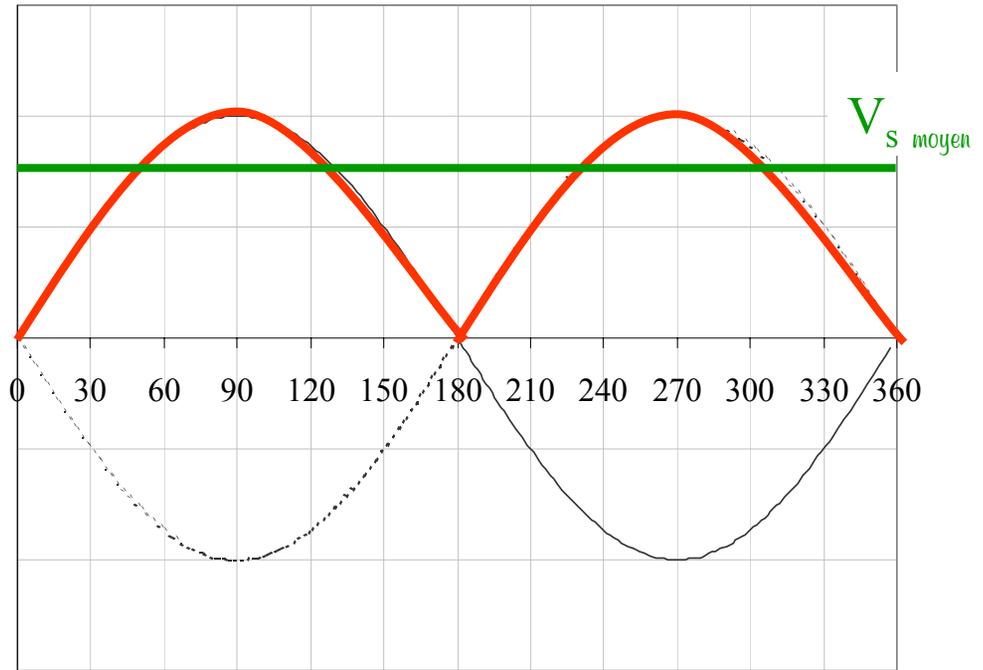
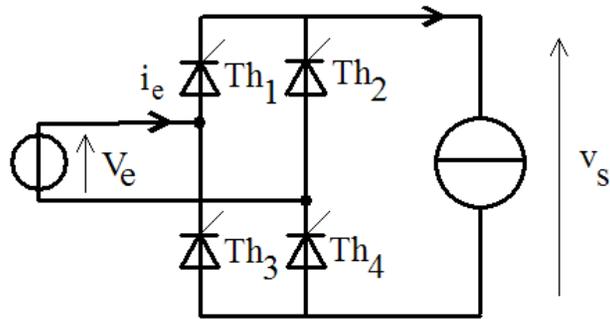
Commande des thyristors



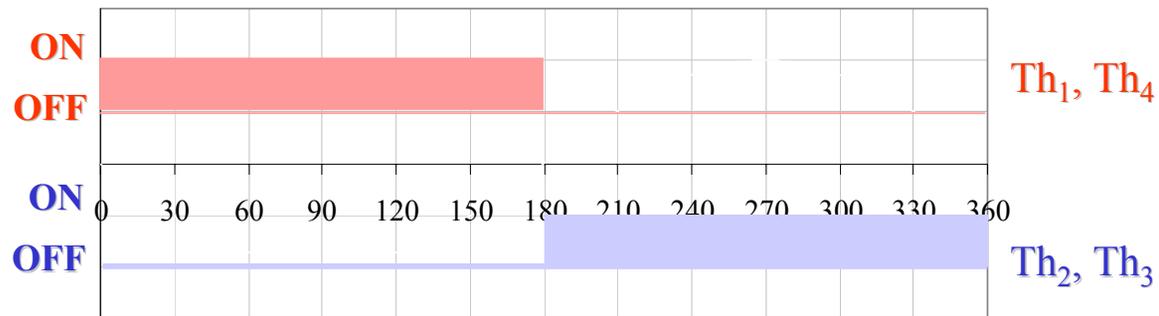
$\Psi = 180^\circ$

Variation de Ψ = Variation de tension moyenne de sortie

Tension de sortie



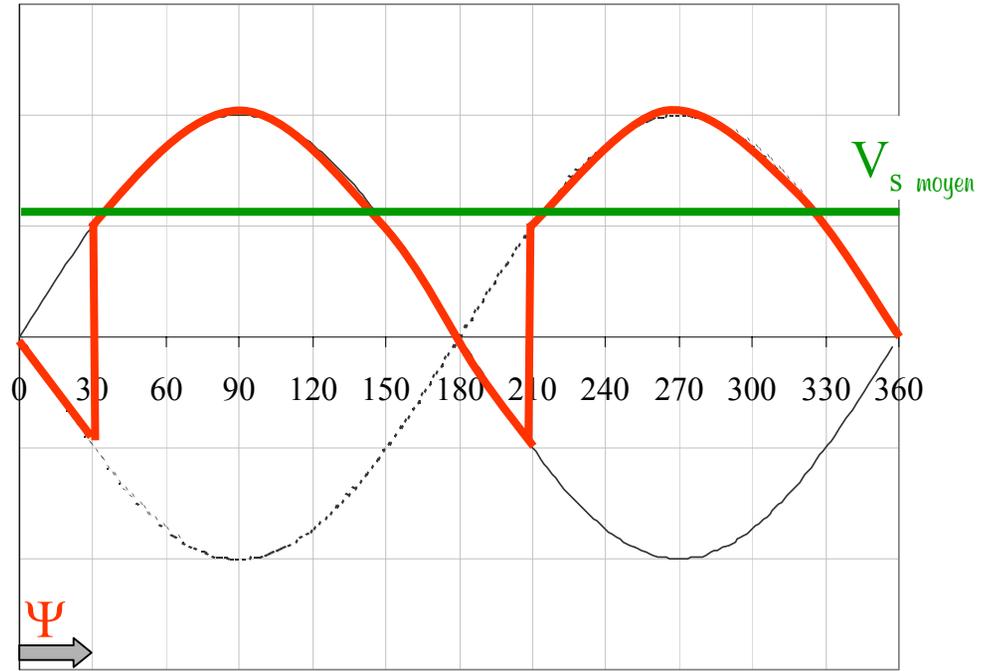
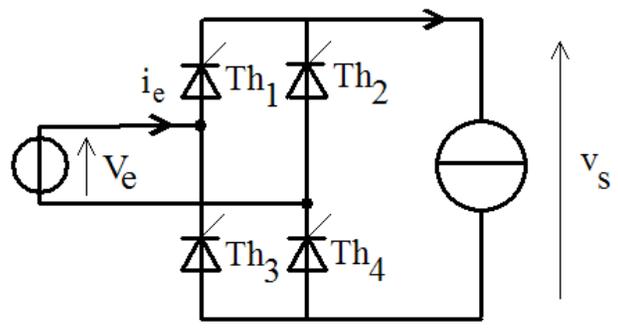
Commande des thyristors



