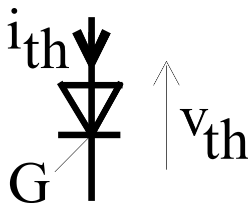
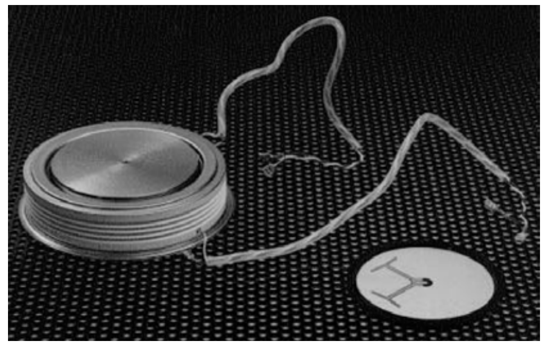
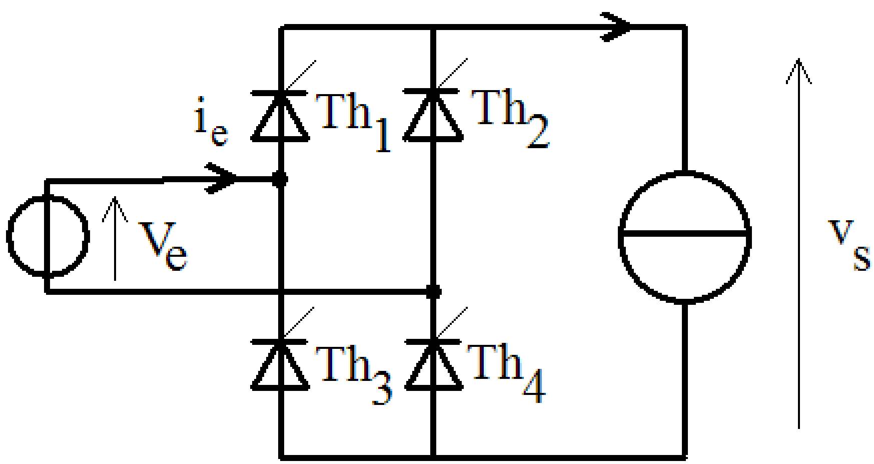
II.2 Redressement monophasé commandé en pont complet

→ Ponts à Thyristors

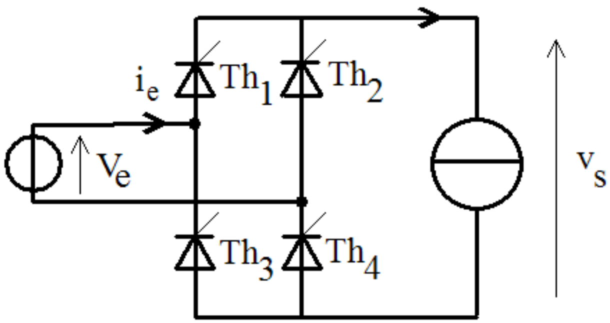




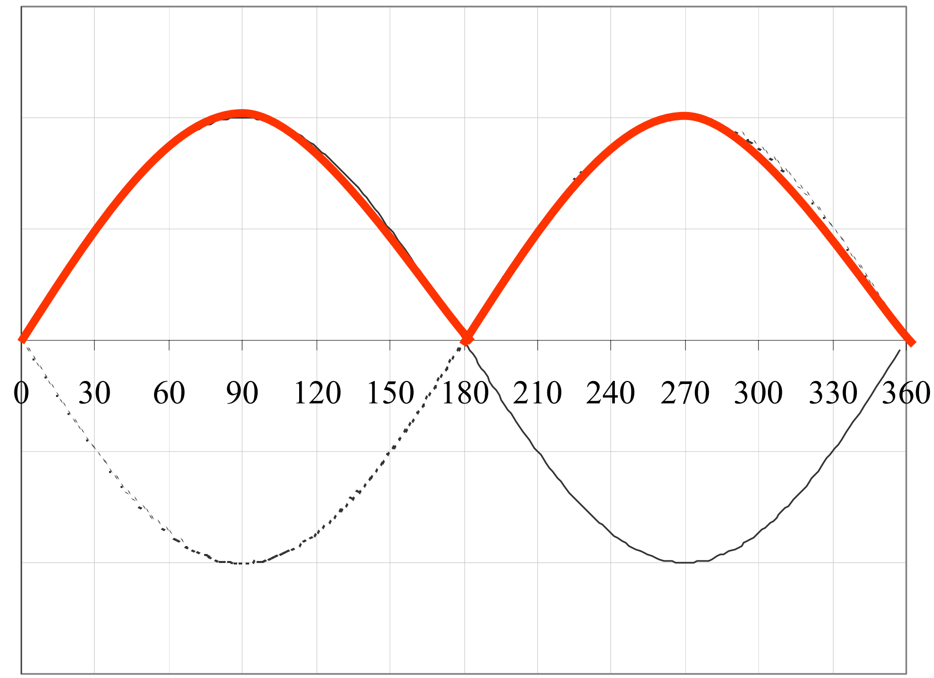
a. Montage



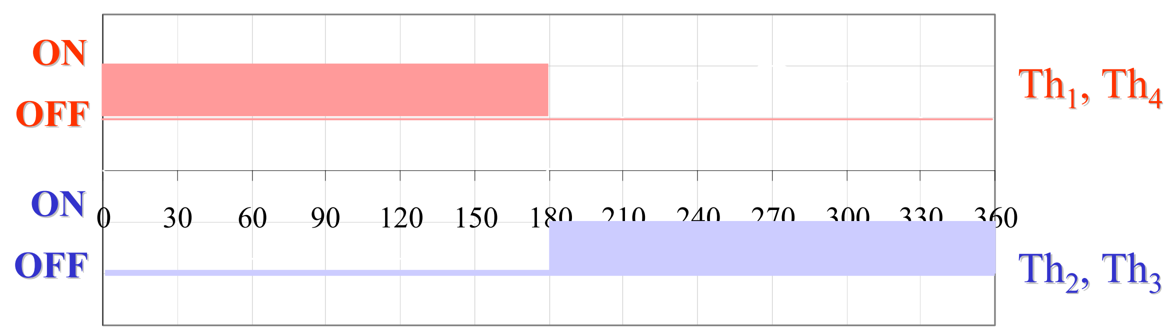
Amorçage des thyristors : définit par rapport aux instants de commutation naturelle