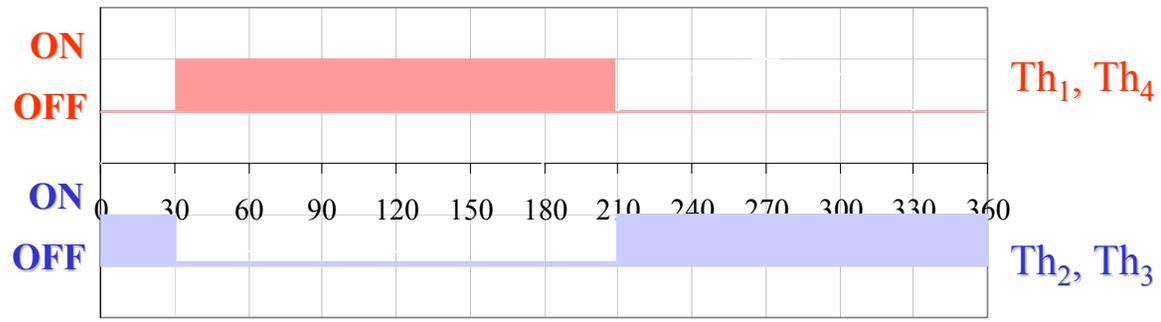
$\Psi = 0$

Variation de Ψ = Variation de tension moyenne de sortie

Tension de sortie



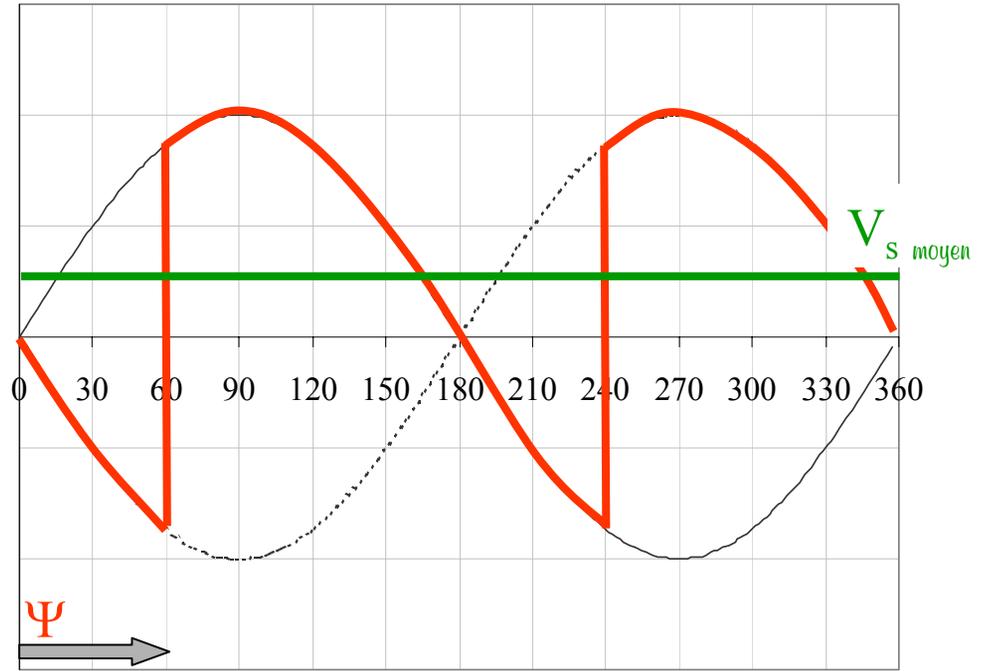
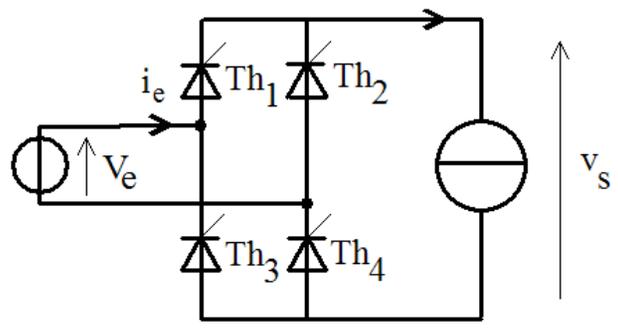
Commande des thyristors