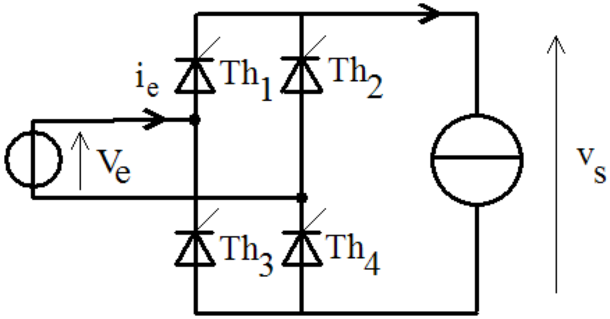
Tension de sortie



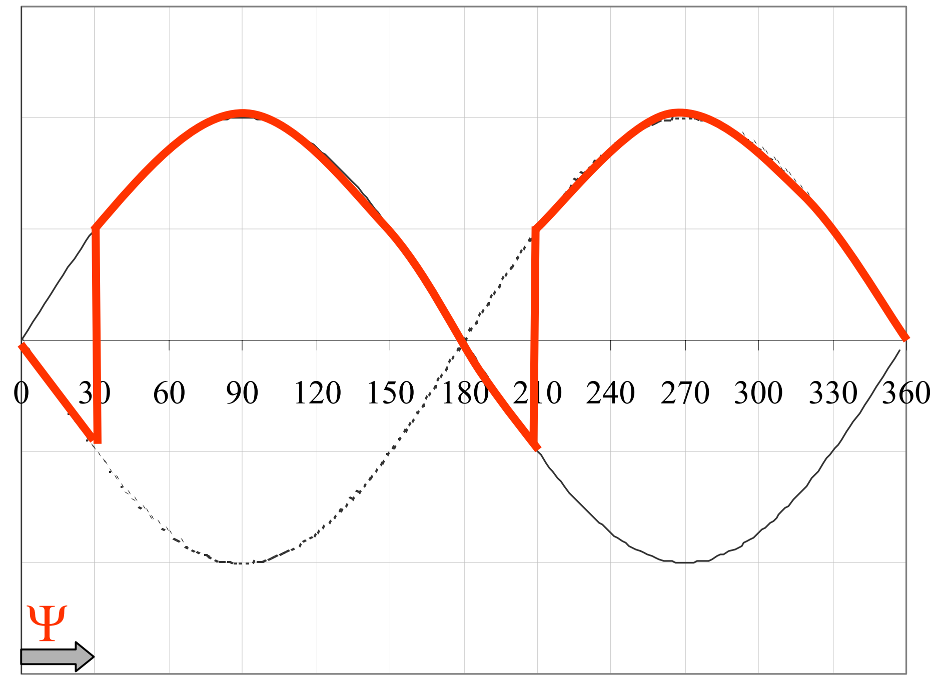
Commande des thyristors



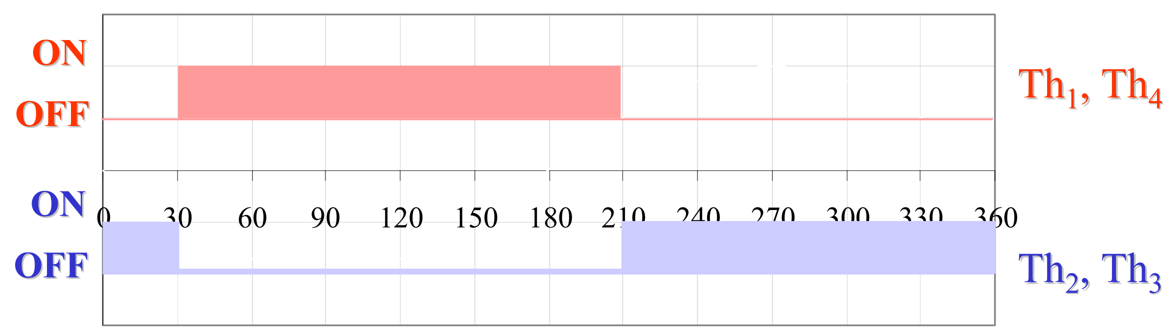
$\Psi = 0$



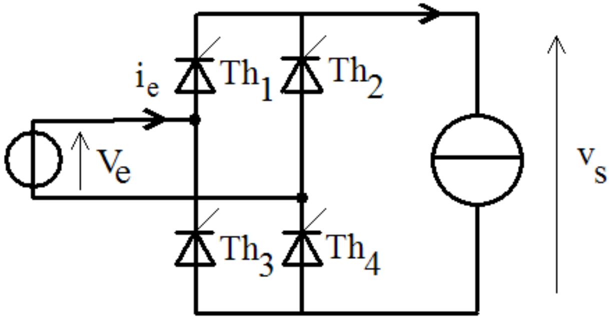
Tension de sortie



Commande des thyristors

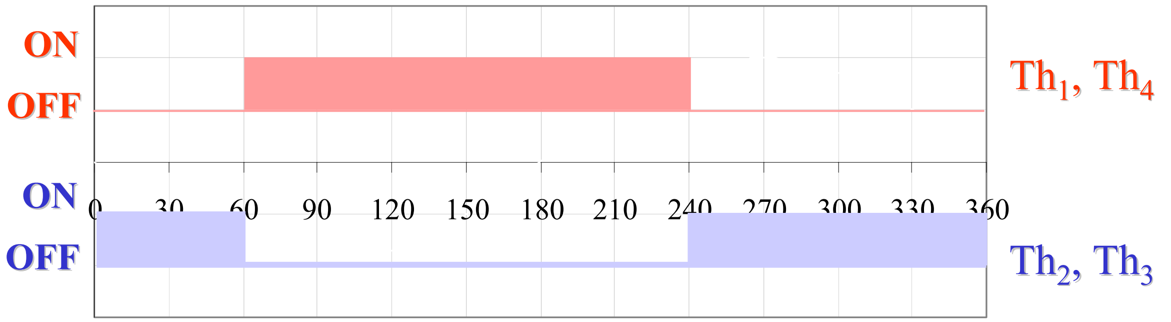


$\Psi = 30°$

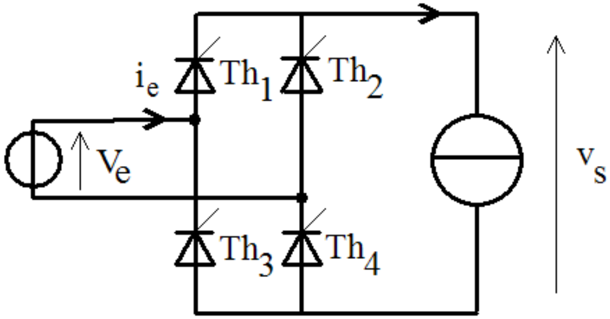


Tension de sortie

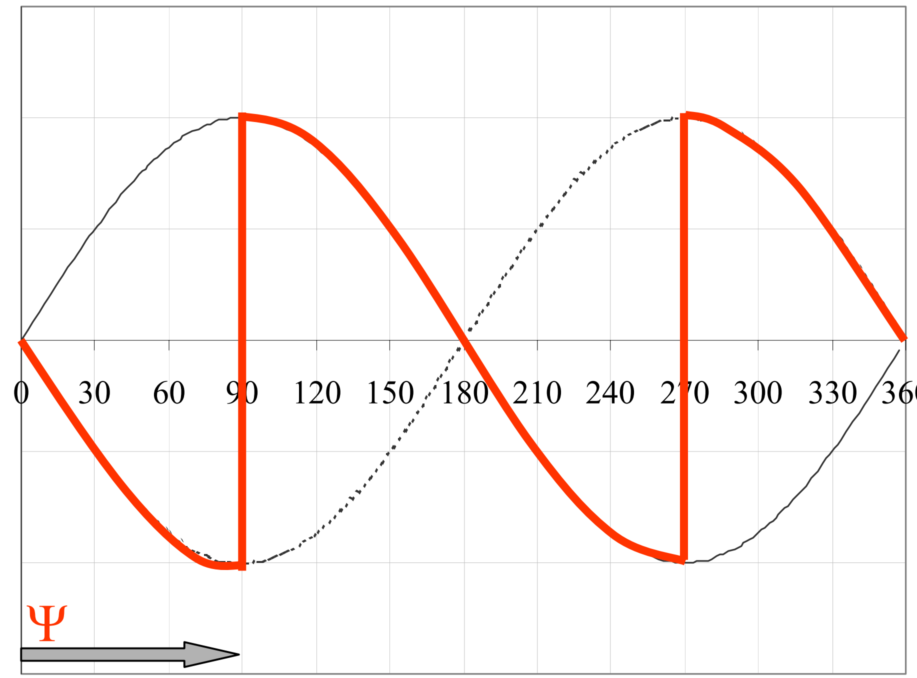
Commande des thyristors



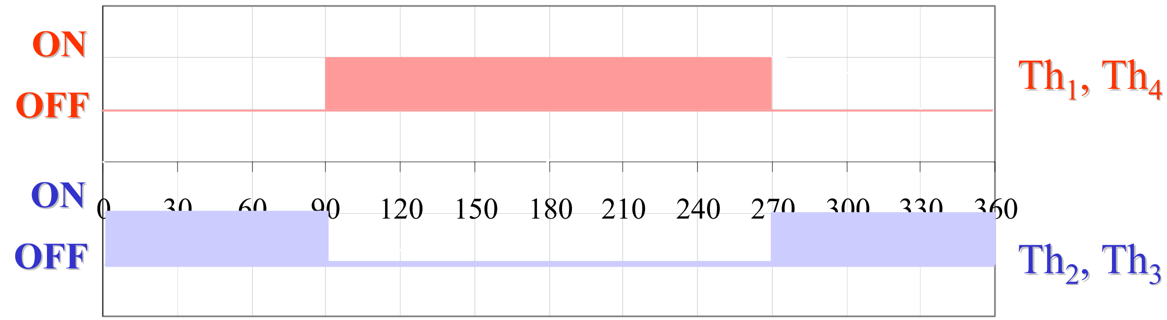
$\Psi = 60°$



Tension de sortie

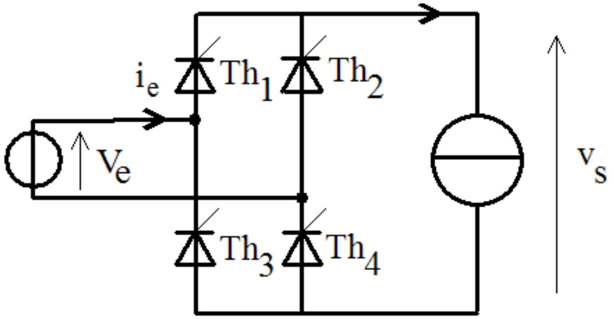


Commande des thyristors

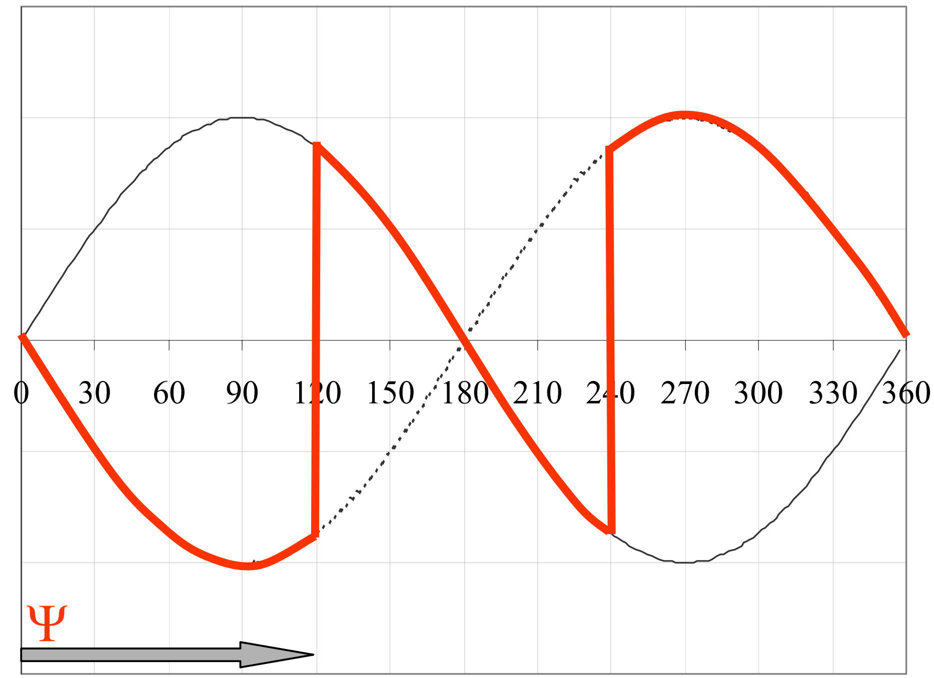


$\Psi = 90°$

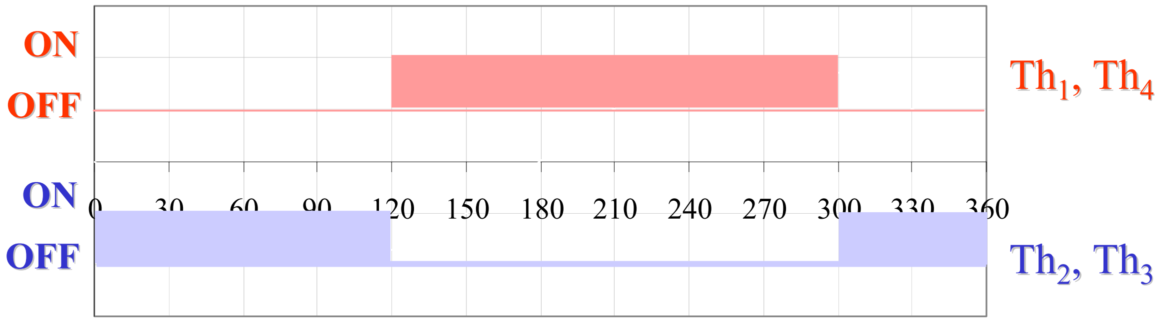
Les redresseurs



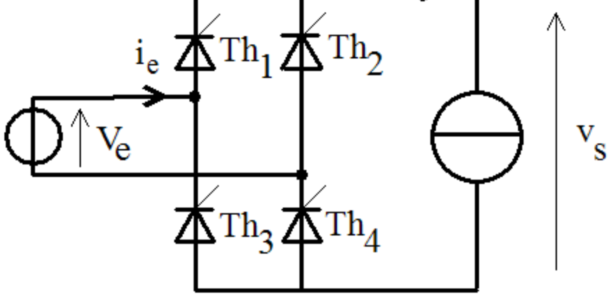
Tension de sortie



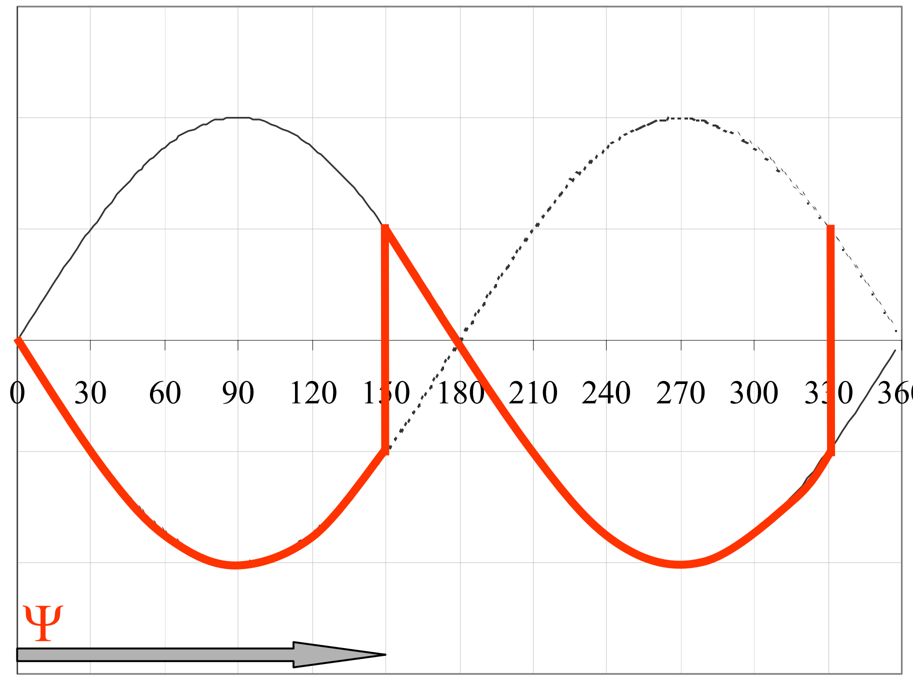
Commande des thyristors



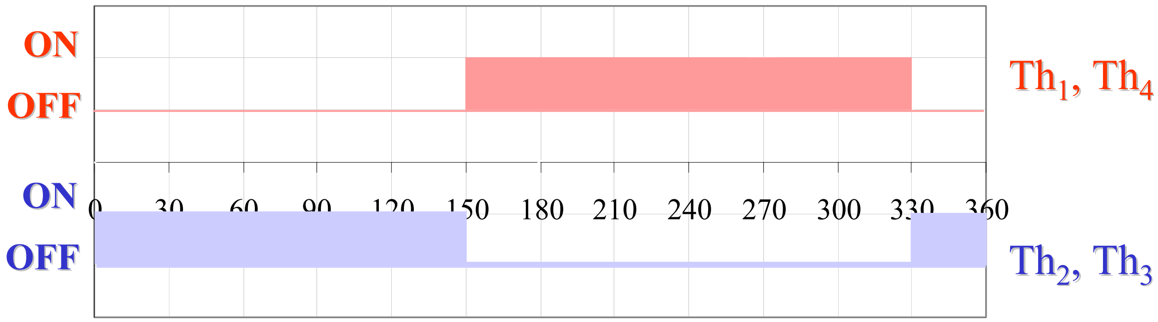
$\Psi = 120°$



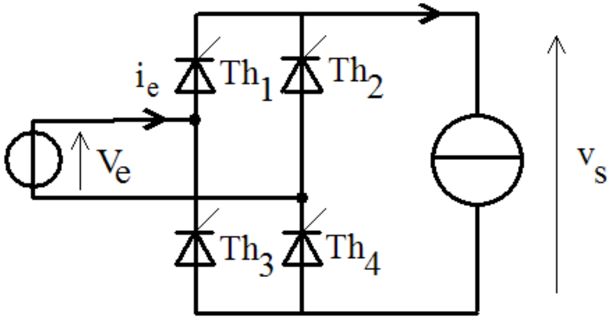
Tension de sortie



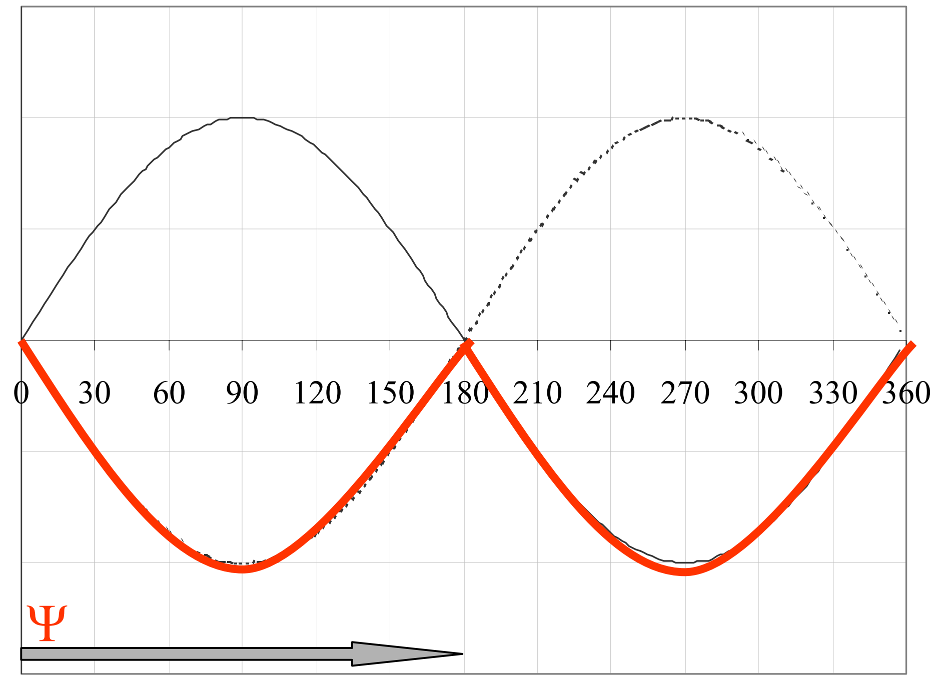
Commande des thyristors



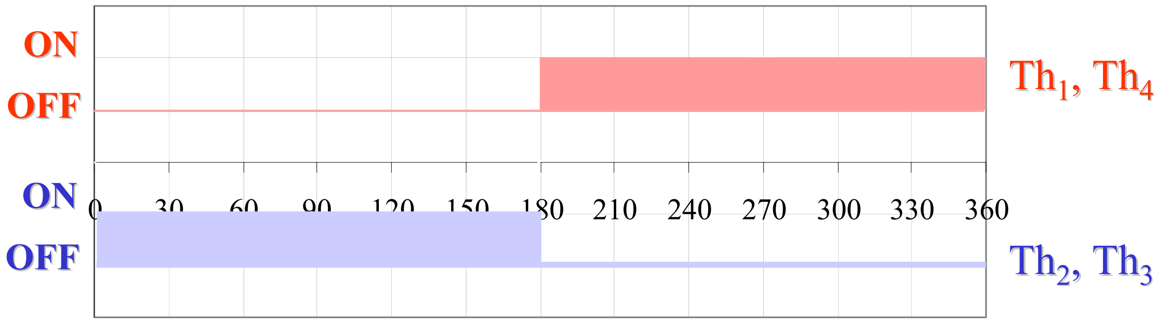
$\Psi = 150°$



Tension de sortie

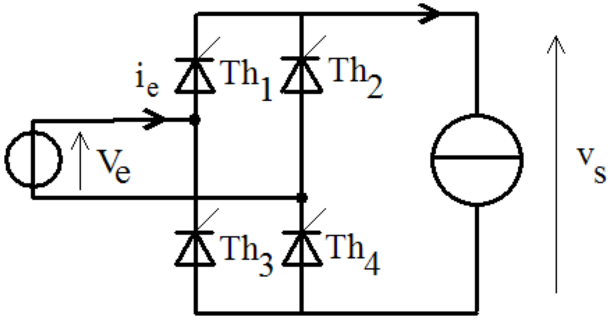


Commande des thyristors

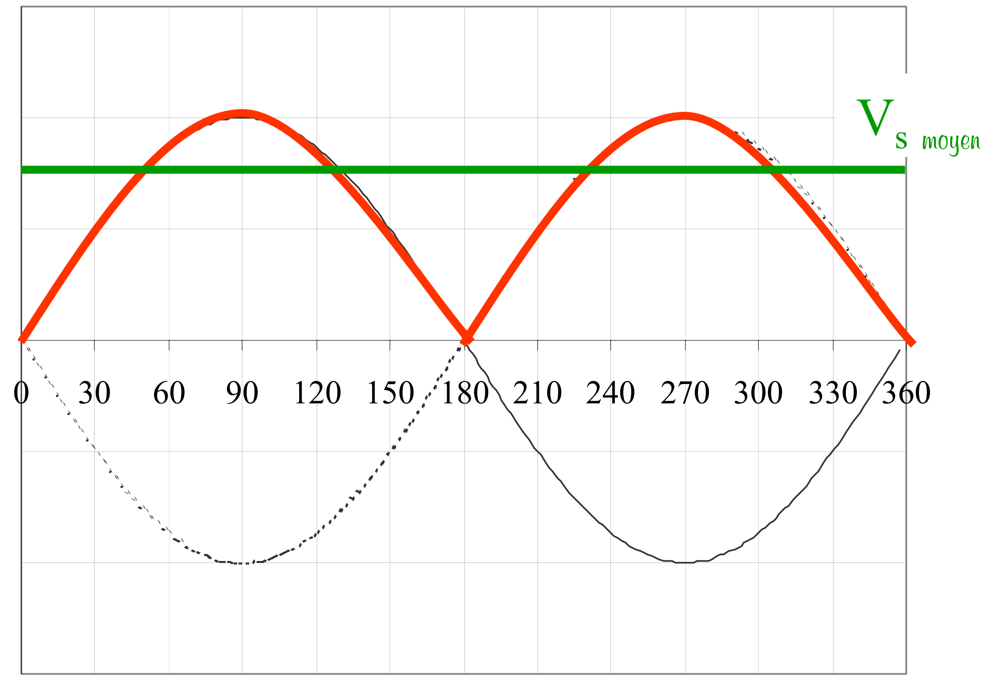


$\Psi = 180°$

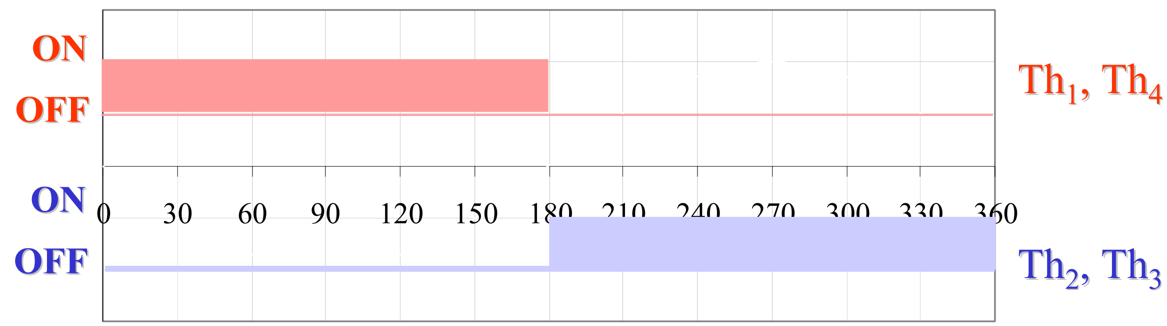
Variation de Ψ = Variation de tension moyenne de sortie



Tension de sortie

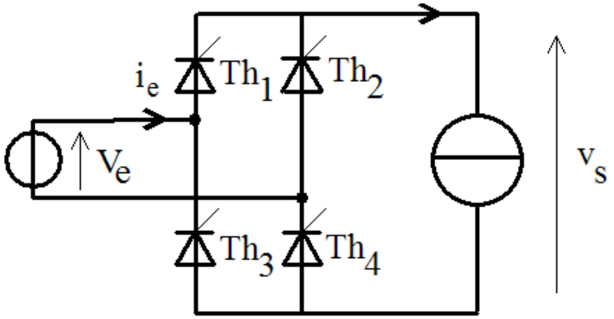


Commande des thyristors

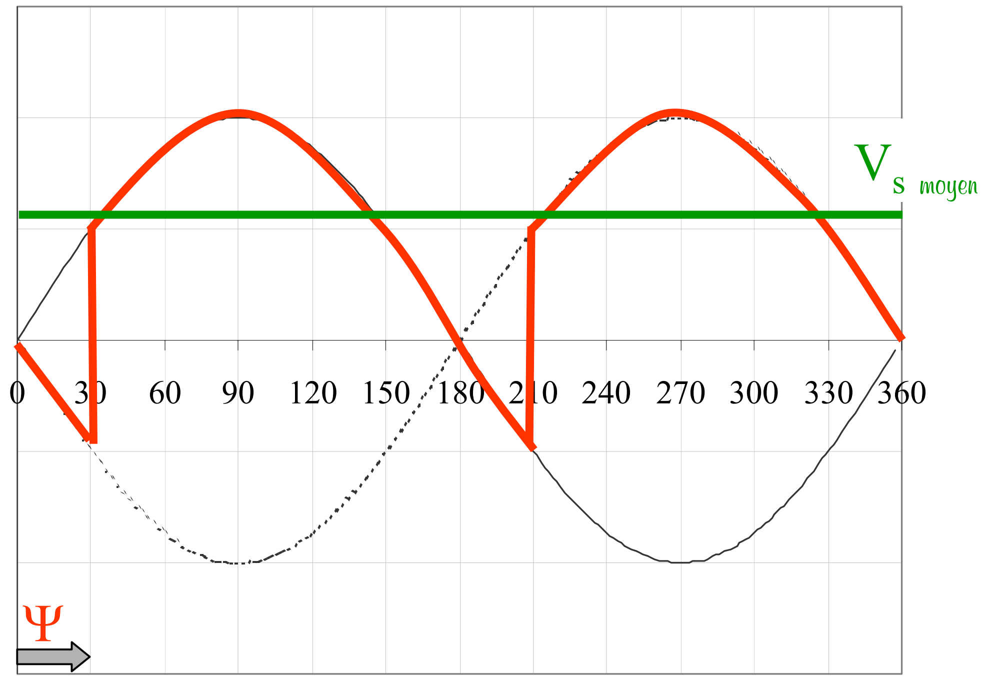


$\Psi = 0$

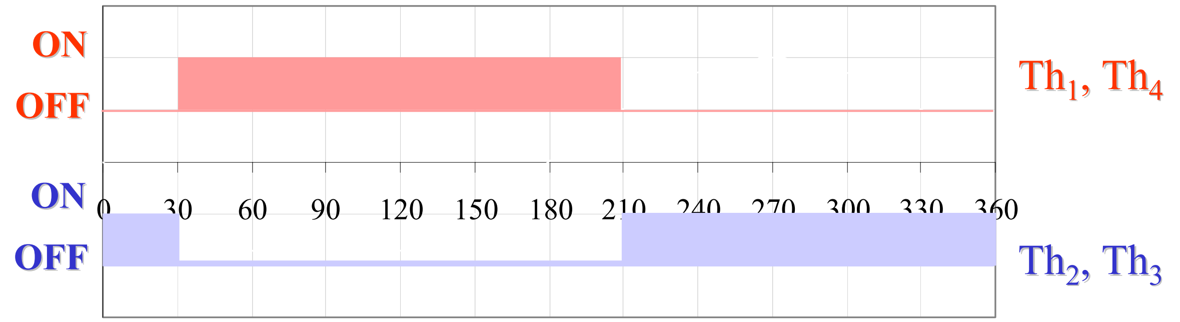
Variation de Ψ = Variation de tension moyenne de sortie



Tension de sortie

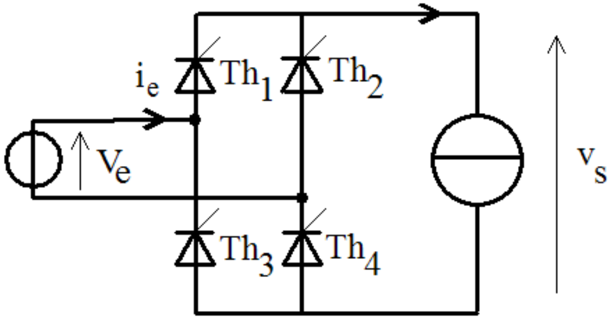


Commande des thyristors

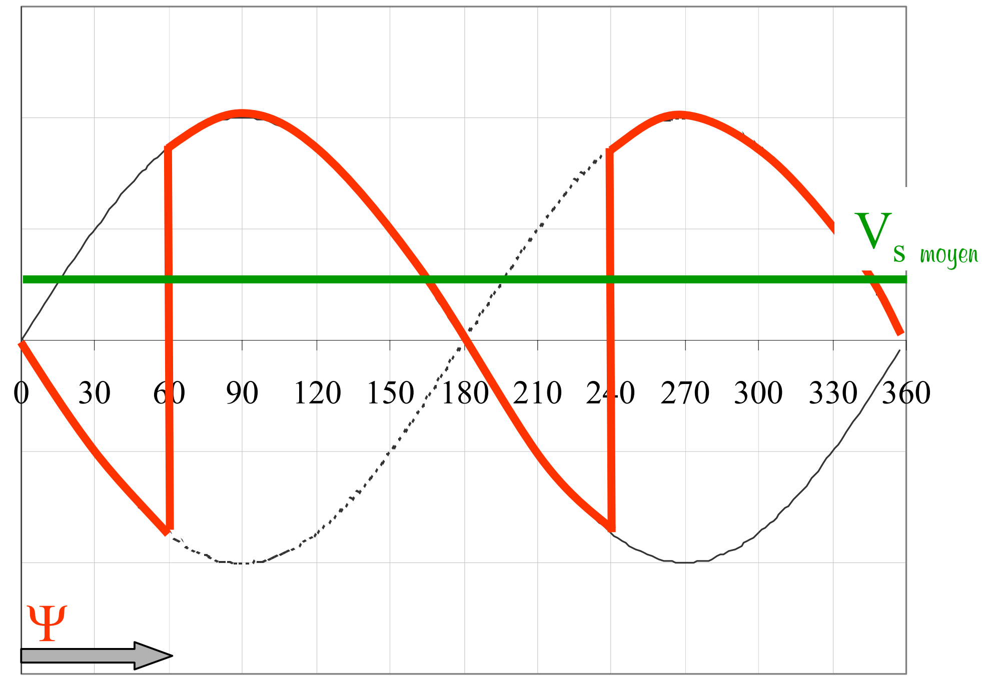


$\Psi = 30°$

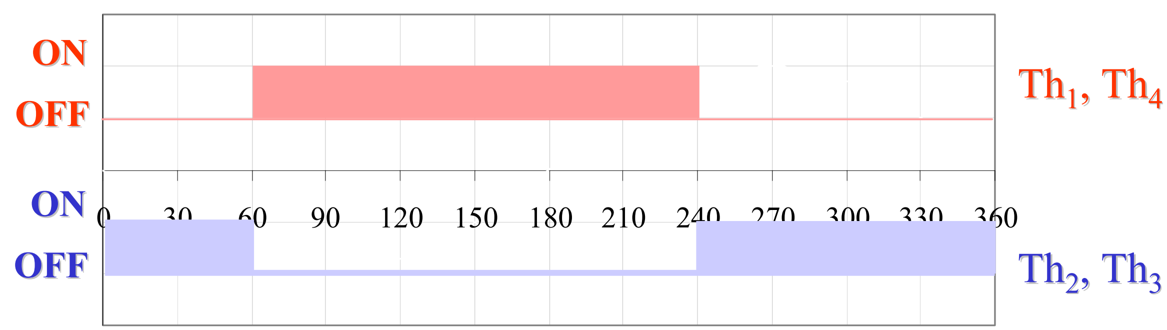
Variation de Ψ = Variation de tension moyenne de sortie



Tension de sortie

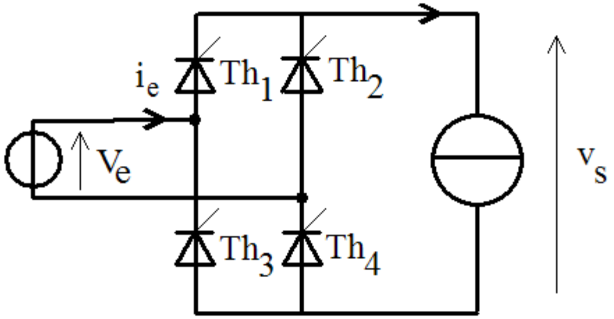


Commande des thyristors

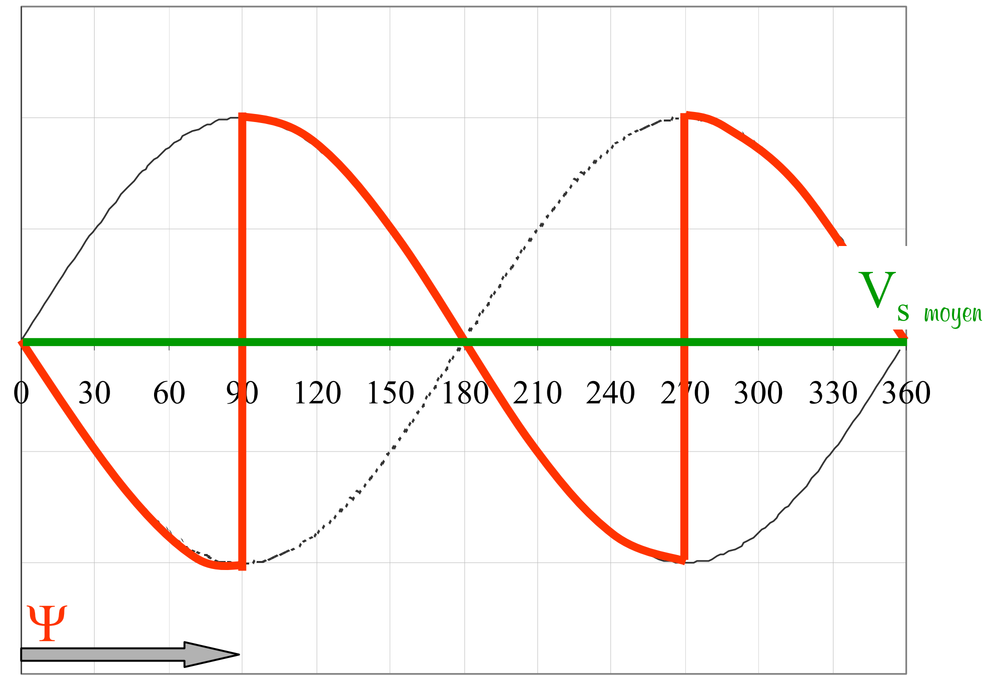


$\Psi = 60°$

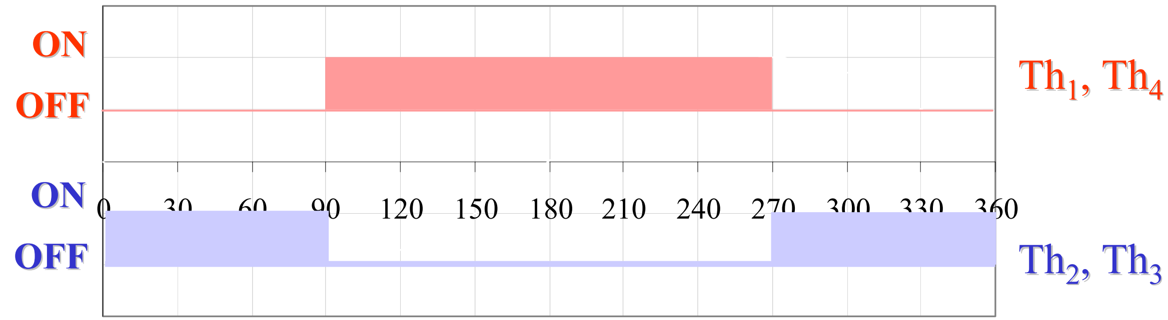
Variation de Ψ = Variation de tension moyenne de sortie



Tension de sortie

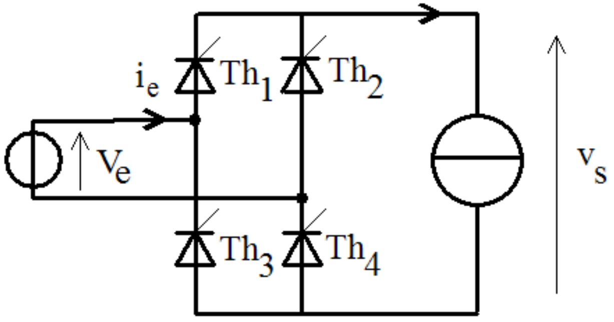


Commande des thyristors

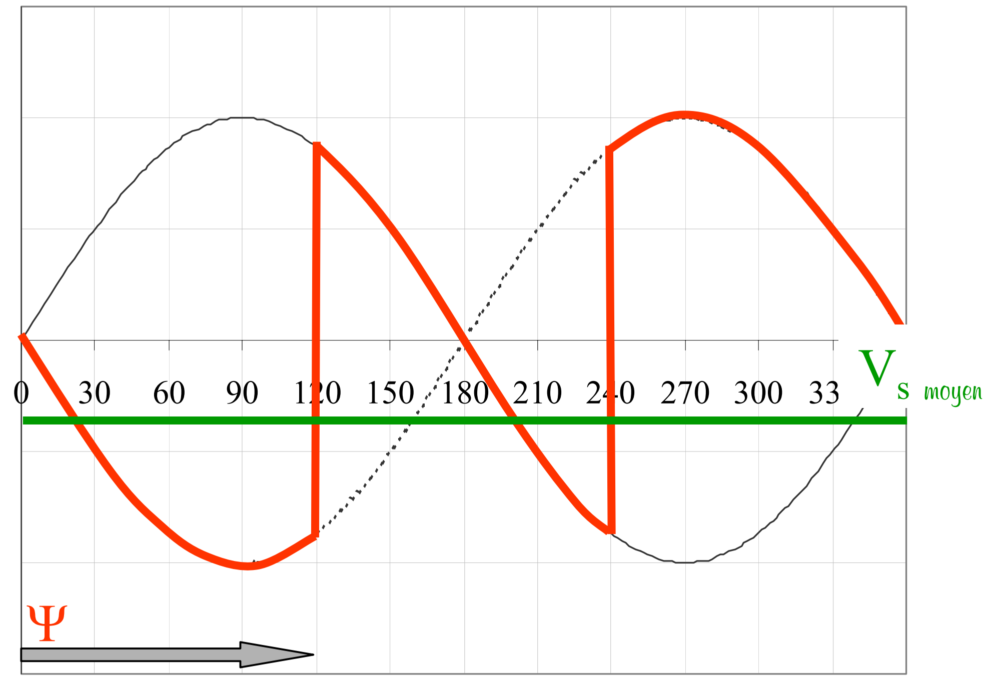


$\Psi = 90°$

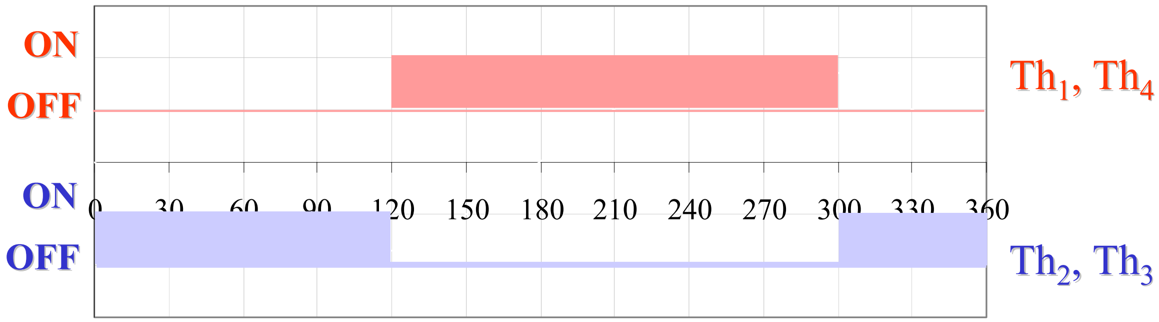
Variation de Ψ = Variation de tension moyenne de sortie



Tension de sortie

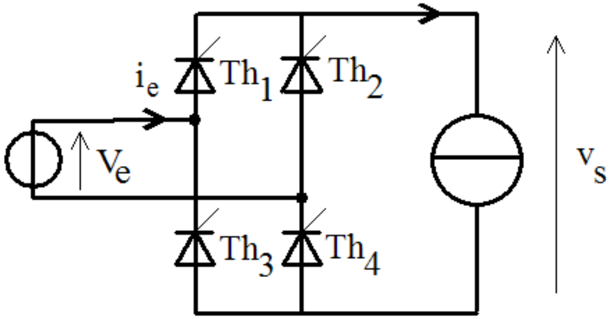


Commande des thyristors

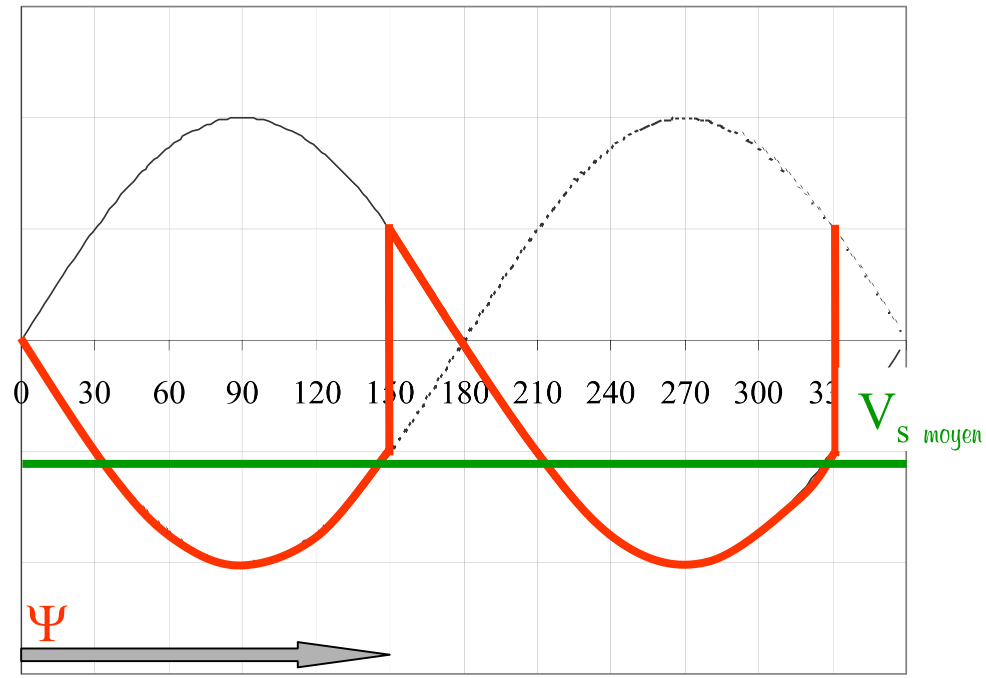


Ψ = 120°

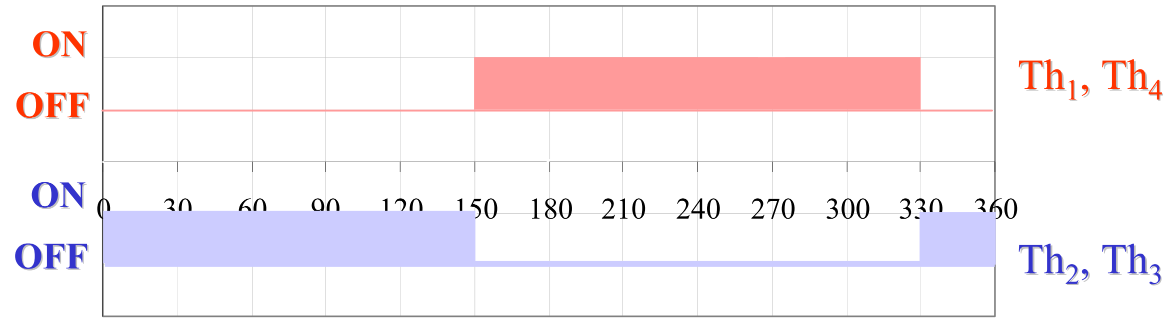
Variation de Ψ = Variation de tension moyenne de sortie



Tension de sortie

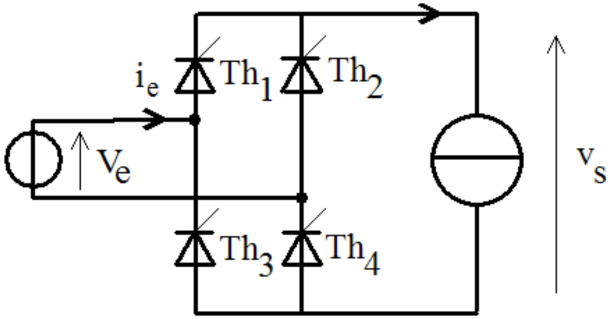


Commande des thyristors

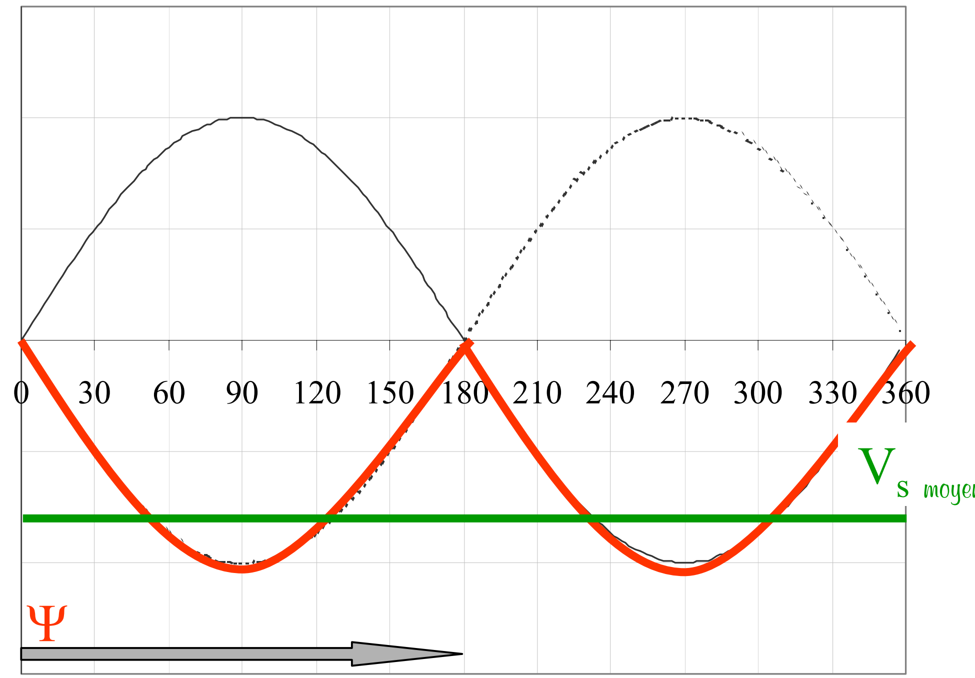


Ψ = 150°

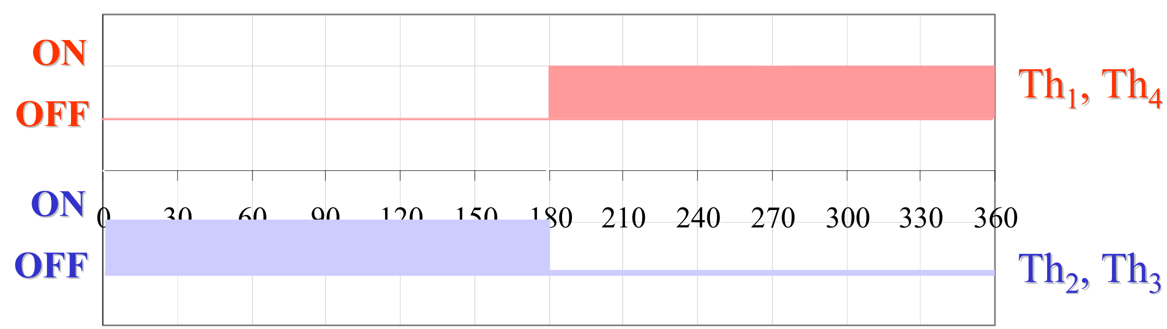
Variation de Ψ = Variation de tension moyenne de sortie