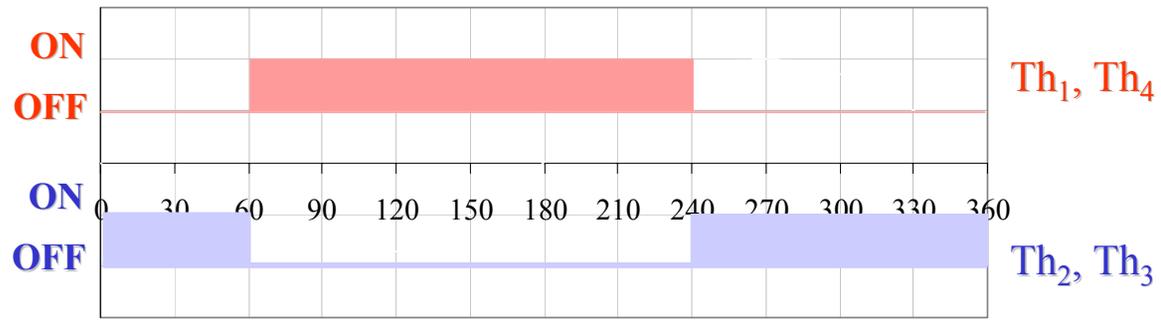
$\Psi = 30^\circ$

Variation de Ψ = Variation de tension moyenne de sortie

Tension de sortie



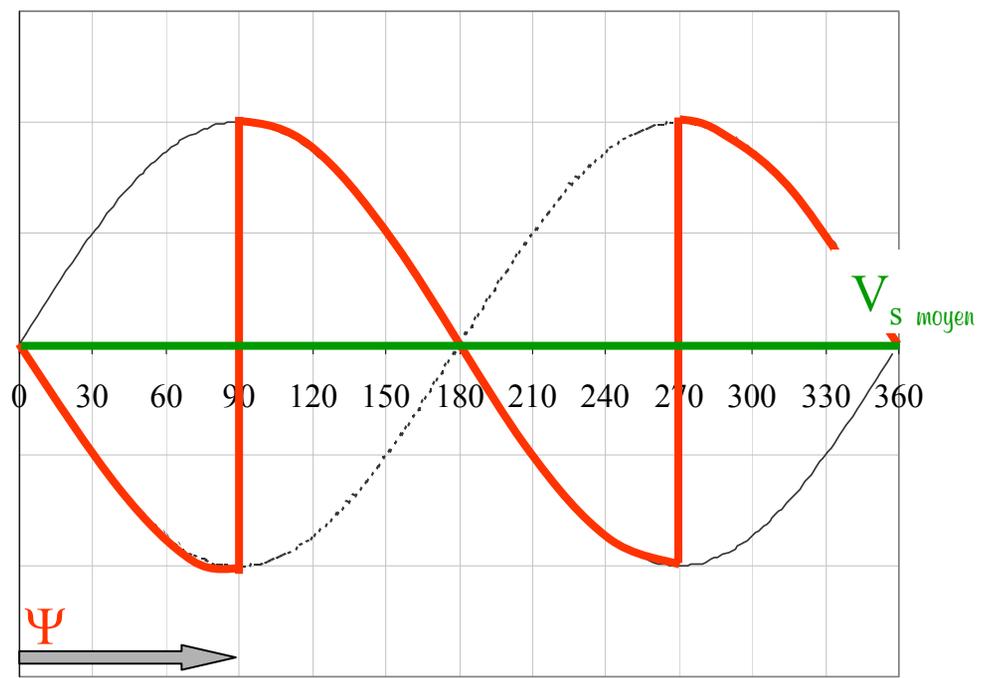
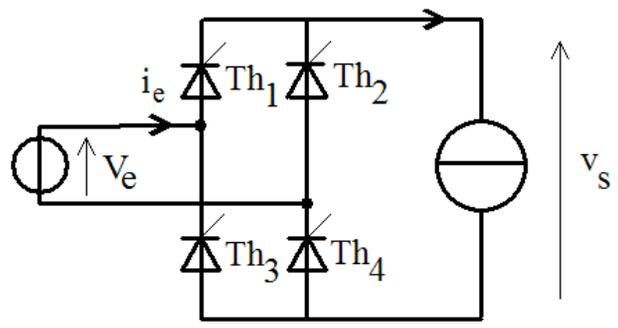
Commande des thyristors



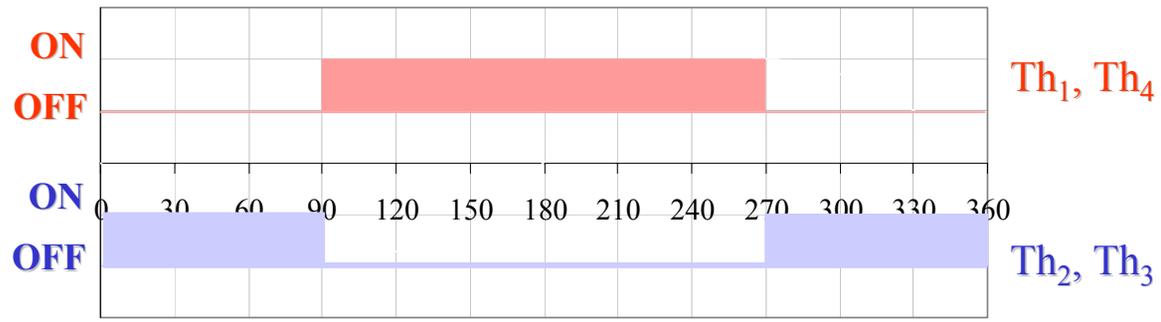
$\Psi = 60^\circ$

Variation de Ψ = Variation de tension moyenne de sortie

Tension de sortie

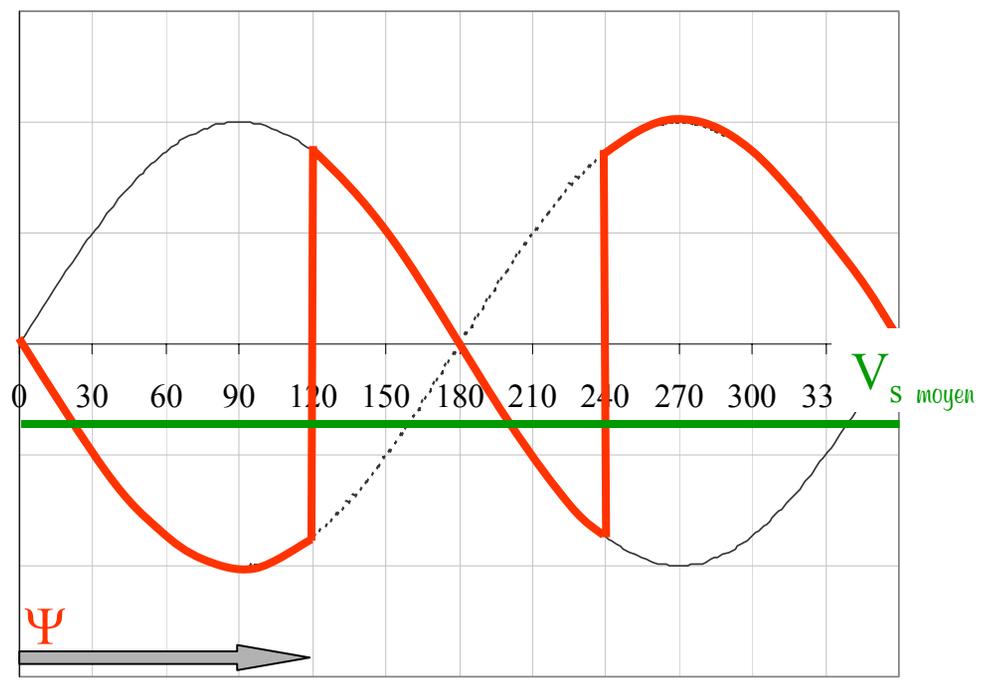
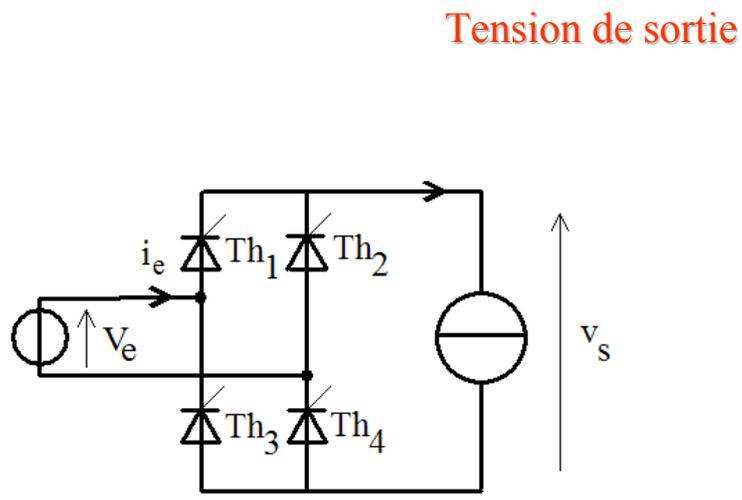


Commande des thyristors

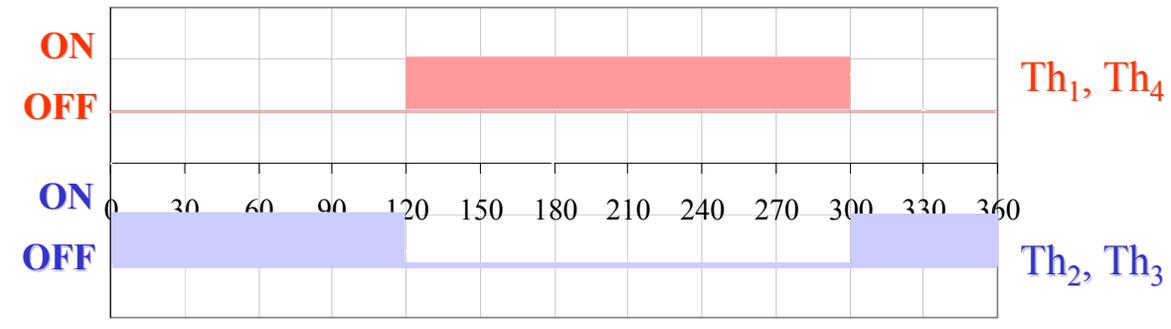


$\Psi = 90^\circ$

Variation de Ψ = Variation de tension moyenne de sortie



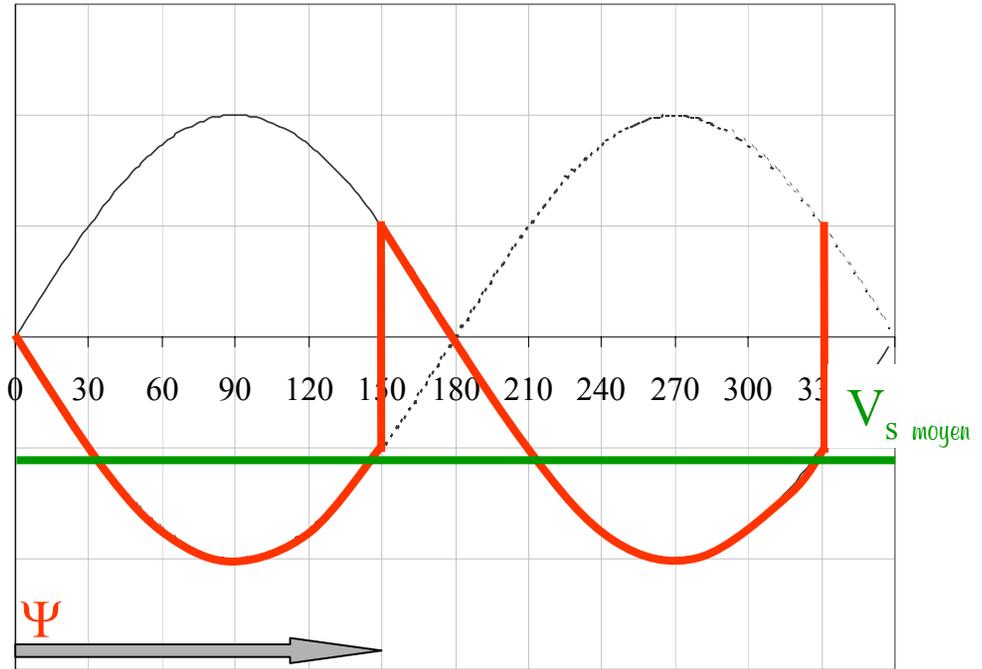
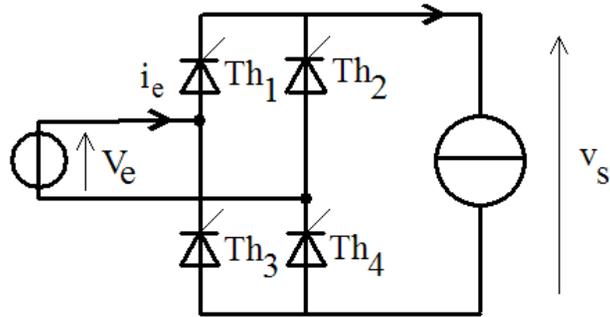
Commande des thyristors



$\Psi = 120^\circ$

Variation de Ψ = Variation de tension moyenne de sortie

Tension de sortie



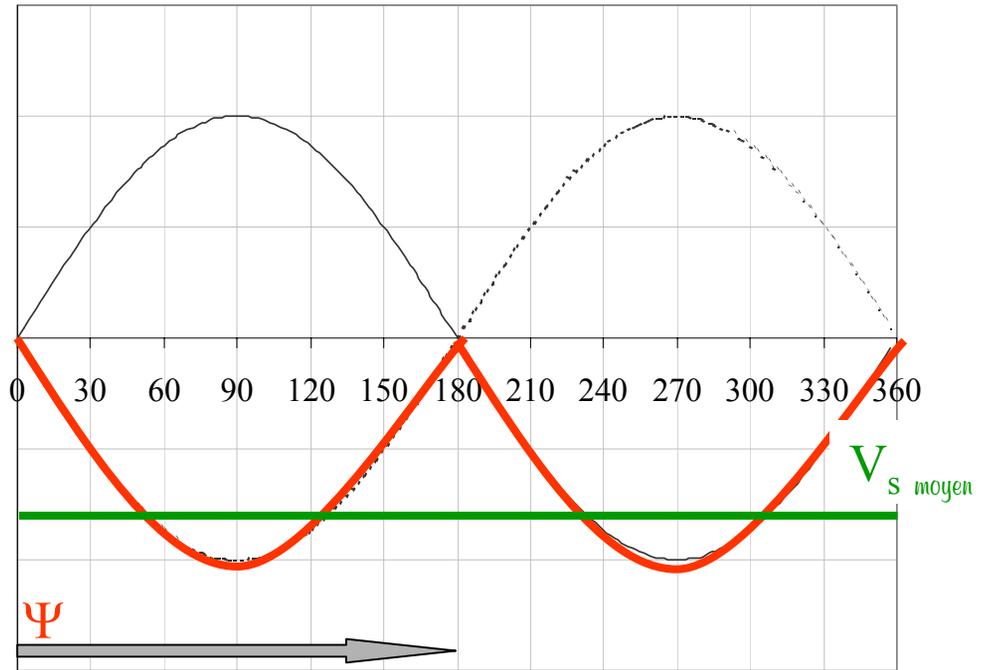
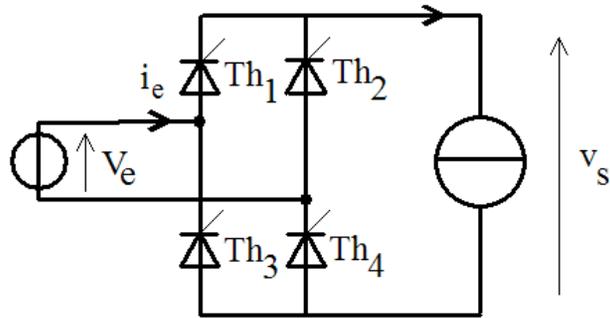
Commande des thyristors