Tension de sortie

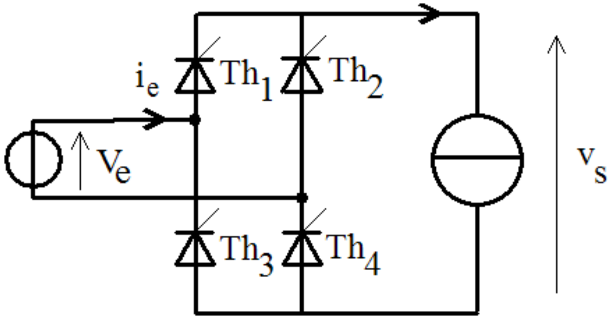


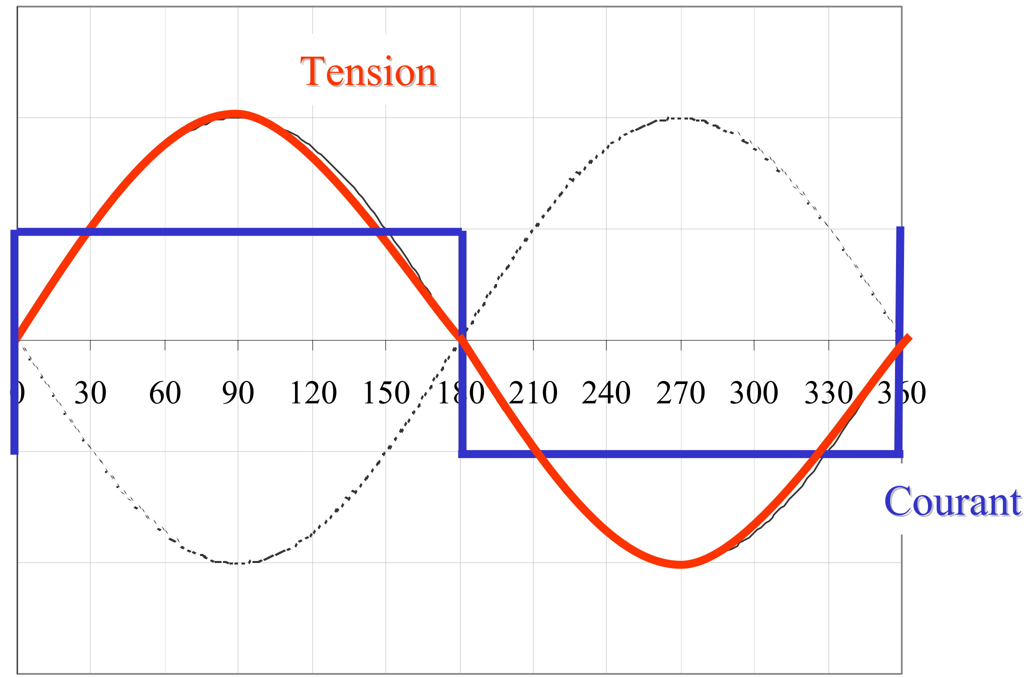
Commande des thyristors



$\Psi = 180°$

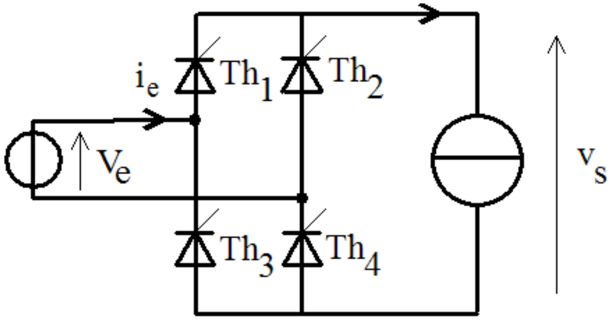
Courant et tension côté alternatif

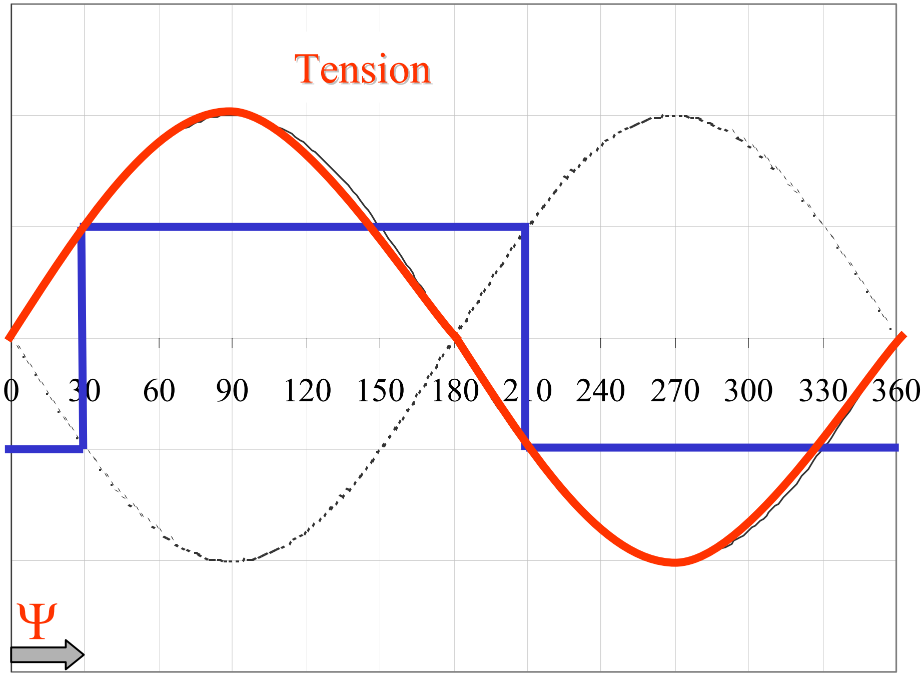




$\Psi = 0$

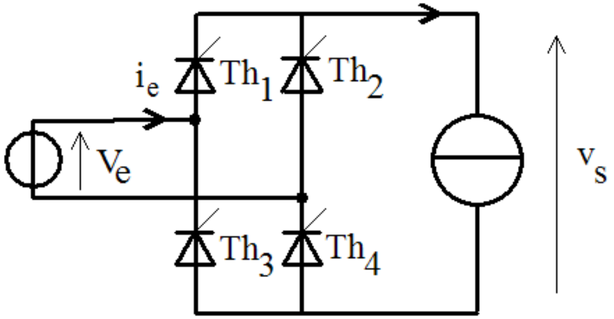
Courant et tension côté alternatif

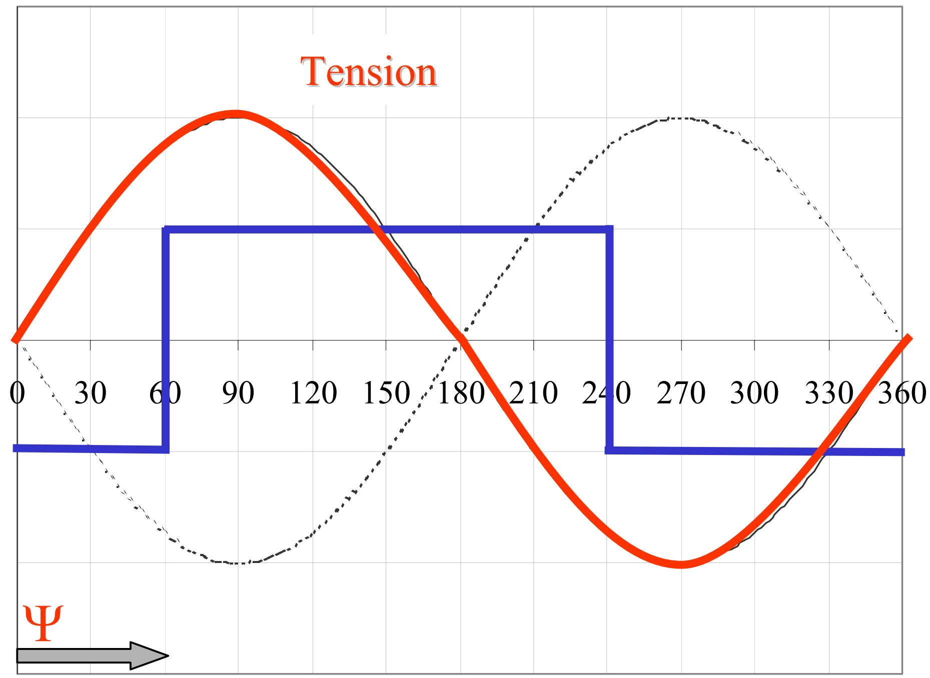




Courant et tension côté alternatif

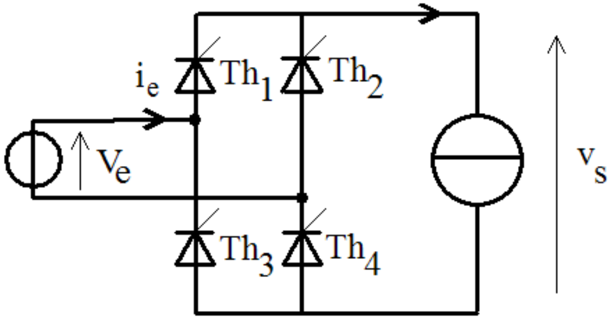
Tension de sortie

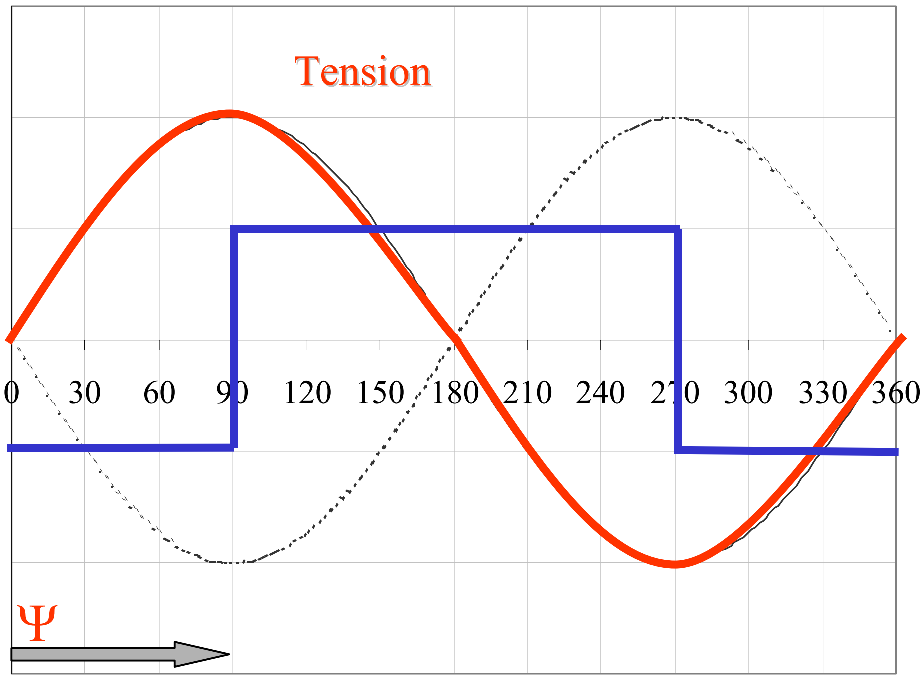




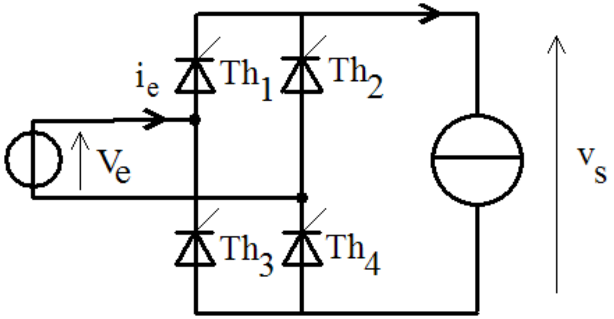
Courant d’entrée

Courant et tension côté alternatif

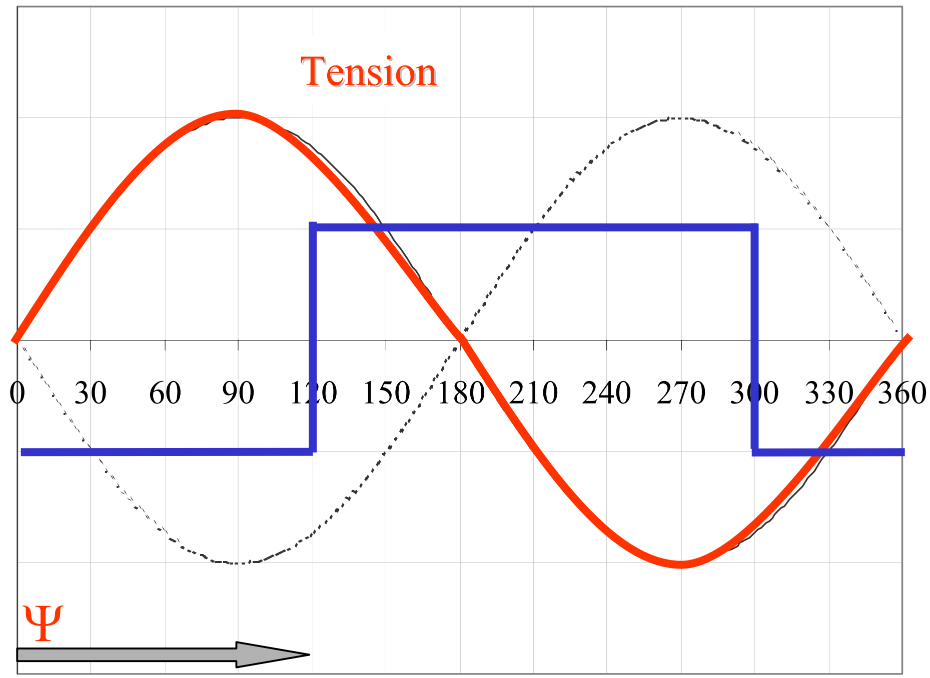




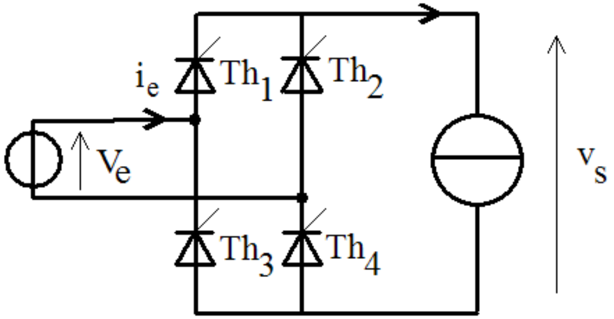
Courant et tension côté alternatif

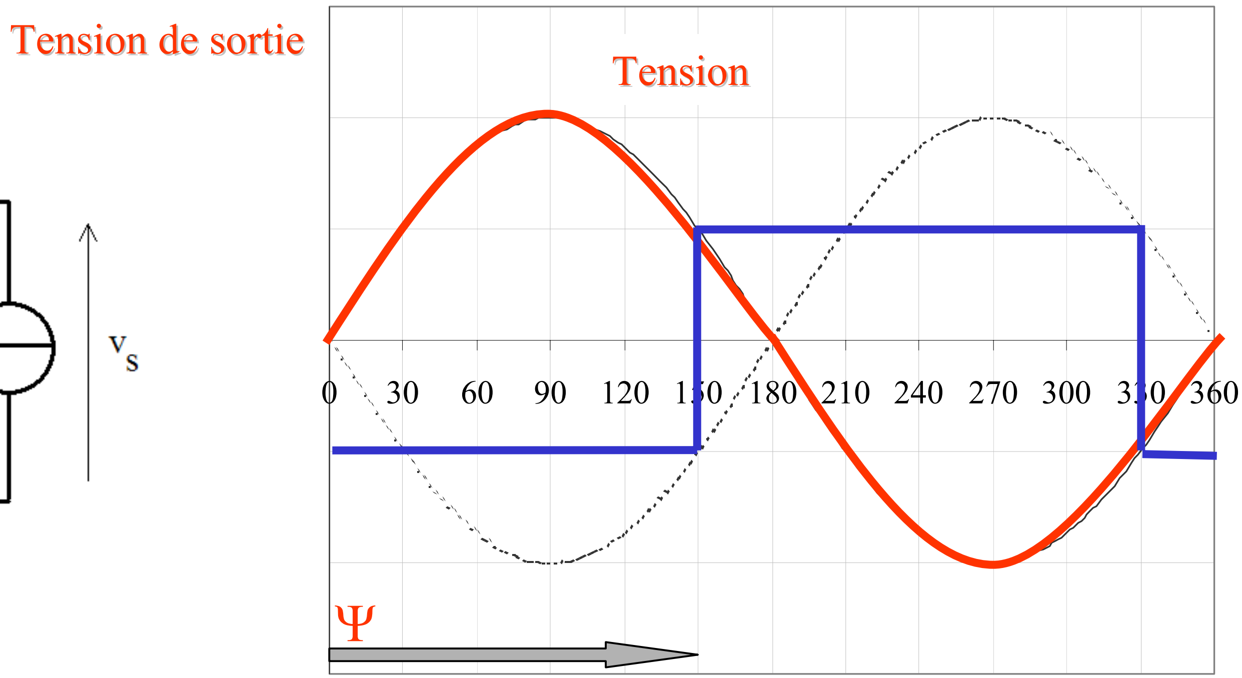


Tension de sortie

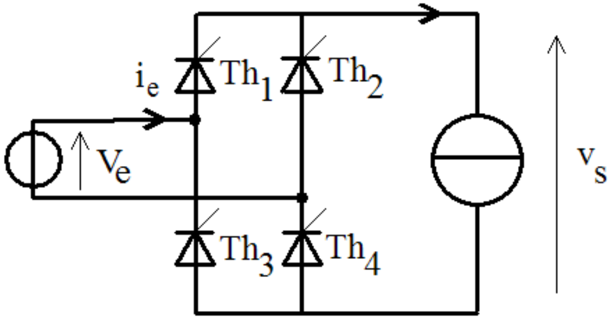


Courant et tension côté alternatif

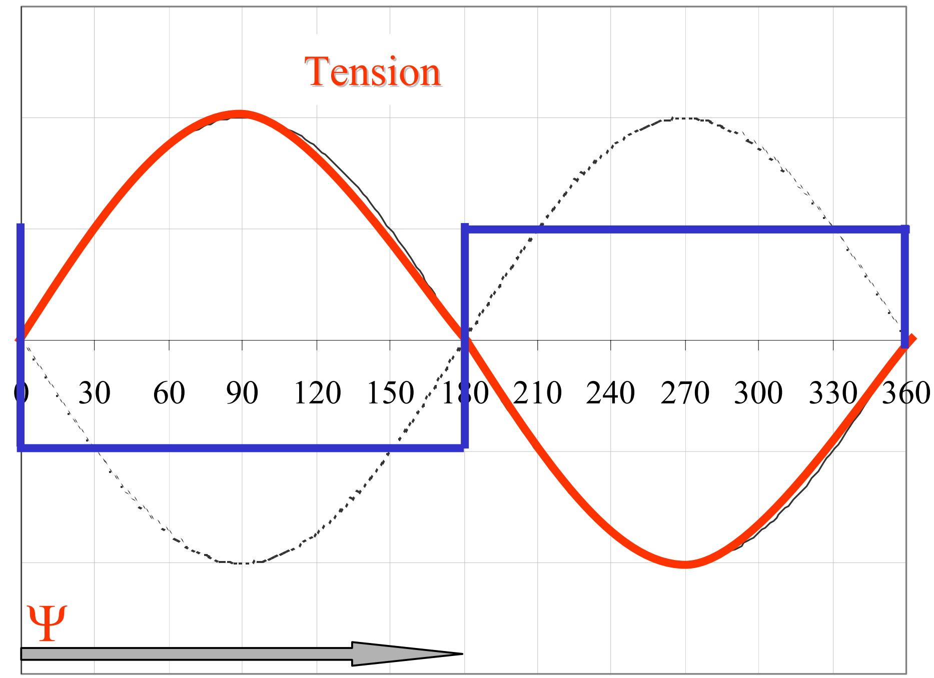




Courant et tension côté alternatif

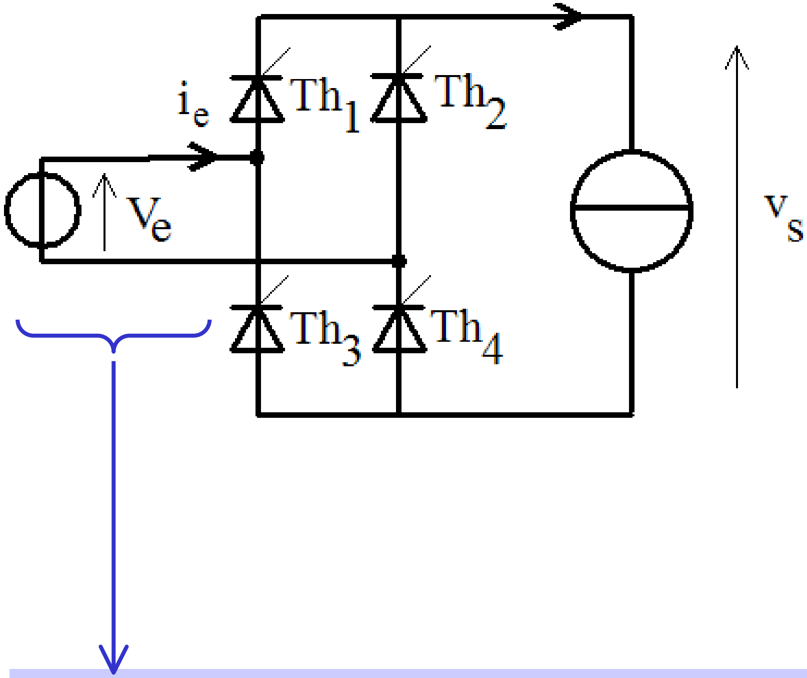


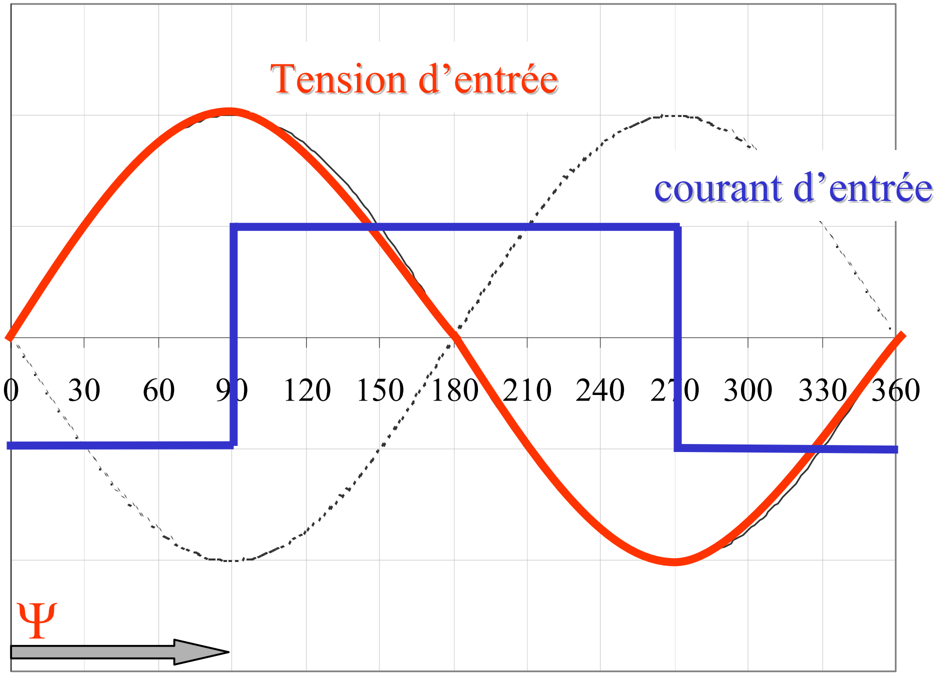
Tension de sortie



Puissance active → Transmise uniquement par le fondamental

c. Puissance active côté alternatif





$$v_e(t) = V_e \cdot \sqrt{2} \cdot \sin\left(\omega t \right)$$

$$i_e(t) = \frac{4.I}{\pi} \cdot \sin\left(\omega t - \varphi_1 \right) + \frac{4.I}{3\pi} \cdot \sin\left(3\omega t - \varphi_3 \right) + \frac{4.I}{5\pi} \cdot \sin\left(5\omega t - \varphi_5 \right) + \ldots$$