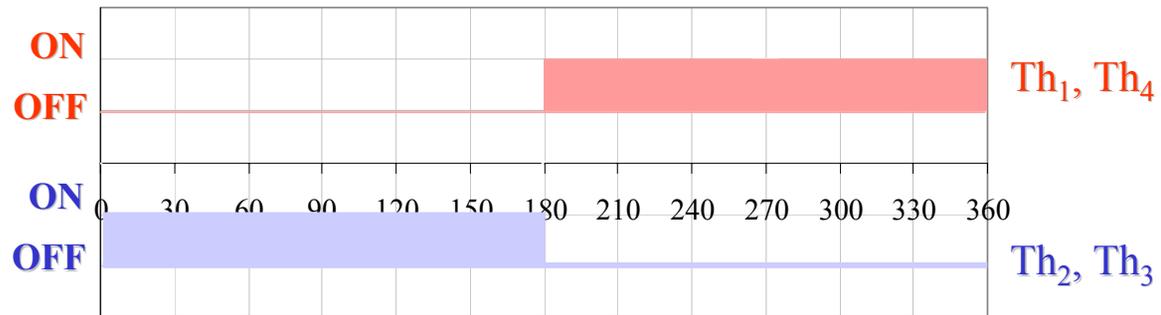
$\Psi = 150^\circ$

Variation de Ψ = Variation de tension moyenne de sortie

Tension de sortie

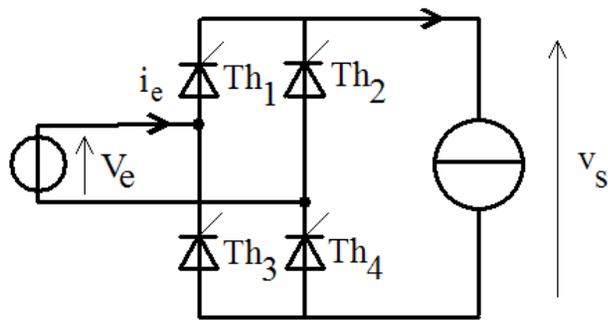


Commande des thyristors

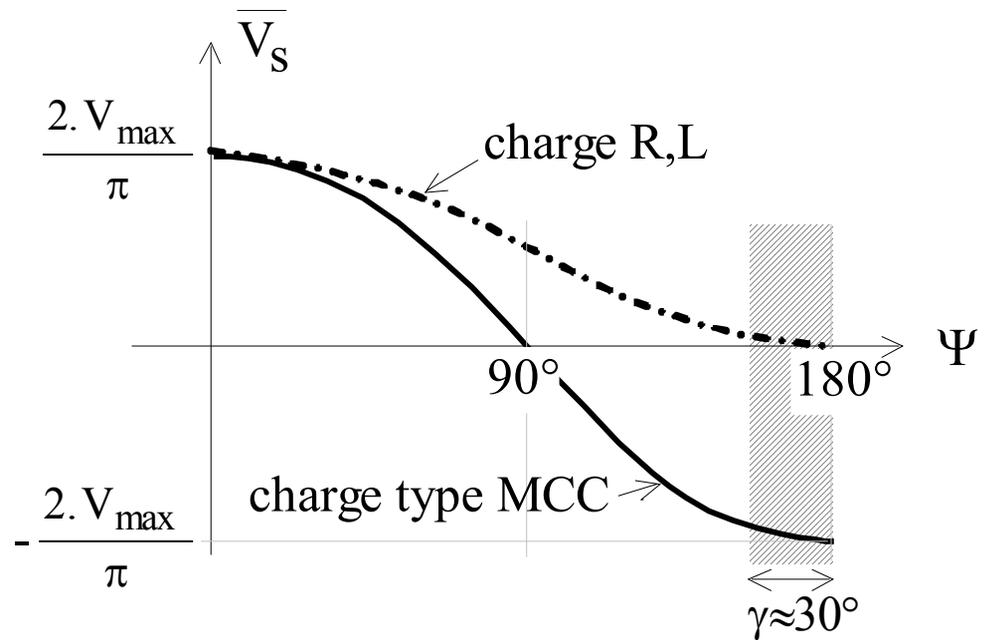


$\Psi = 180^\circ$

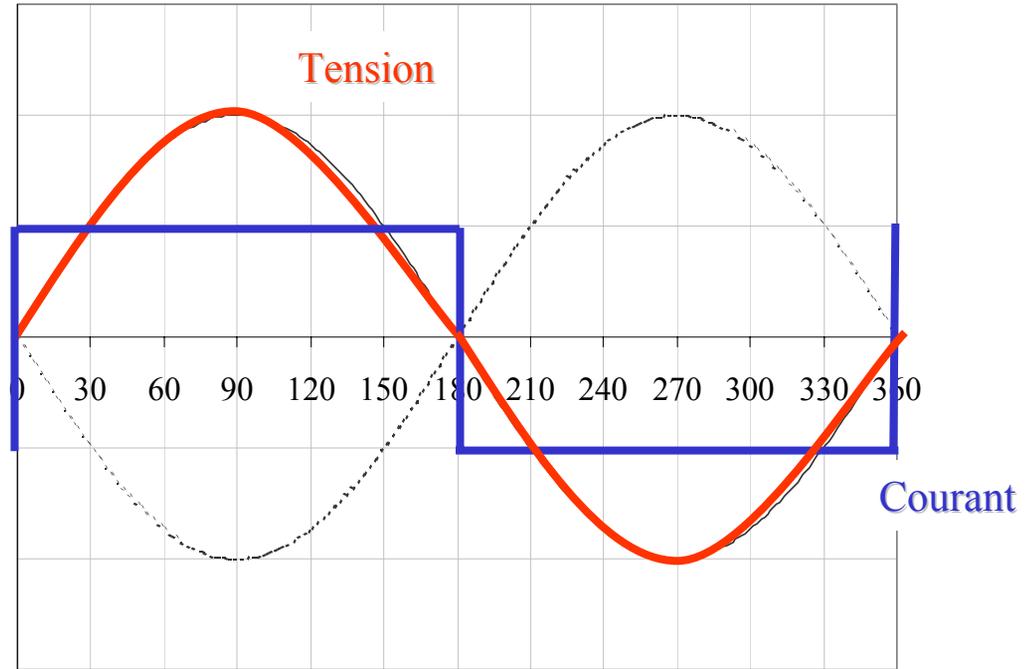
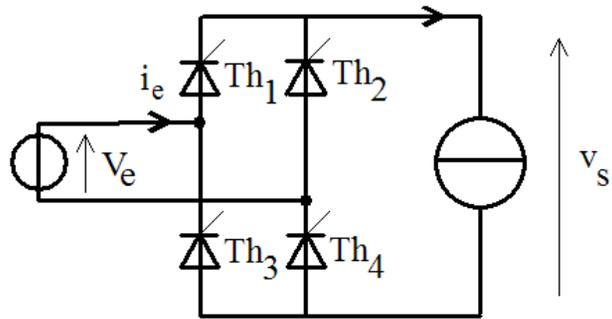
b. Tension moyenne de sortie



$$V_{s \text{ moyen}} = \frac{2 \cdot V_{\max}}{\pi} \cdot \cos \Psi$$

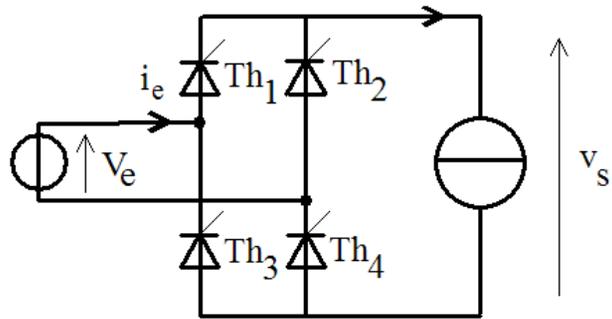


Courant et tension côté alternatif

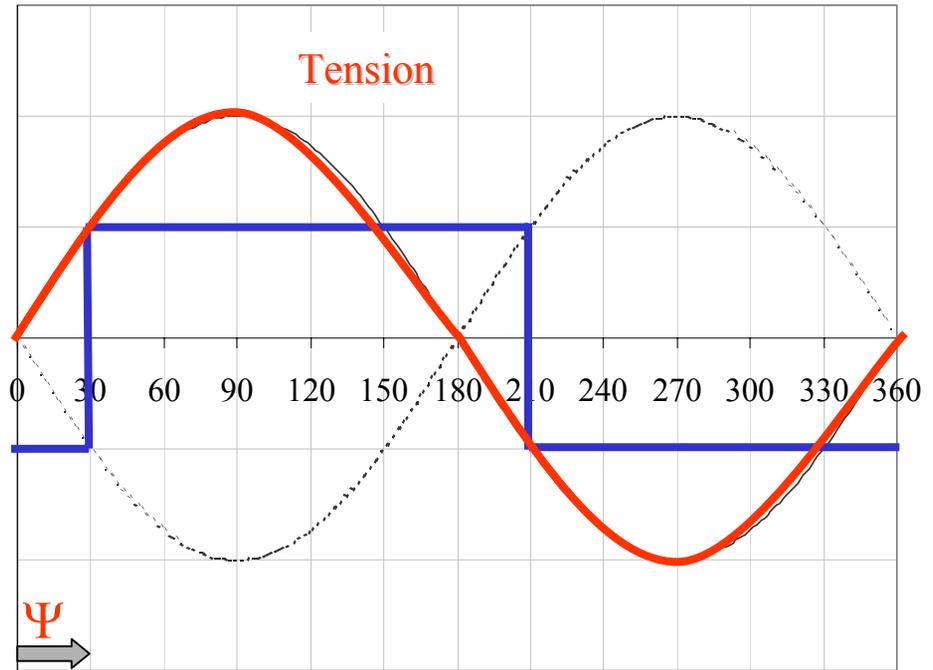


$$\Psi = 0$$

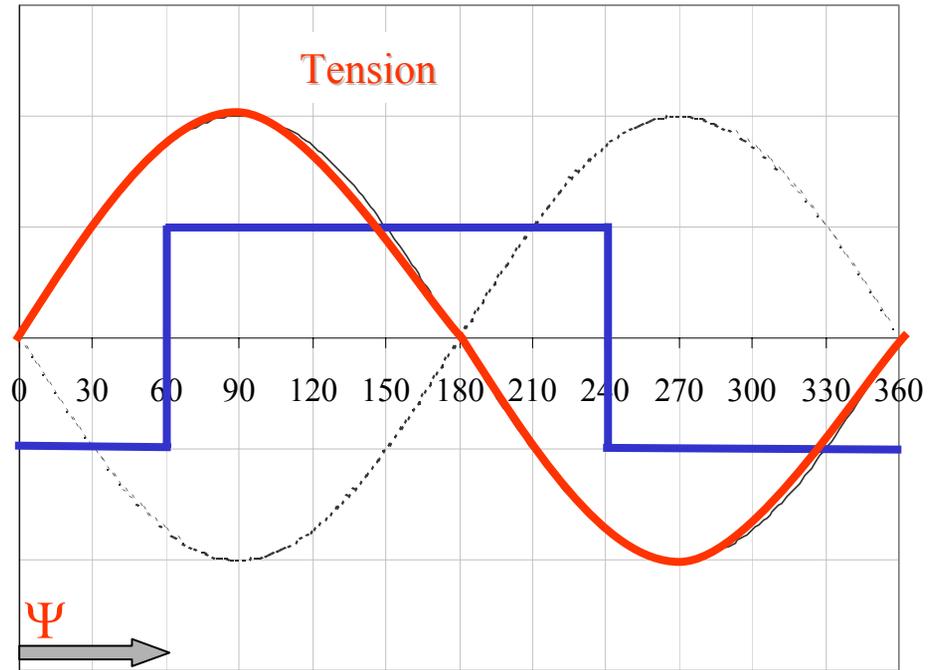
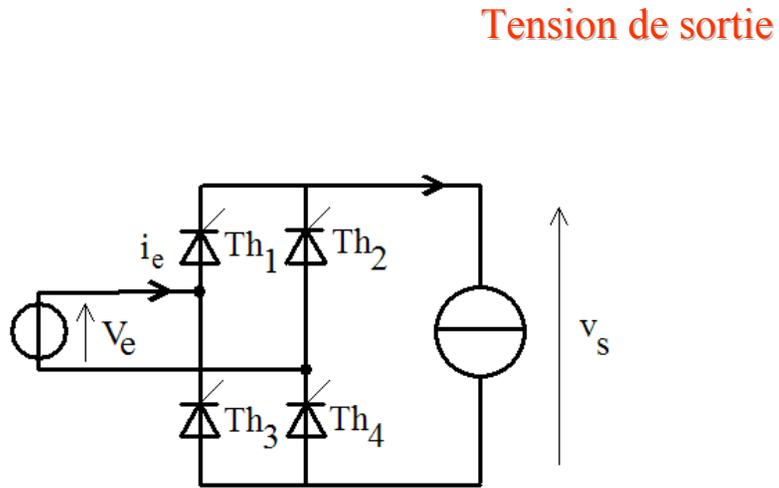
Courant et tension côté alternatif