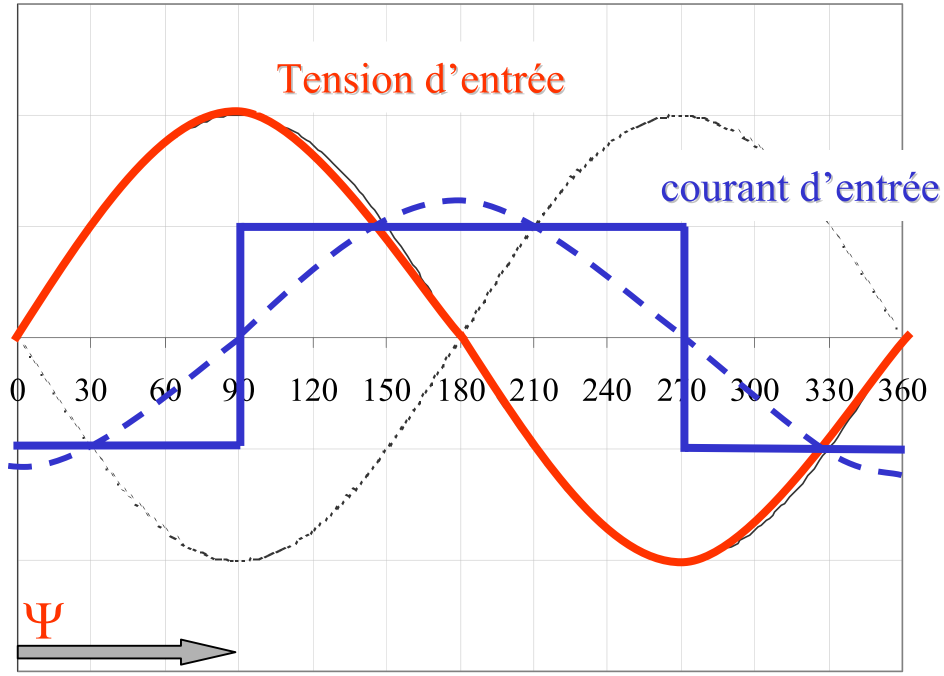
Rappel :

$$P = \frac{1}{T} . \int_0^T v_e(t) . i_e(t) . dt$$

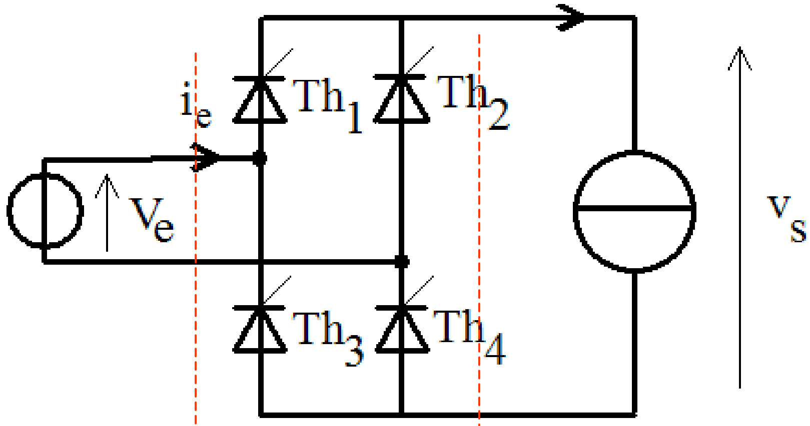
Intégrale nulle
si
i_e et v_e sont de périodes différentes

Pour le Pont monophasé à thyristors :

$$\begin{cases} P = V . I_{e1} . \sin(\varphi_1) \\ \varphi_1 = \Psi \\ i_{e1} = \dfrac{4.I}{\pi} \end{cases}$$



c. Bilan des puissances



Côté alternatif

$$P = \frac{2 . V . \sqrt{2} . I}{\pi} . \cos(\Psi)$$

$$Q = \frac{2 . V . \sqrt{2} . I}{\pi} . \sin(\Psi)$$

$$S = V . I_e = V . I$$

Côté continu

$$P = V_{s\ moyen} . I = \frac{2 . V . \sqrt{2} . I}{\pi} . \cos(\Psi)$$

Théorème de BOUCHEROT en régime non sinusoïdal :

$$S^2 \neq P^2 + Q^2$$

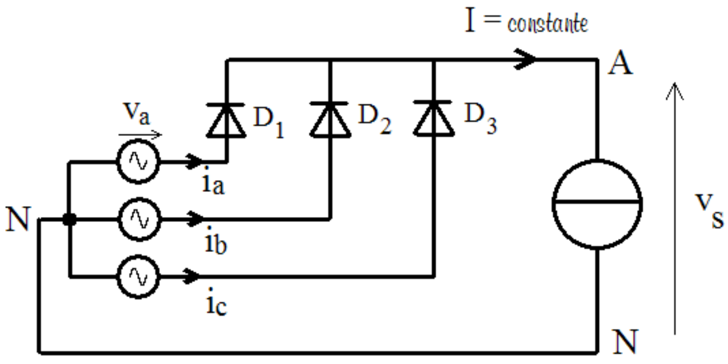
→ Ajout d'une autre puissance …. **La puissance déformante**

$$S^2 = P^2 + Q^2 + D^2$$

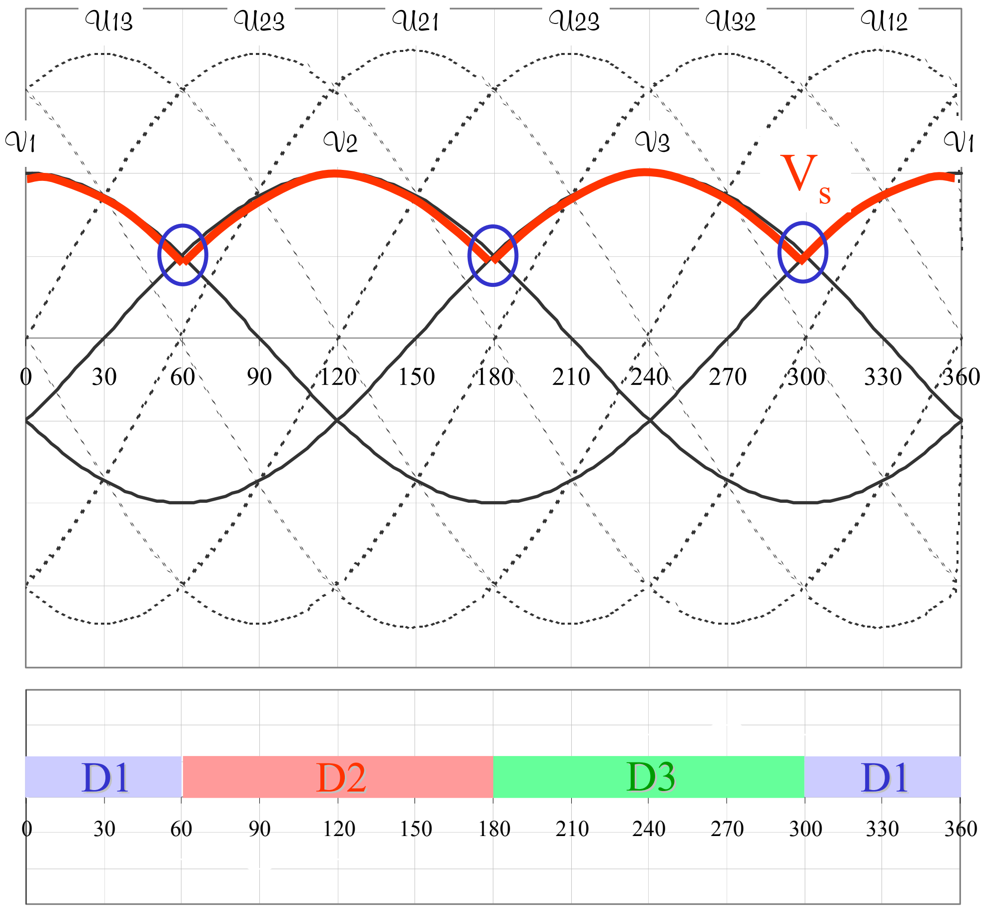
en [VAD]

II.3 Redressement triphasé non commandé

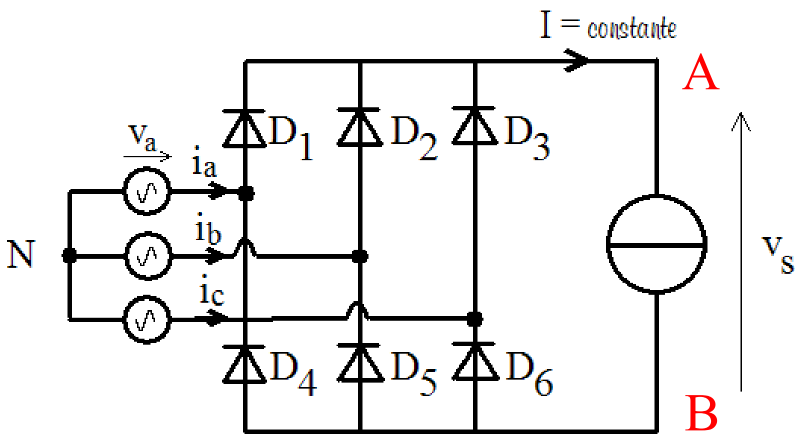
a. Pont simple (P3) à cathodes communes

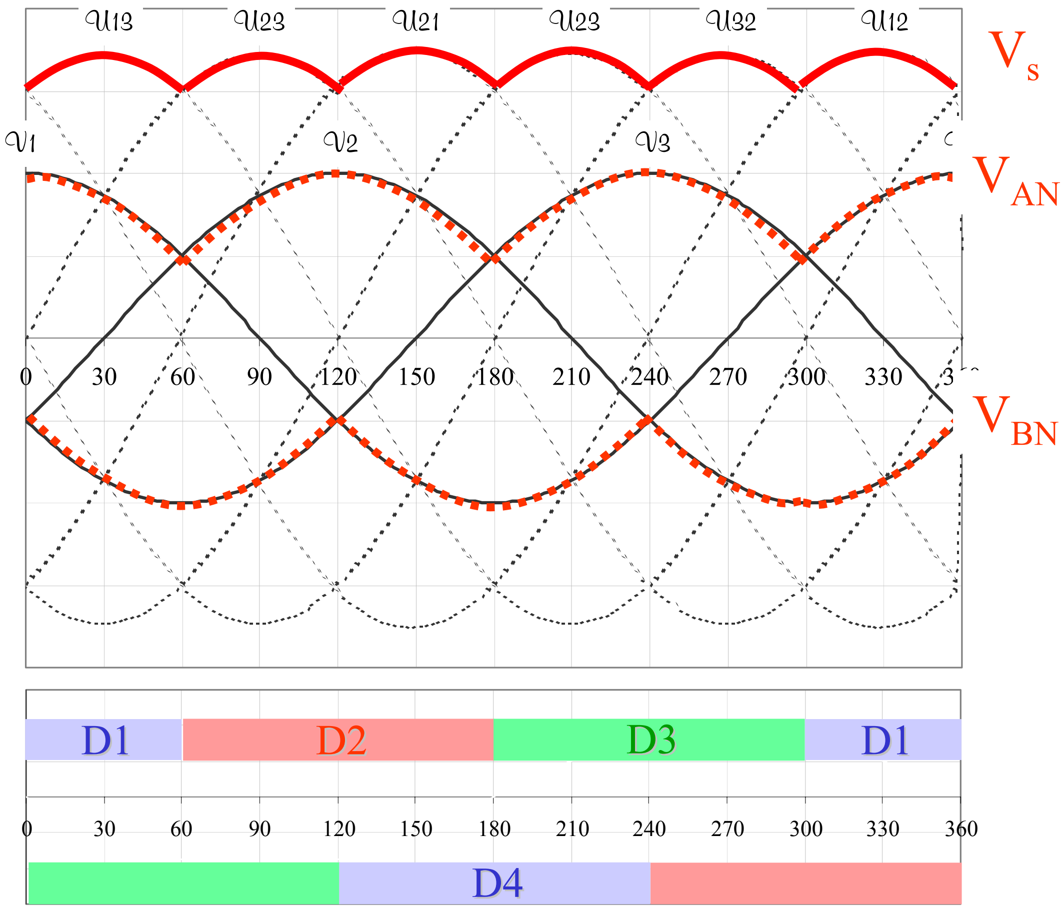


$$V_{s\ moyen} = \frac{3.\sqrt{3}.V_{max}}{2\pi}$$



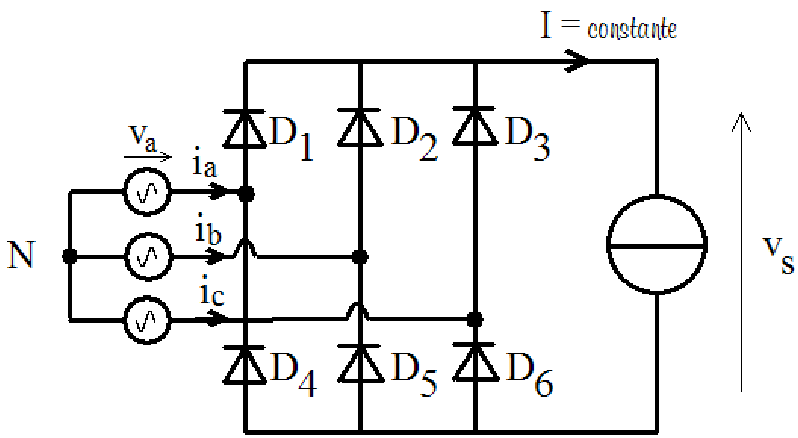
b. Pont double (PD3)



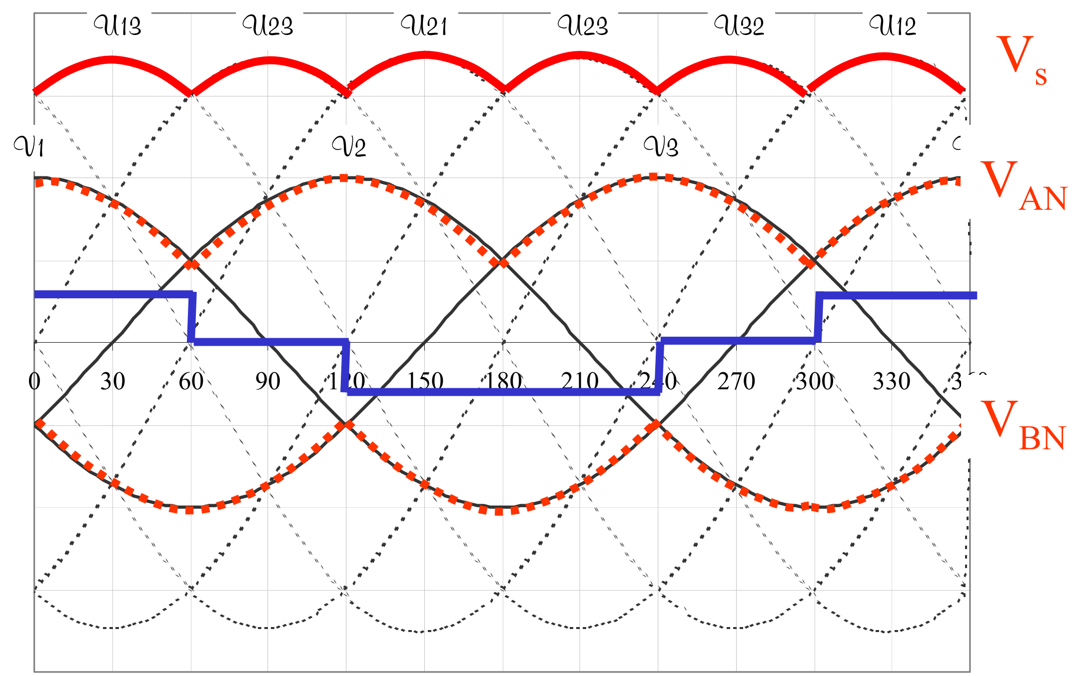


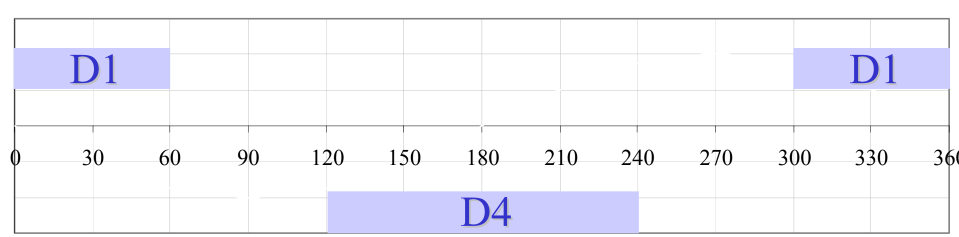
$$V_{s\ moyen} = \frac{3.\sqrt{3}.V\max}{\pi}$$

b. Pont double (PD3)



Courant de ligne

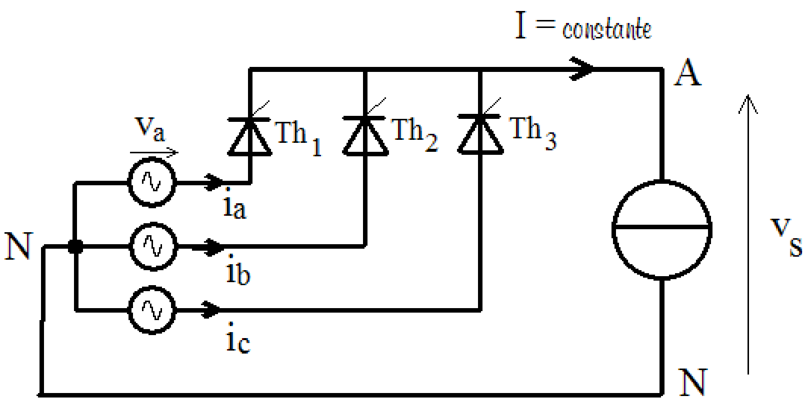


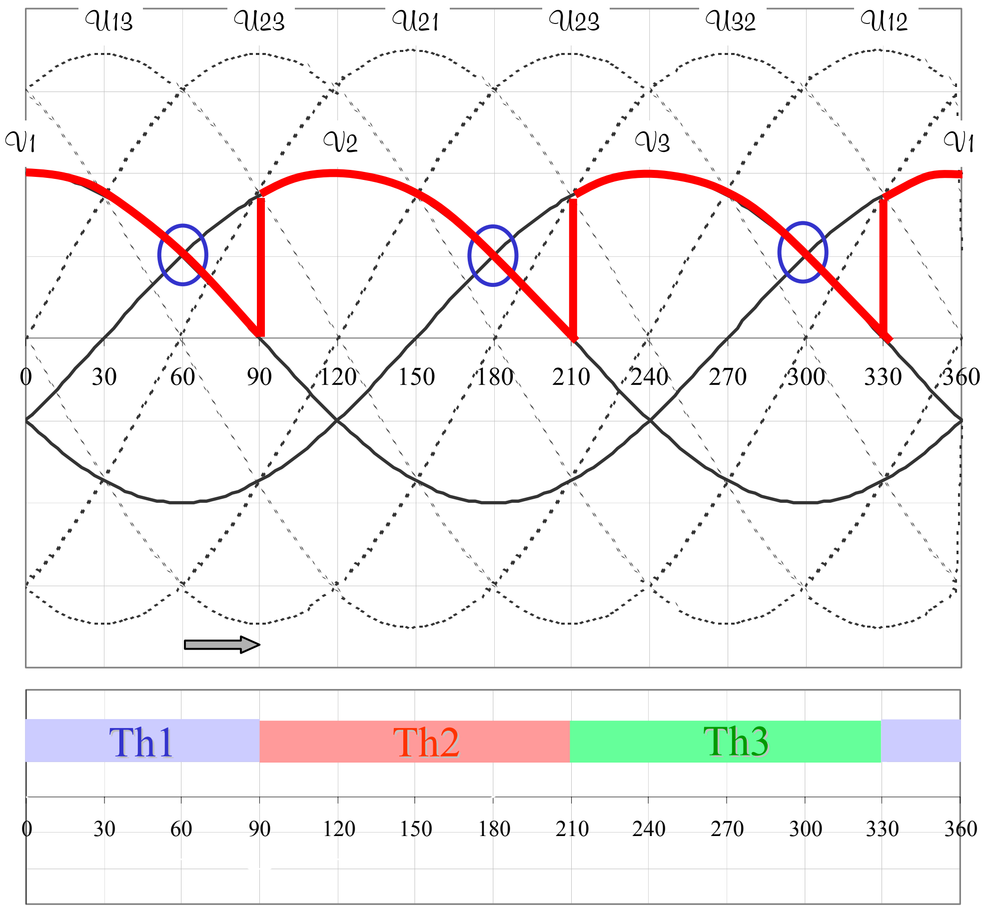


$$V_{s\ moyen} = \frac{3.\sqrt{3}\,.\,V\max}{\pi}$$

II.4 Redressement triphasé commandé

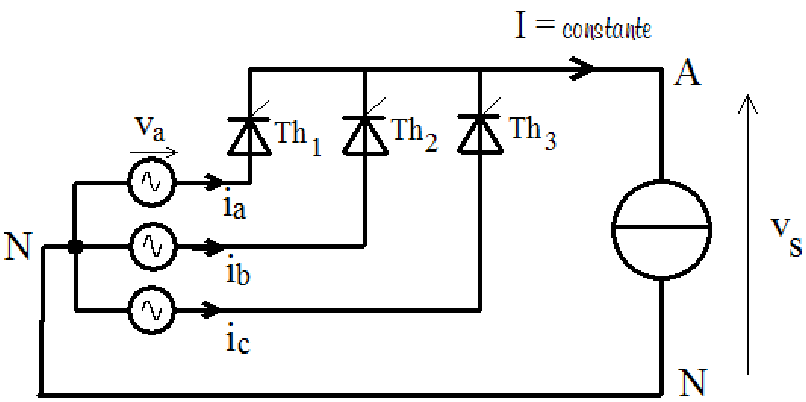
a. Pont simple (P3)