Tension de sortie

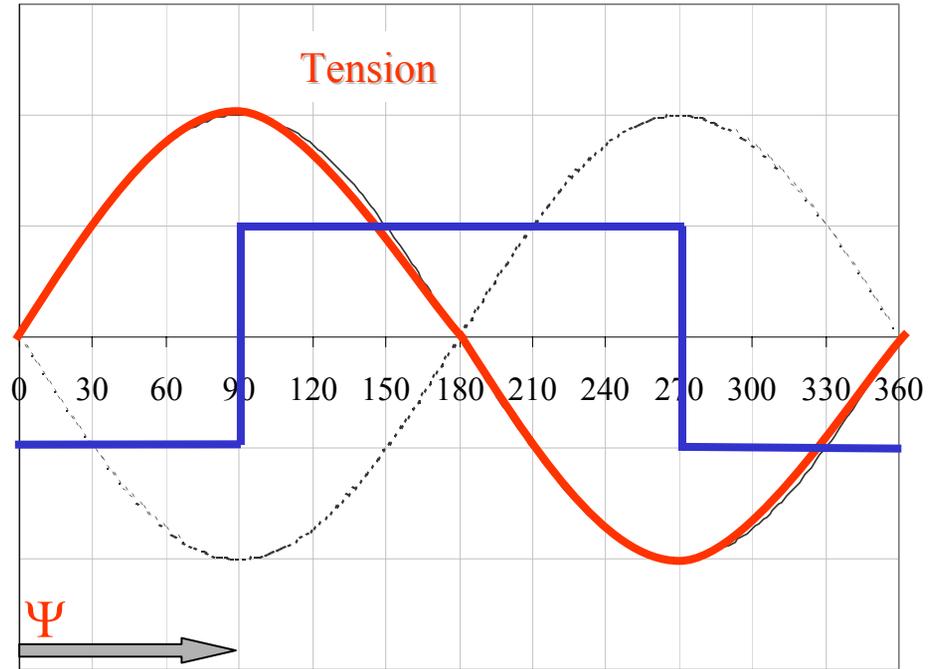
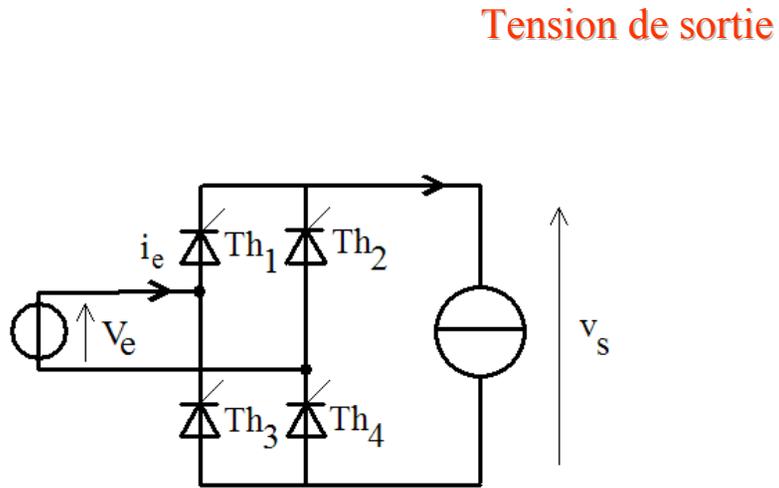


Courant et tension côté alternatif

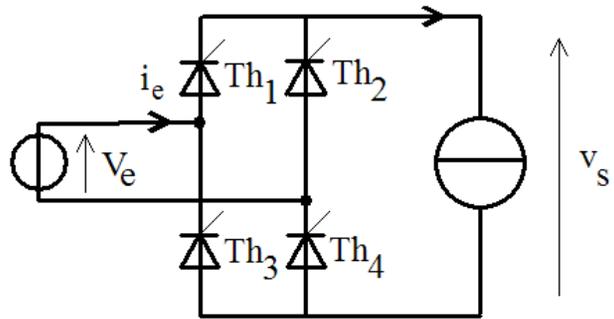


Courant d'entrée

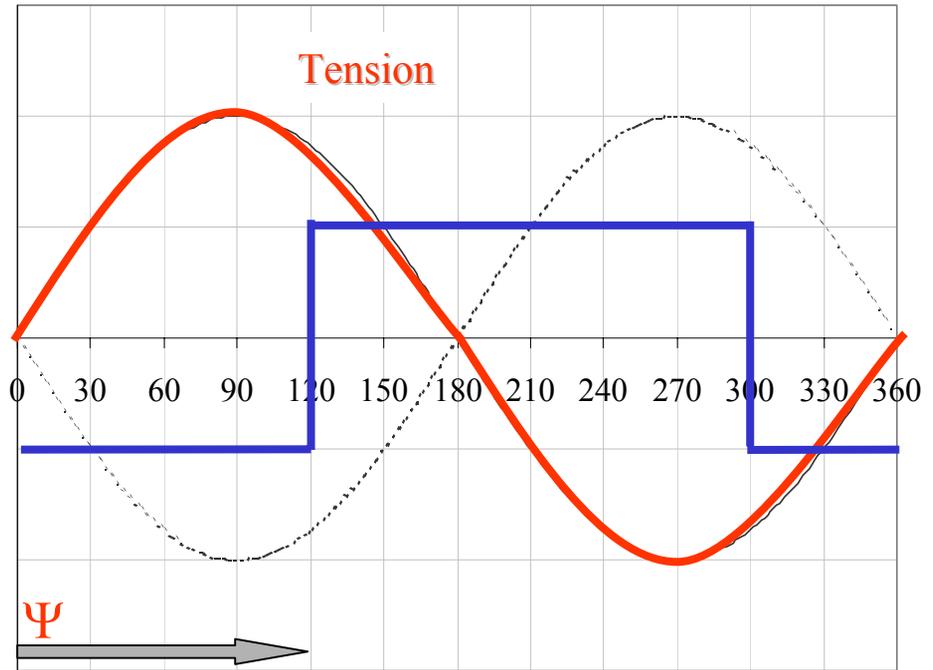
Courant et tension côté alternatif



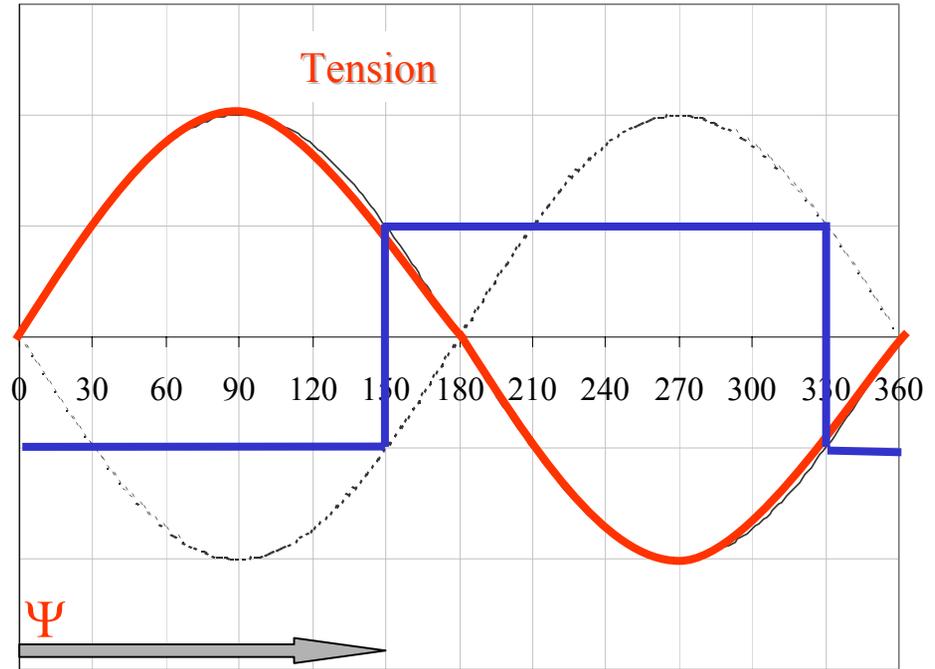
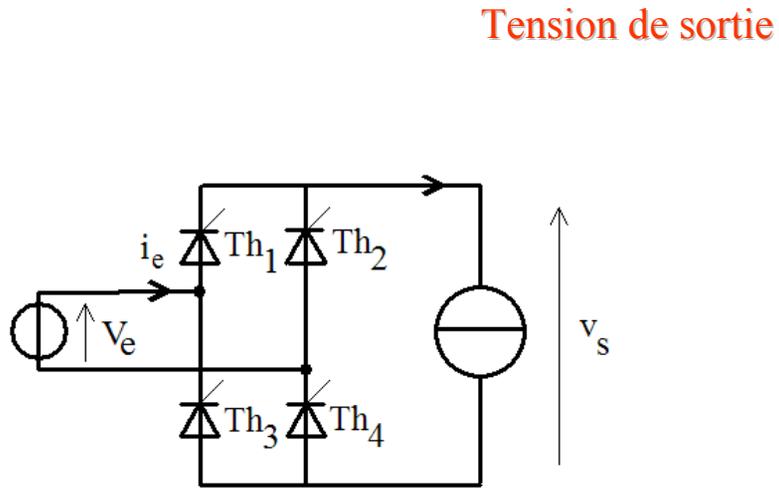
Courant et tension côté alternatif



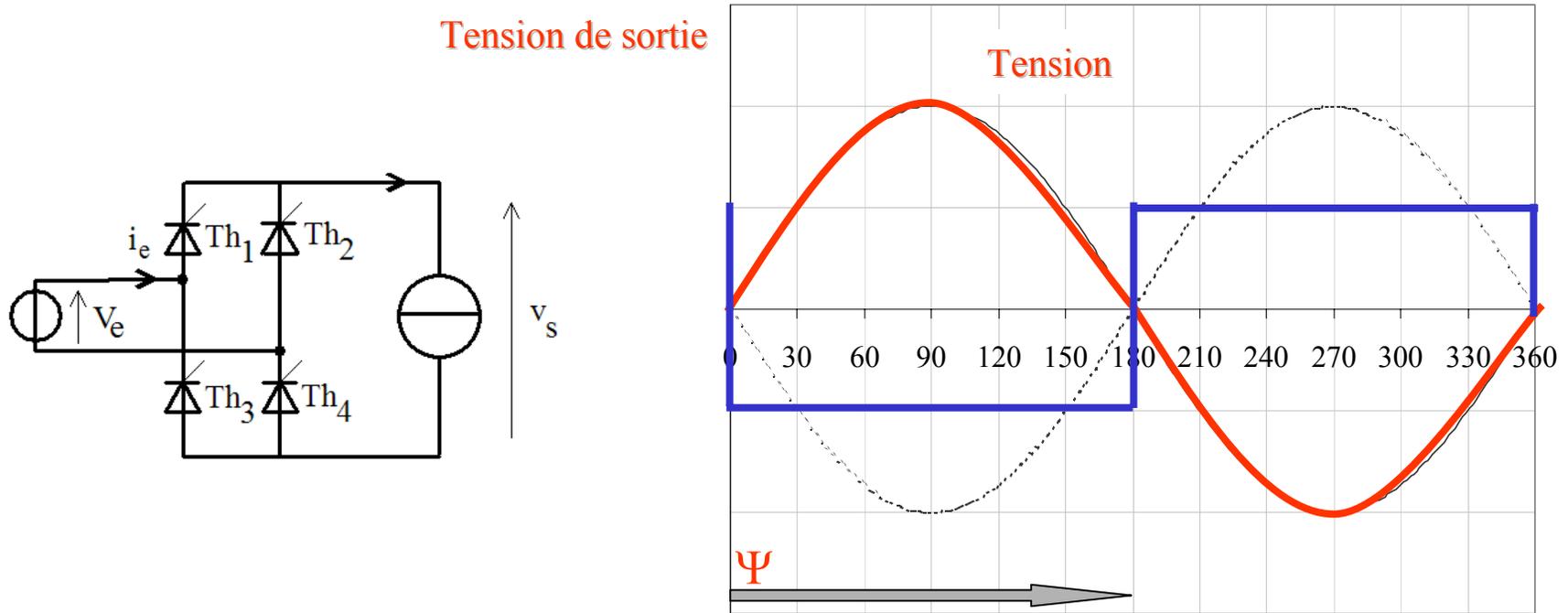
Tension de sortie



Courant et tension côté alternatif



Courant et tension côté alternatif



Puissance active \longrightarrow Transmise uniquement par le fondamental