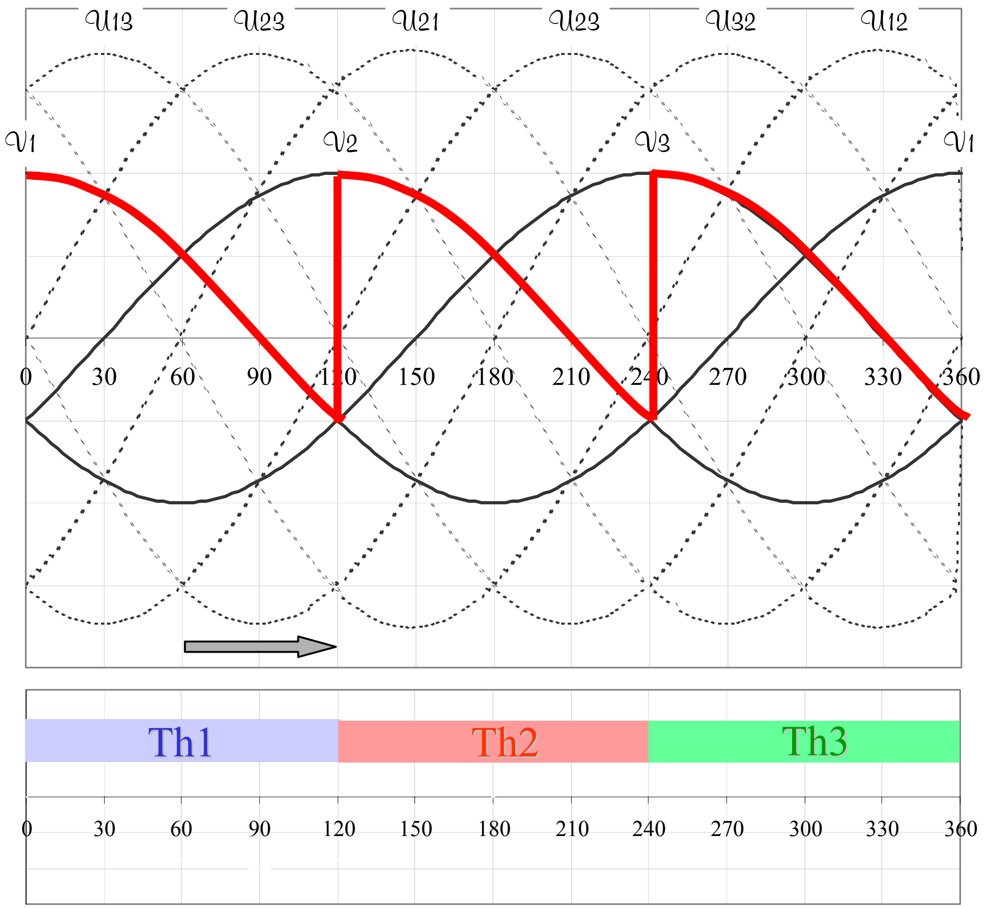




$\Psi = 30°$

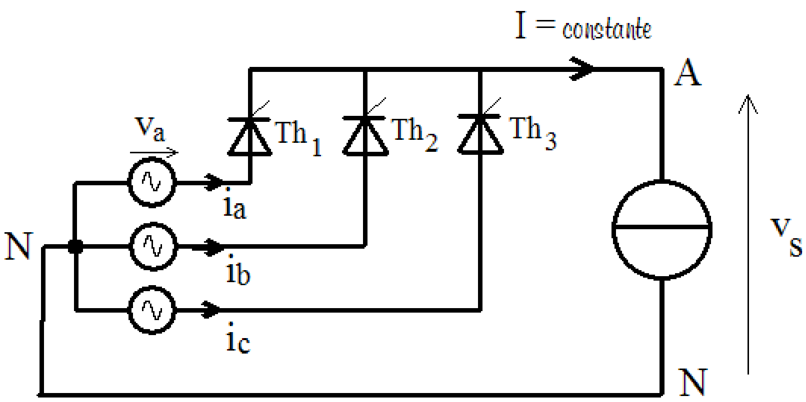
a. Pont simple (P3)

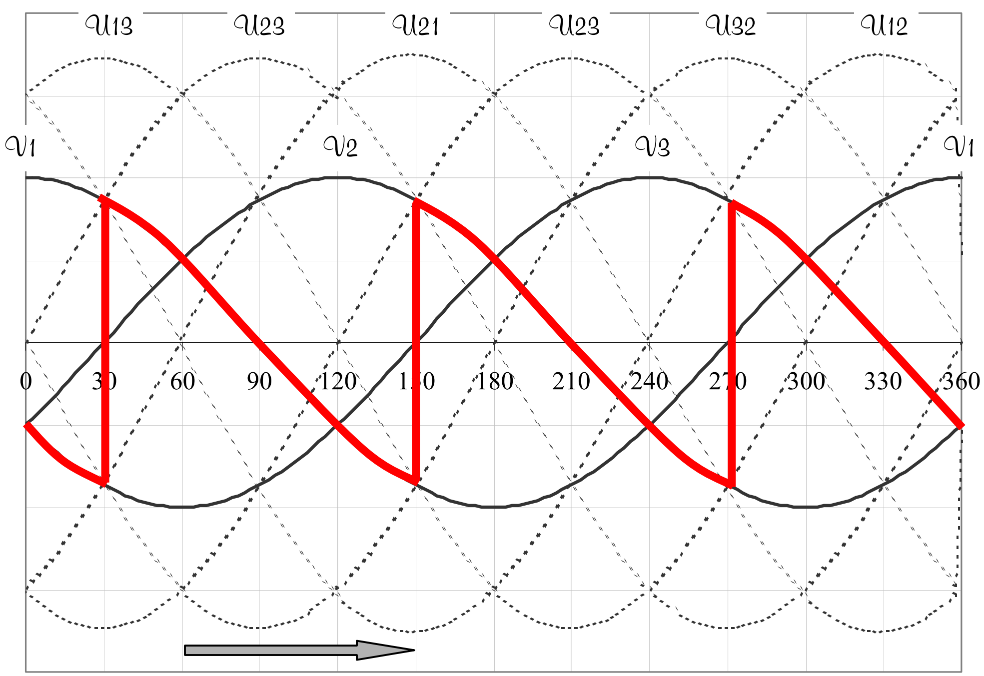


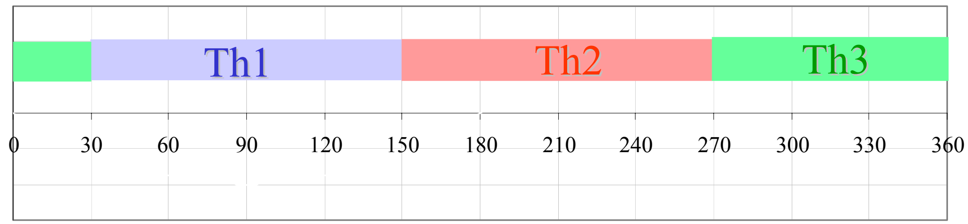


$\Psi = 60°$

a. Pont simple (P3)

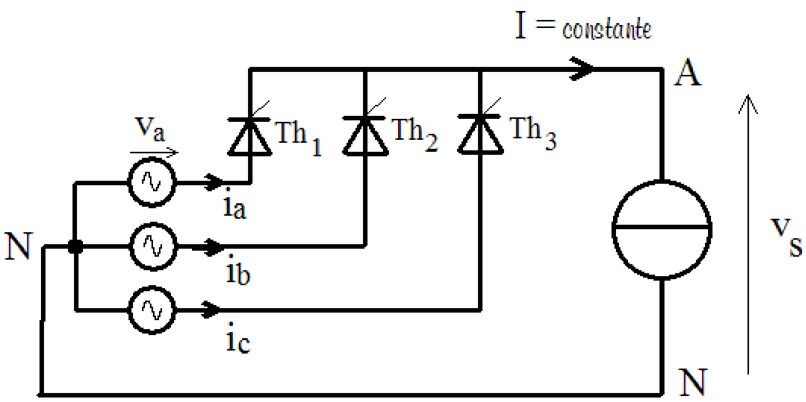


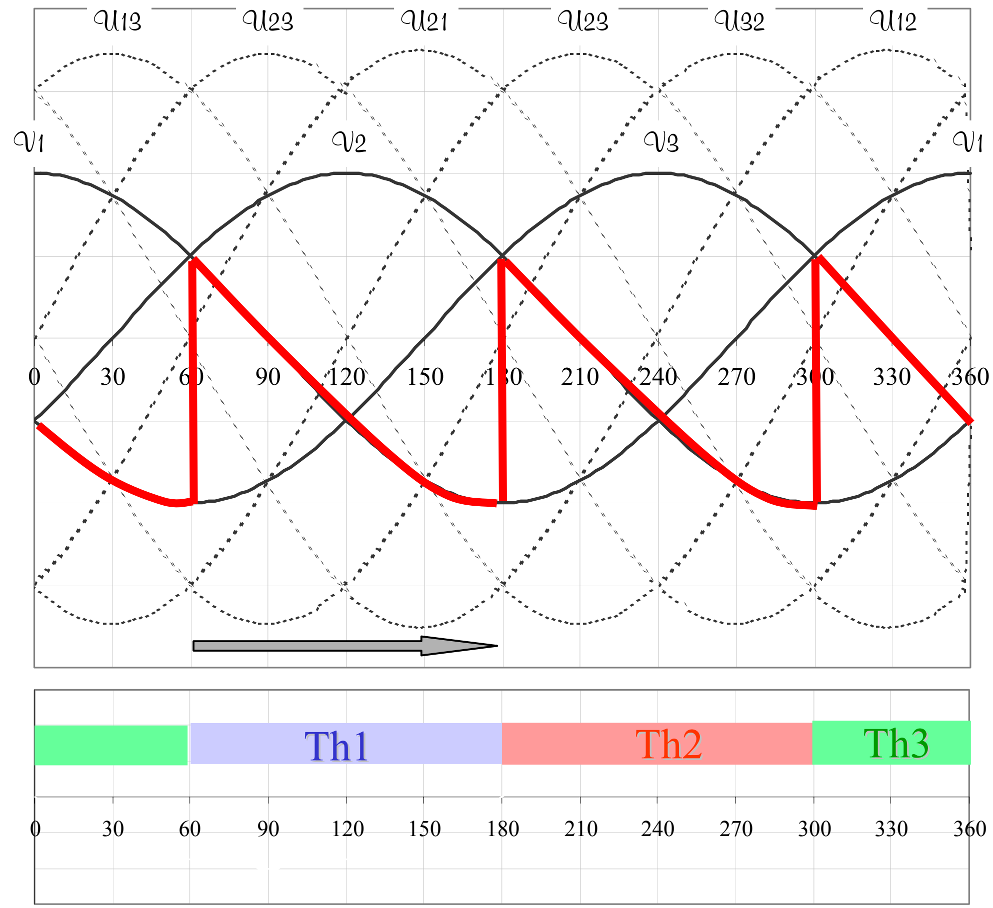




$\Psi = 90°$

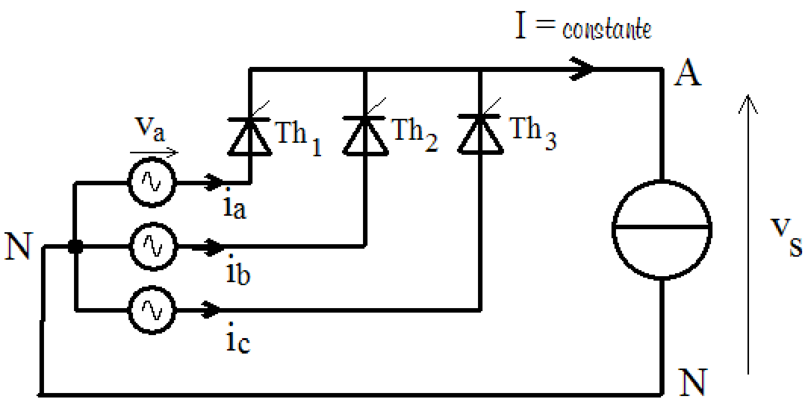
a. Pont simple (P3)

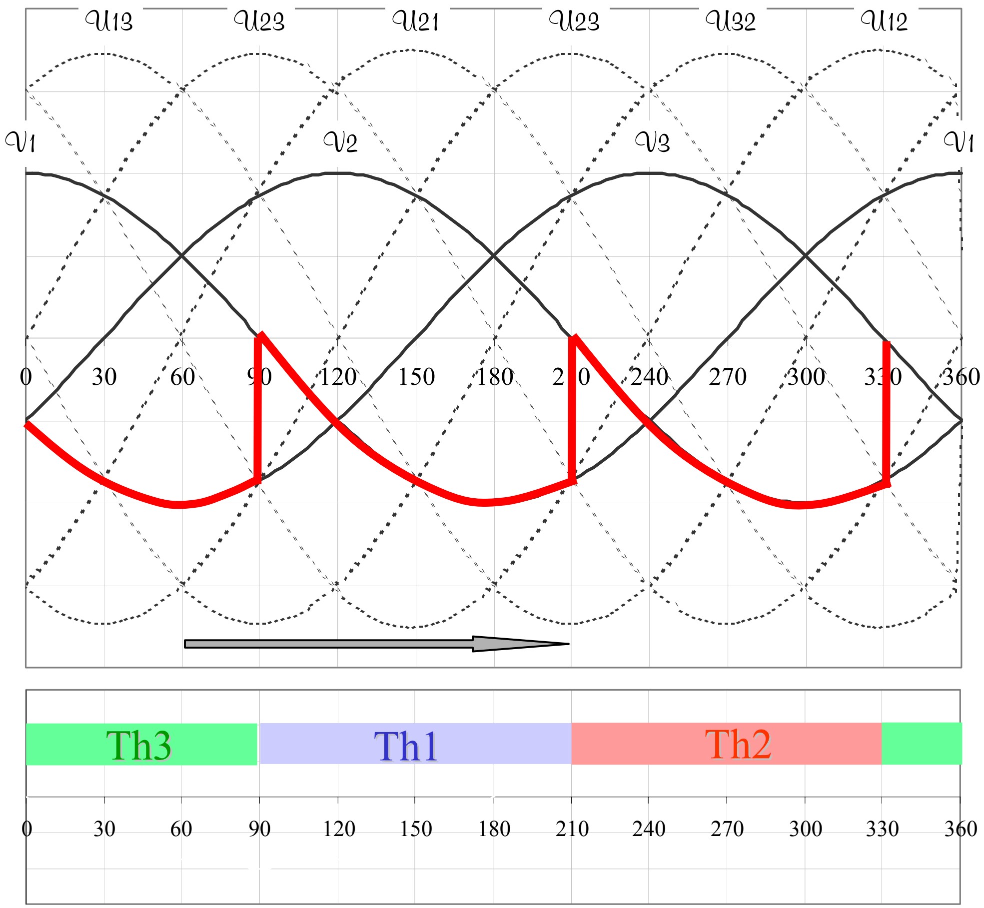




$\Psi = 120°$

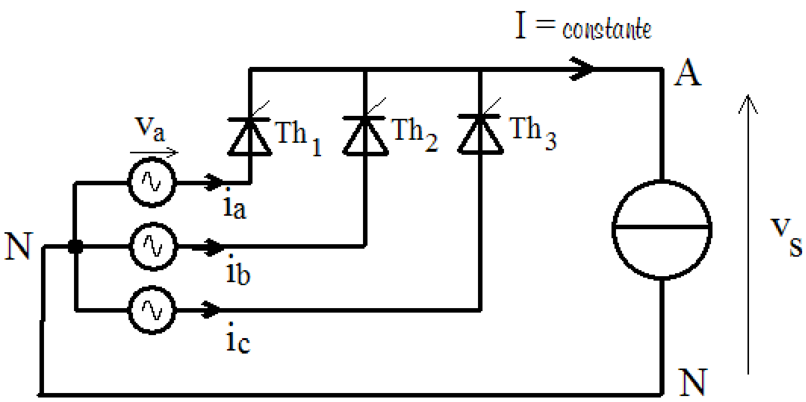
a. Pont simple (P3)

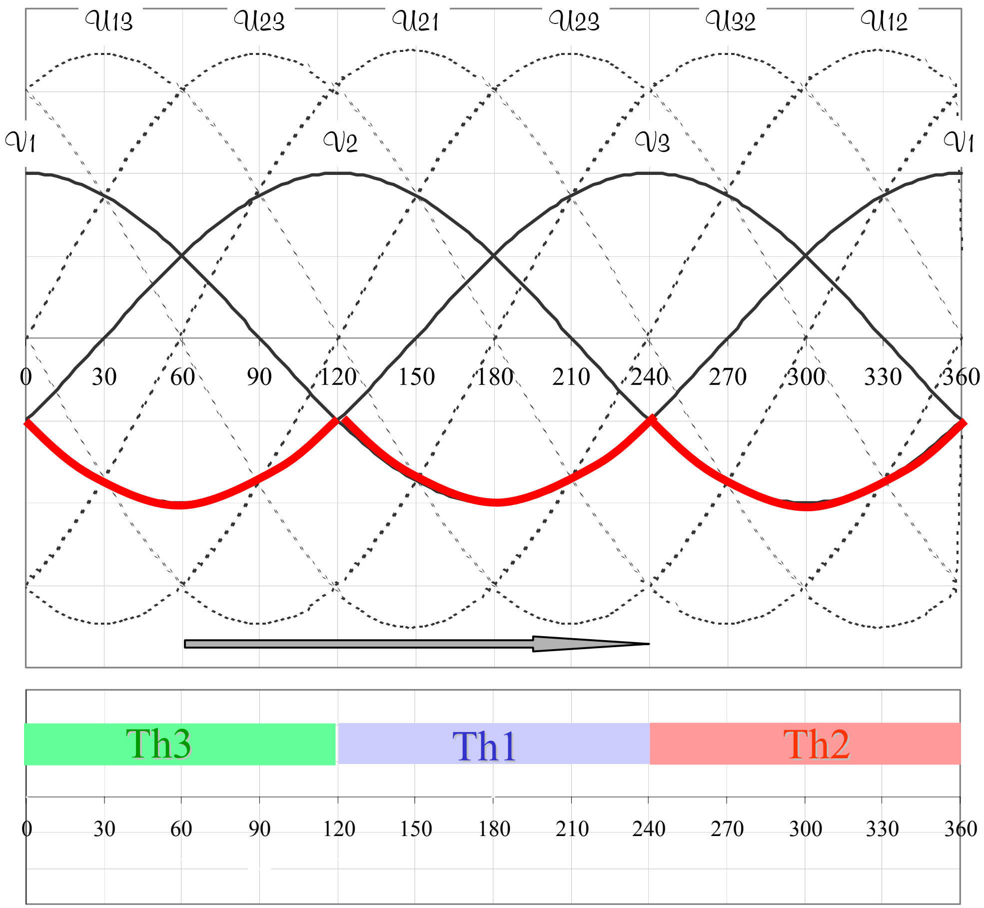




$\Psi = 150°$

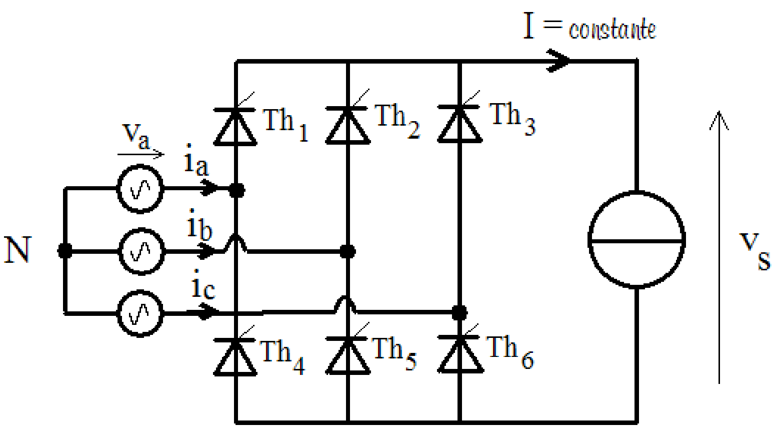
a. Pont simple (P3)

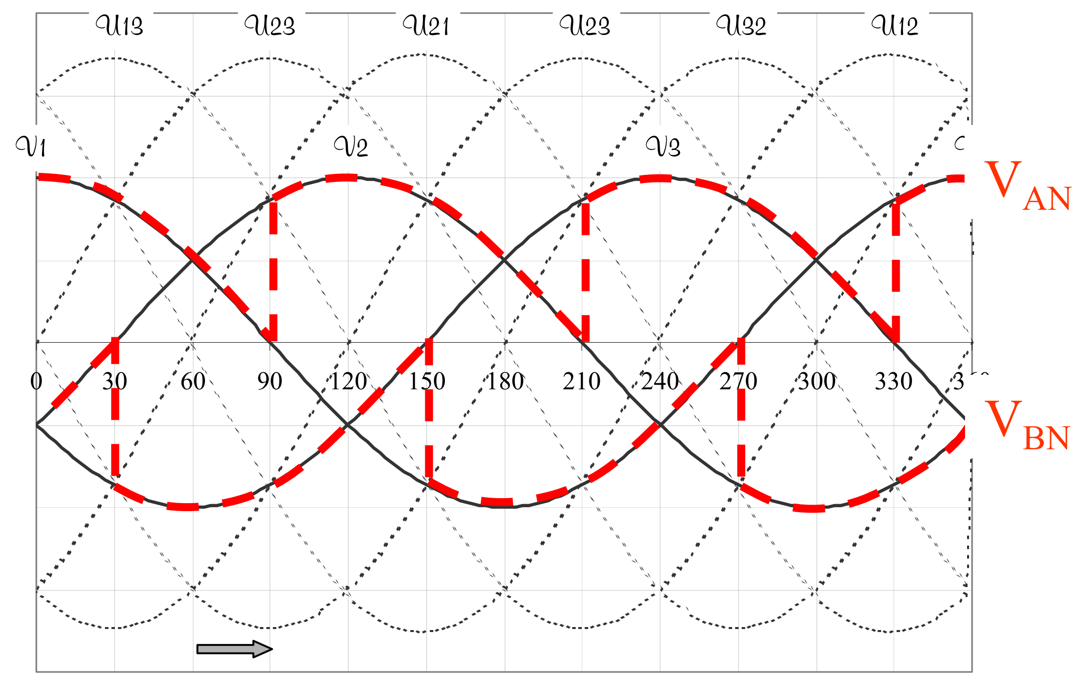




$\Psi = 180°$

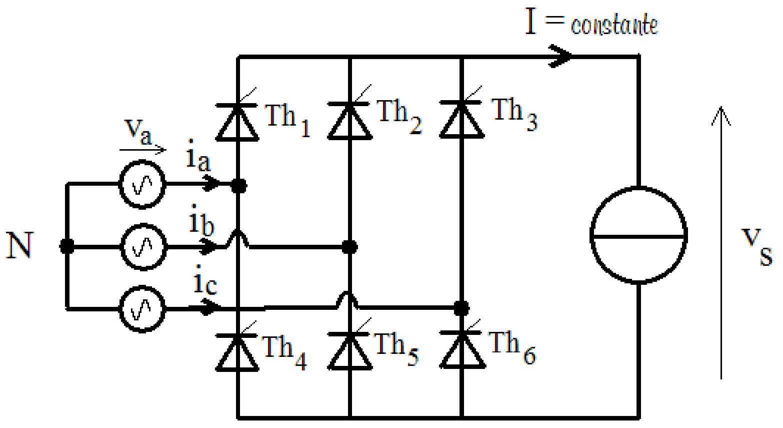
b. Pont double (PD3)

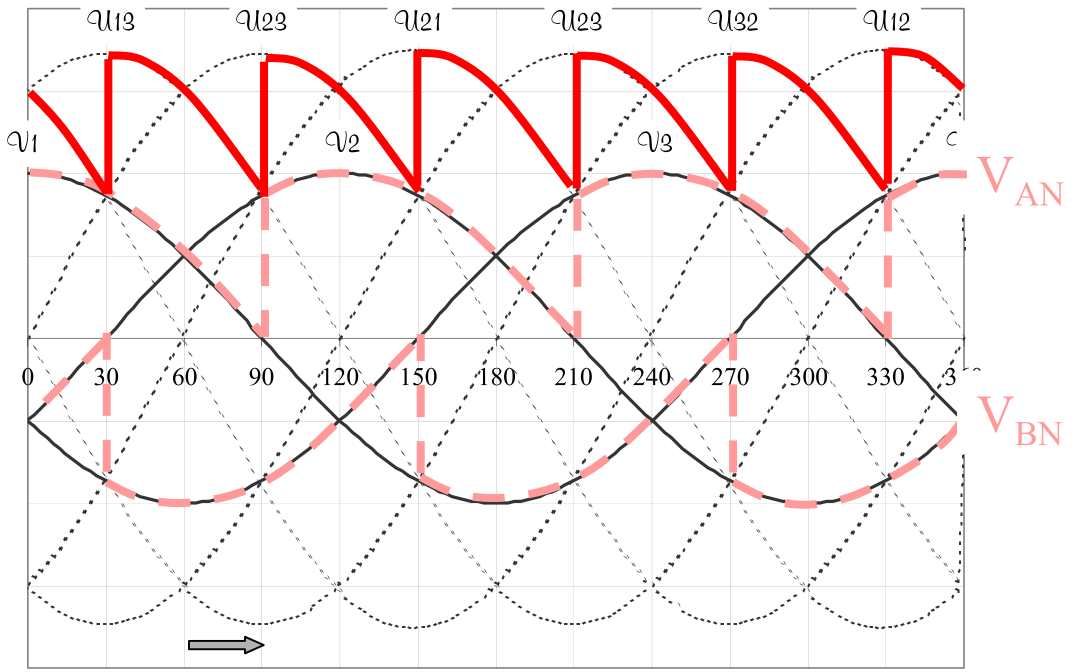




$\Psi = 30°$

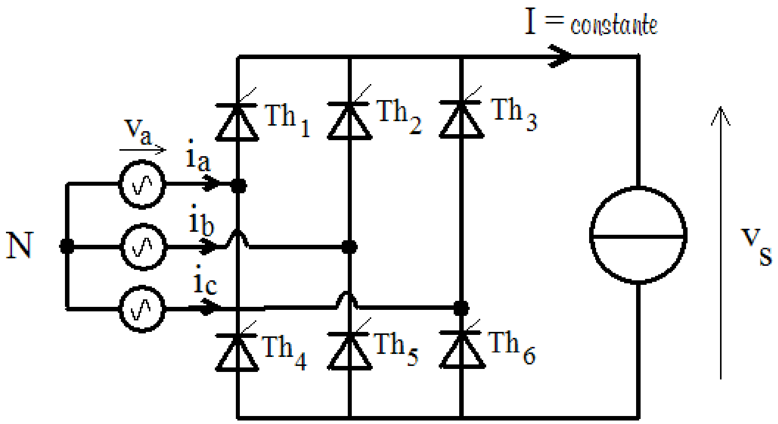
b. Pont double (PD3)

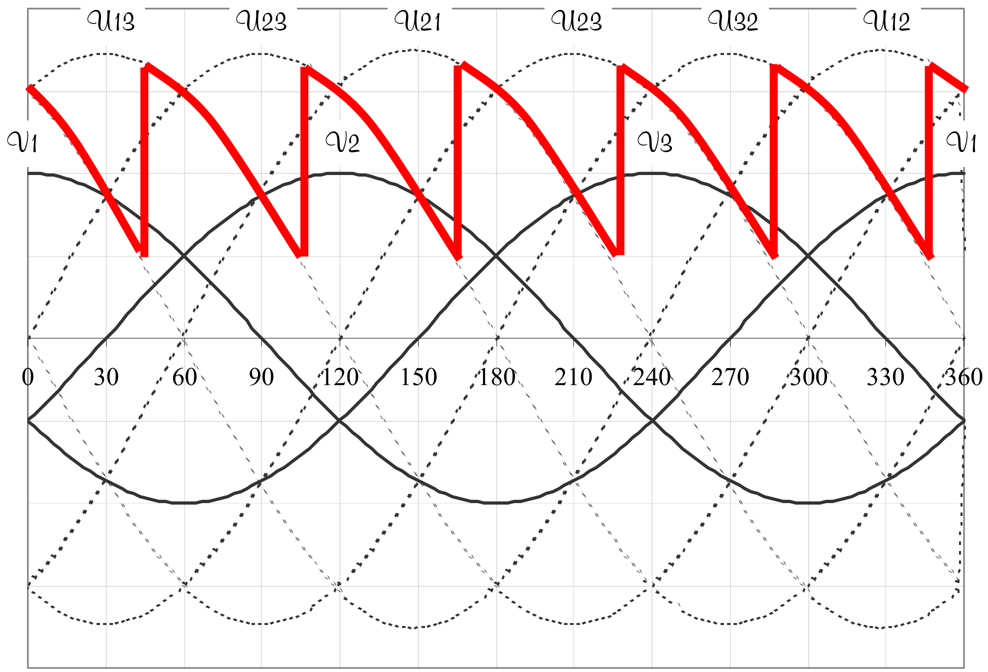




$\Psi = 30°$

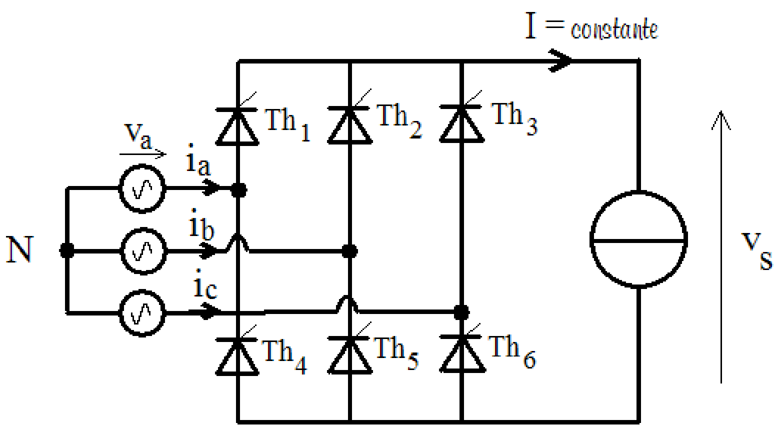
b. Pont double (PD3)

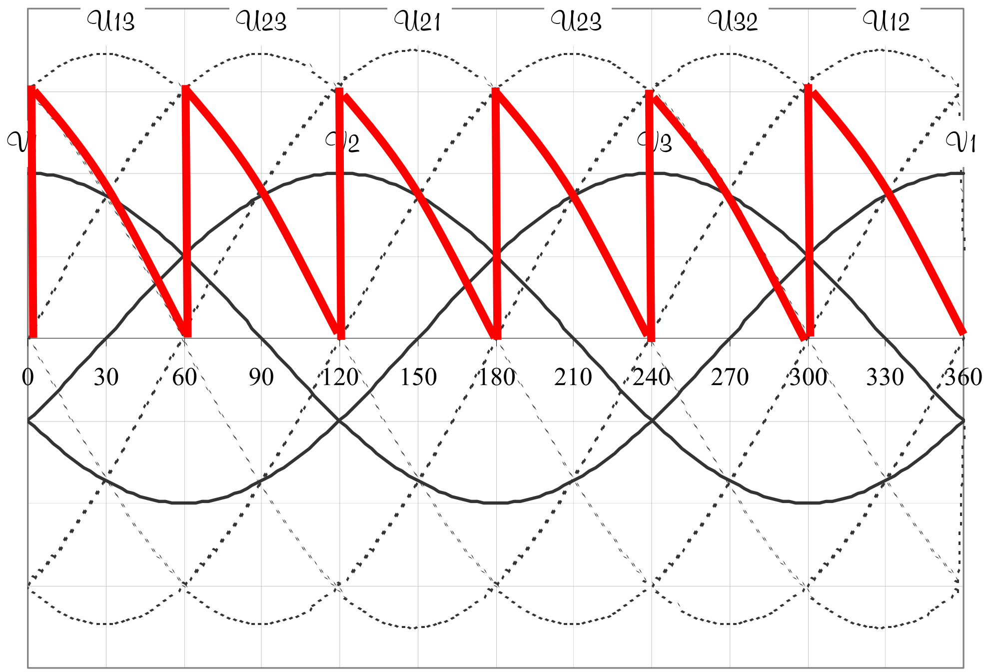




$\Psi = 45°$

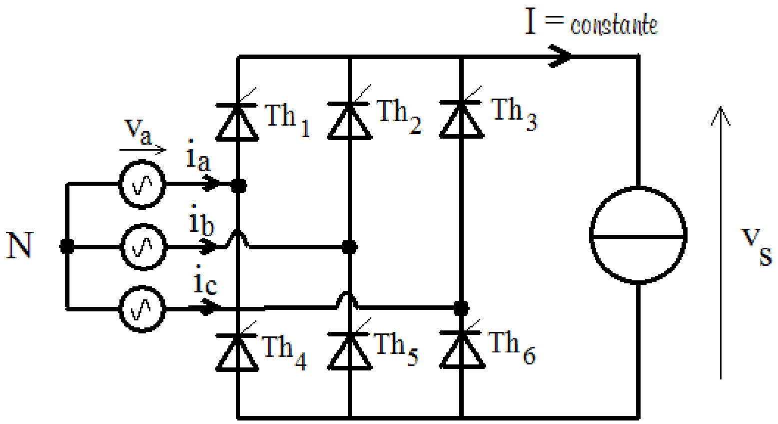
b. Pont double (PD3)

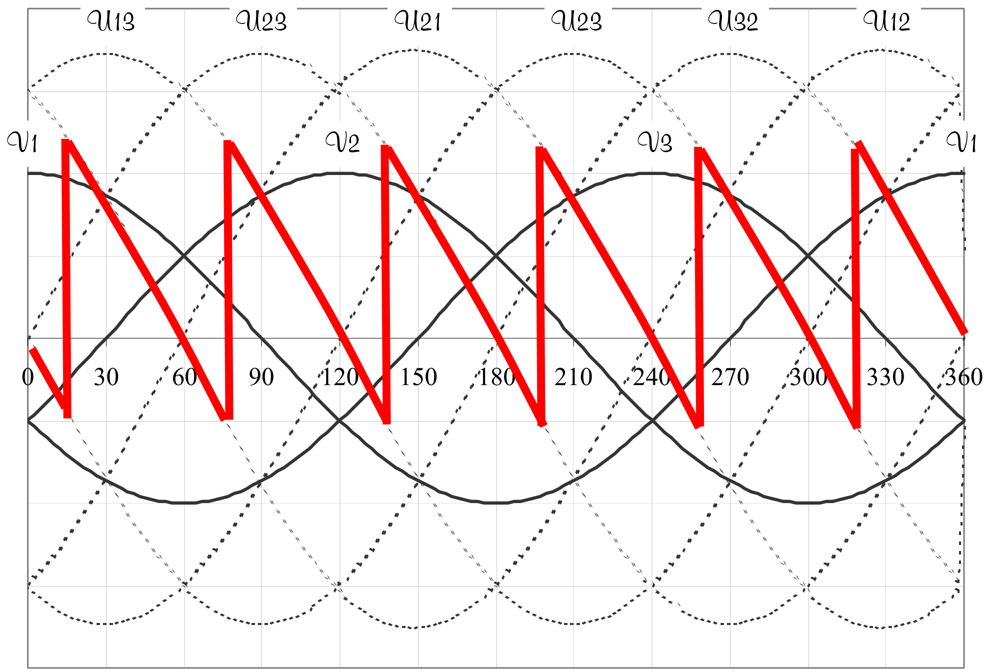




$\Psi = 60°$

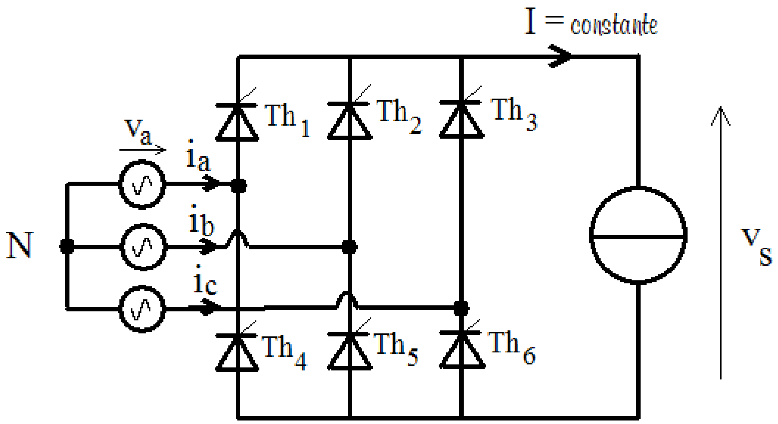
b. Pont double (PD3)

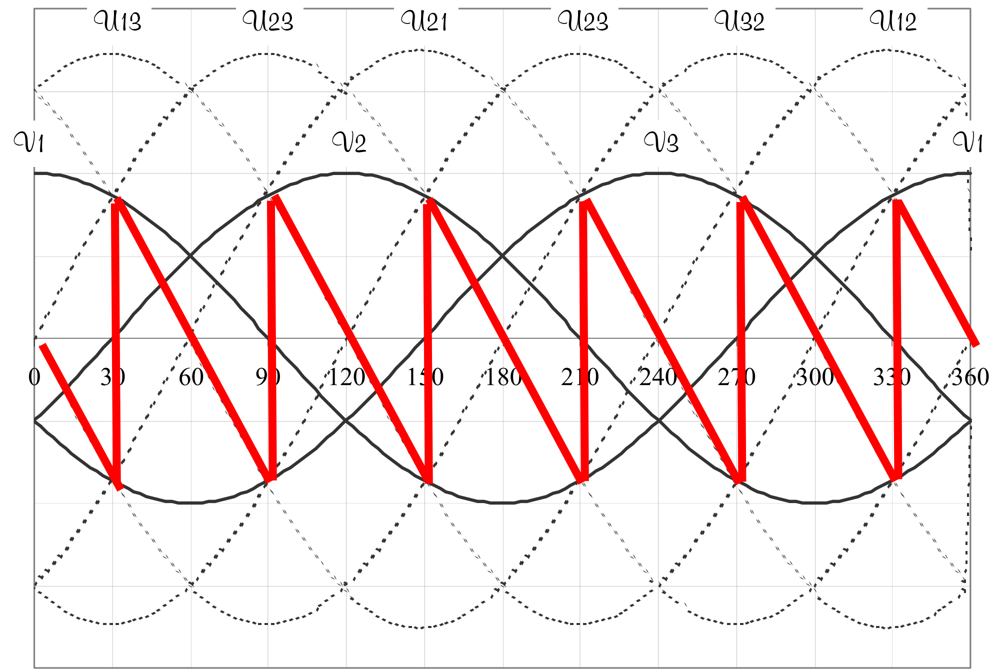




$\Psi = 75°$

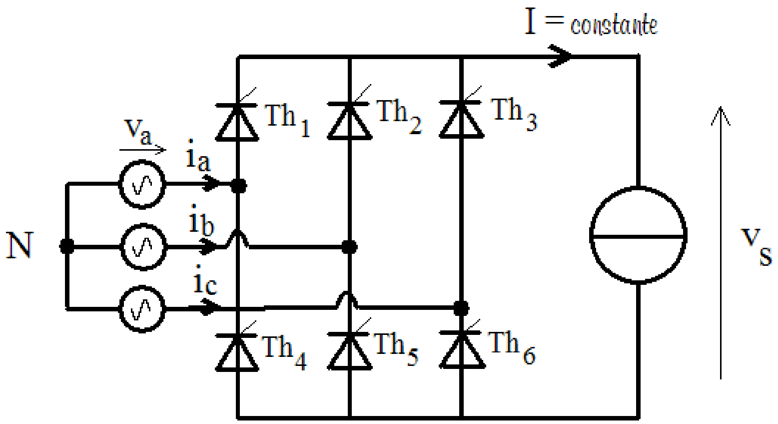
b. Pont double (PD3)

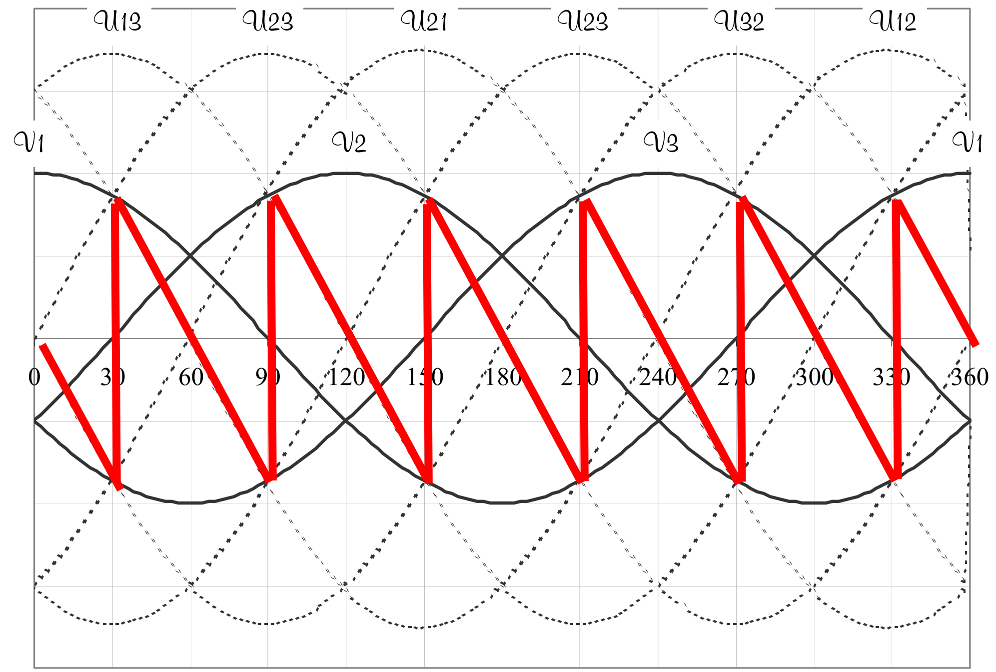




$\Psi = 90°$

b. Pont double (PD3)



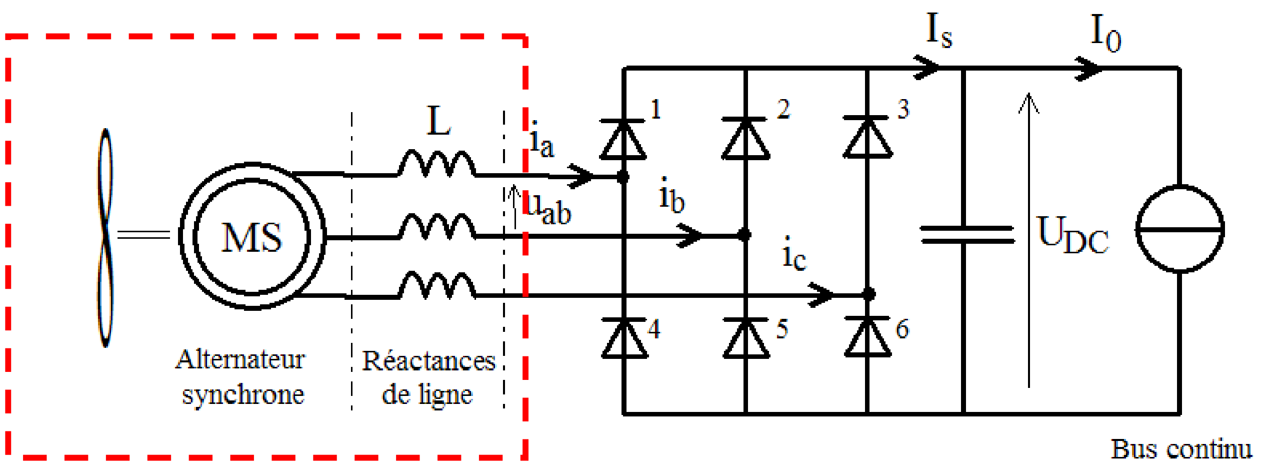


$$V_{s\ moyen} = \frac{3.\sqrt{3}.V_{max}}{\pi}.\cos(\Psi)$$

II.5 Fonctionnement en redresseur de courant

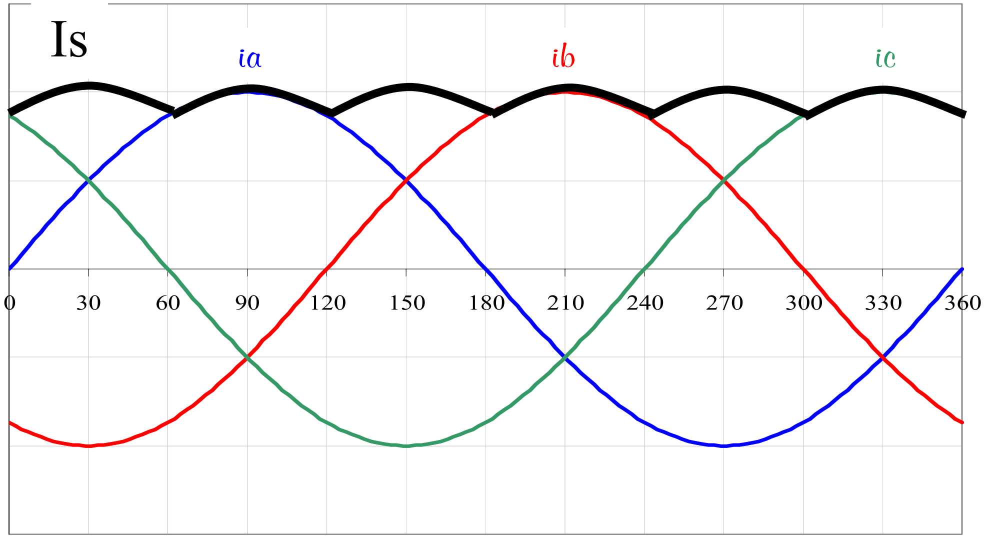
→ Redresseur alimenté par une source de courant

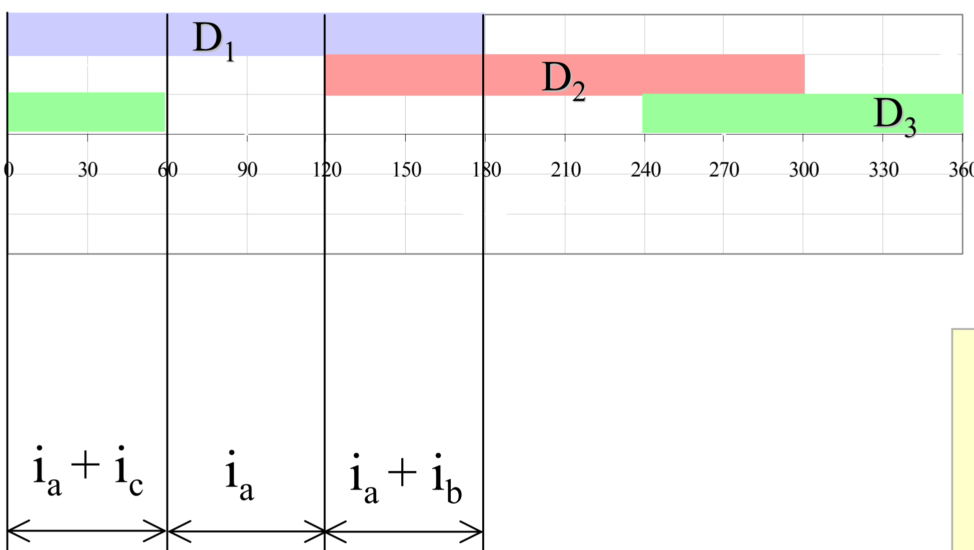
Exemple d'application : production éolienne de petite puissance

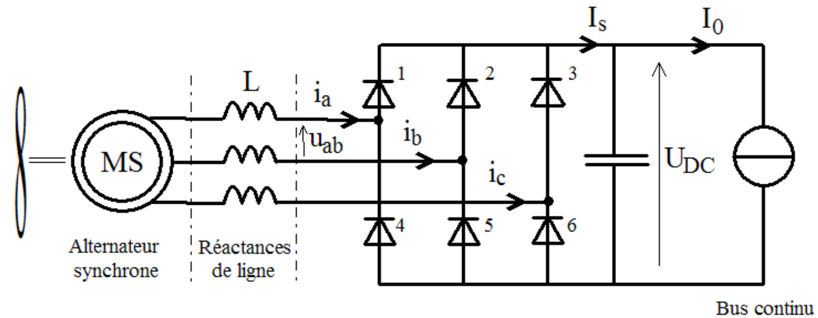


Source triphasée de courants

II.5 Fonctionnement en redresseur de courant







$$I_{s\,moyen} = \frac{3 \cdot I_{max}}{\pi}$$

Puissance produite

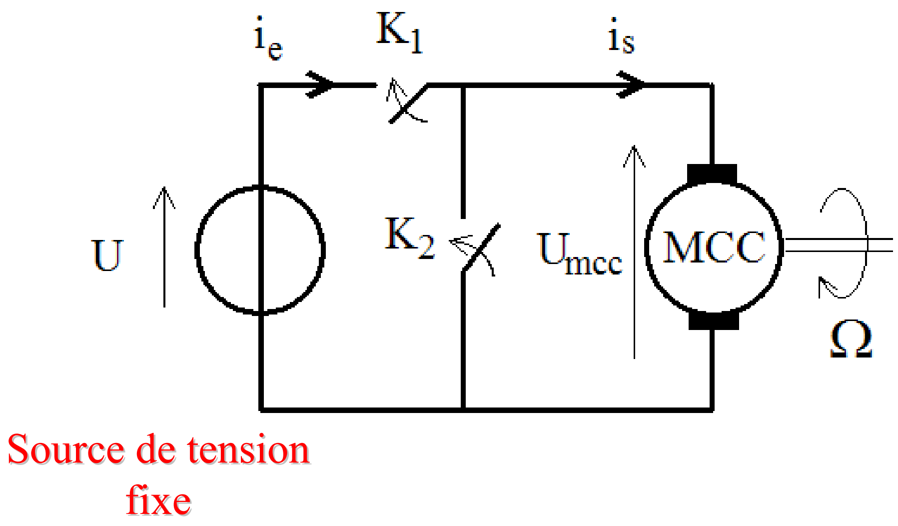
$$P_s = \frac{3 \cdot U_{DC} \cdot I_{max}}{\pi}$$

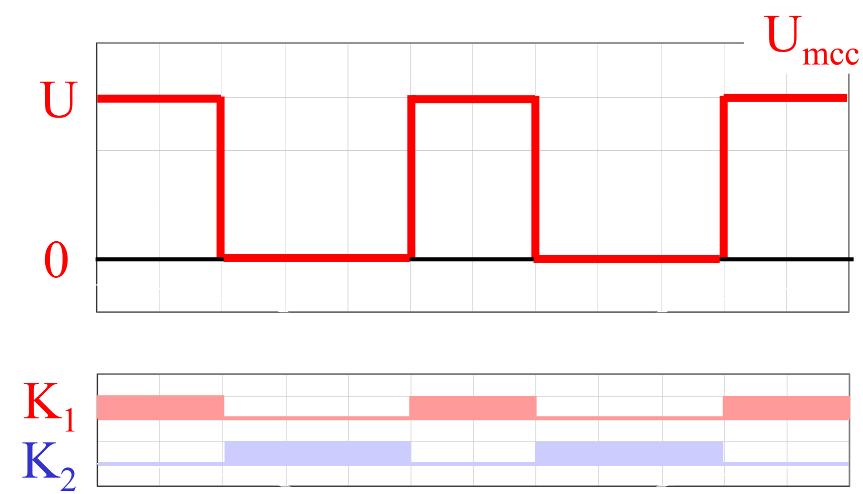
III
LES CONVERTISSEURS A DECOUPAGE (Convertisseurs rapides)

Fréquence de commutation imposée par la commande

→ Fréquence de découpage

III.1 Principe



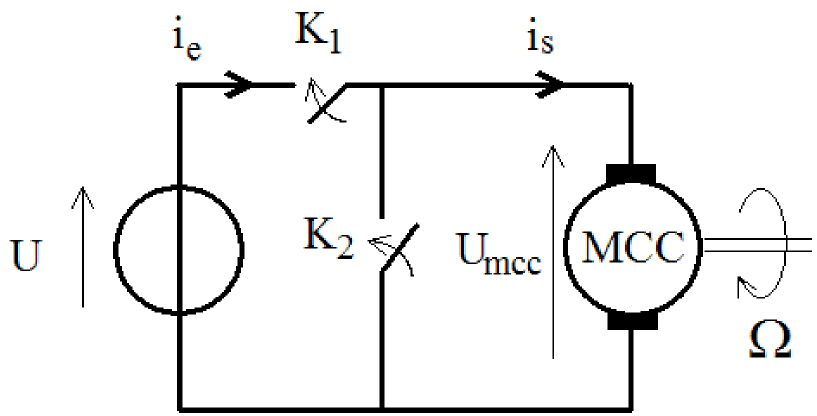


III
LES CONVERTISSEURS A DECOUPAGE (Convertisseurs rapides)

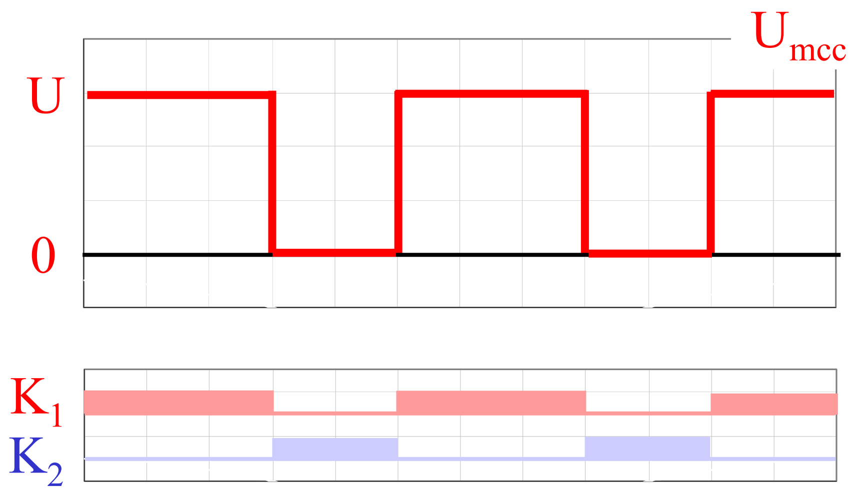
Fréquence de commutation imposée par la commande

→ Fréquence de découpage

III.1 Principe



Source de tension fixe



III
LES CONVERTISSEURS A DECOUPAGE (Convertisseurs rapides)

Fréquence de commutation imposée par la commande

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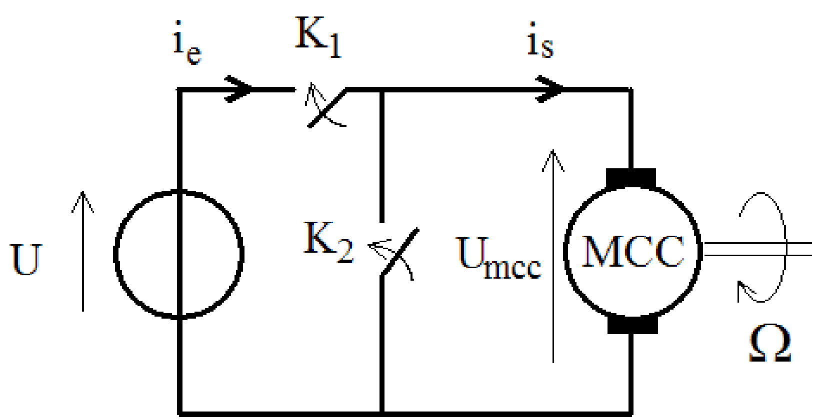
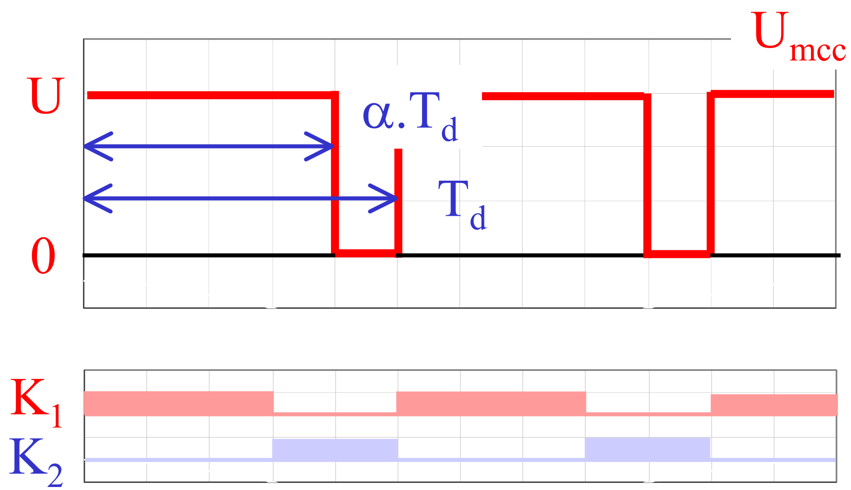
III.1 Principe



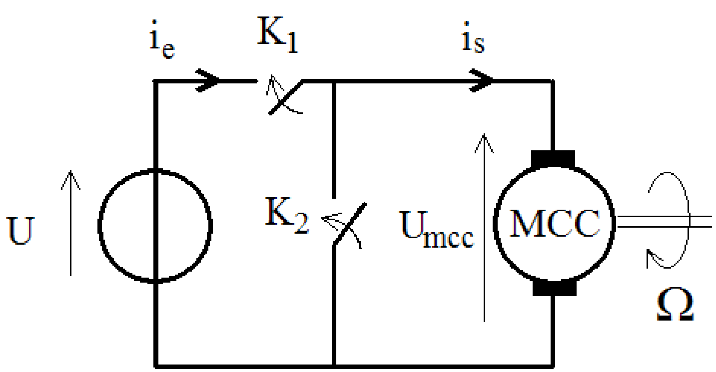
Source de tension fixe



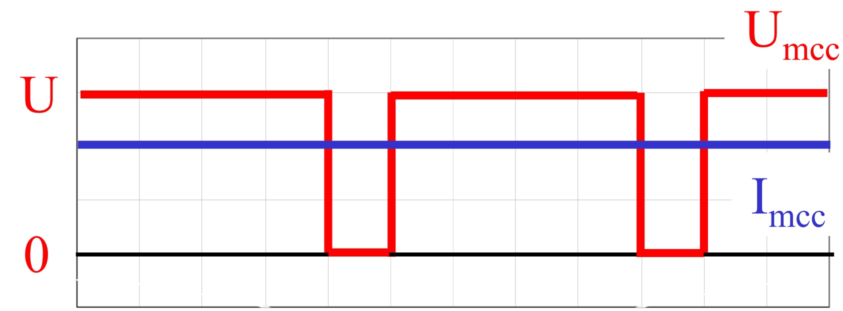
b. Bilan des puissances

Hypothèse :

I_{mcc} = *constante*
Transistors parfaits

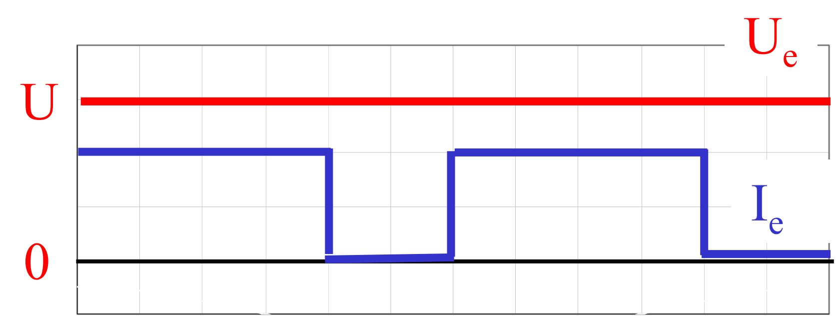


- Côté charge



→ $P_{sortie} = \alpha \cdot U \cdot I$

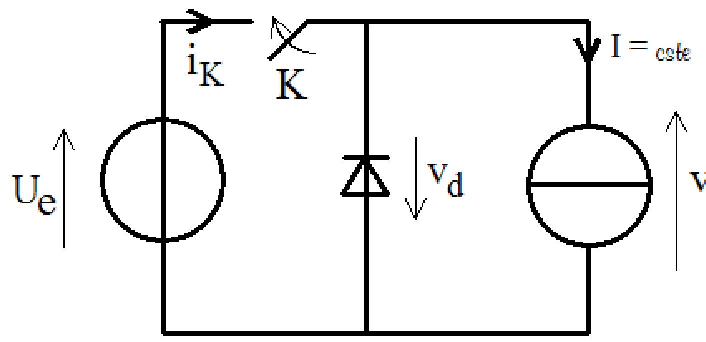
- Côté alimentation



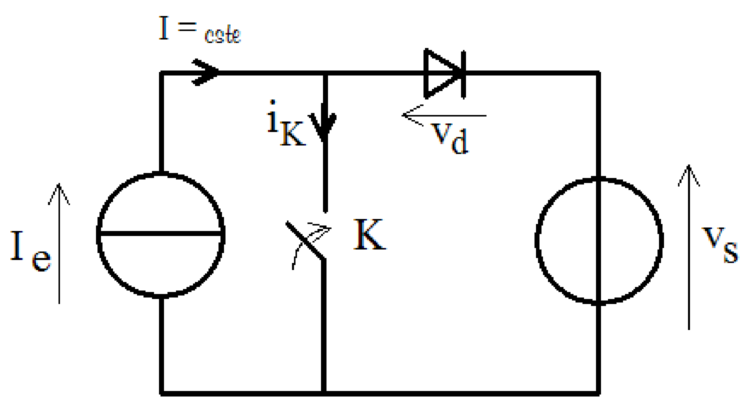
→ $P_{entrée} = \alpha \cdot U \cdot I$

c. Les deux structures de bases

- Hacheur série
- Hacheur parallèle



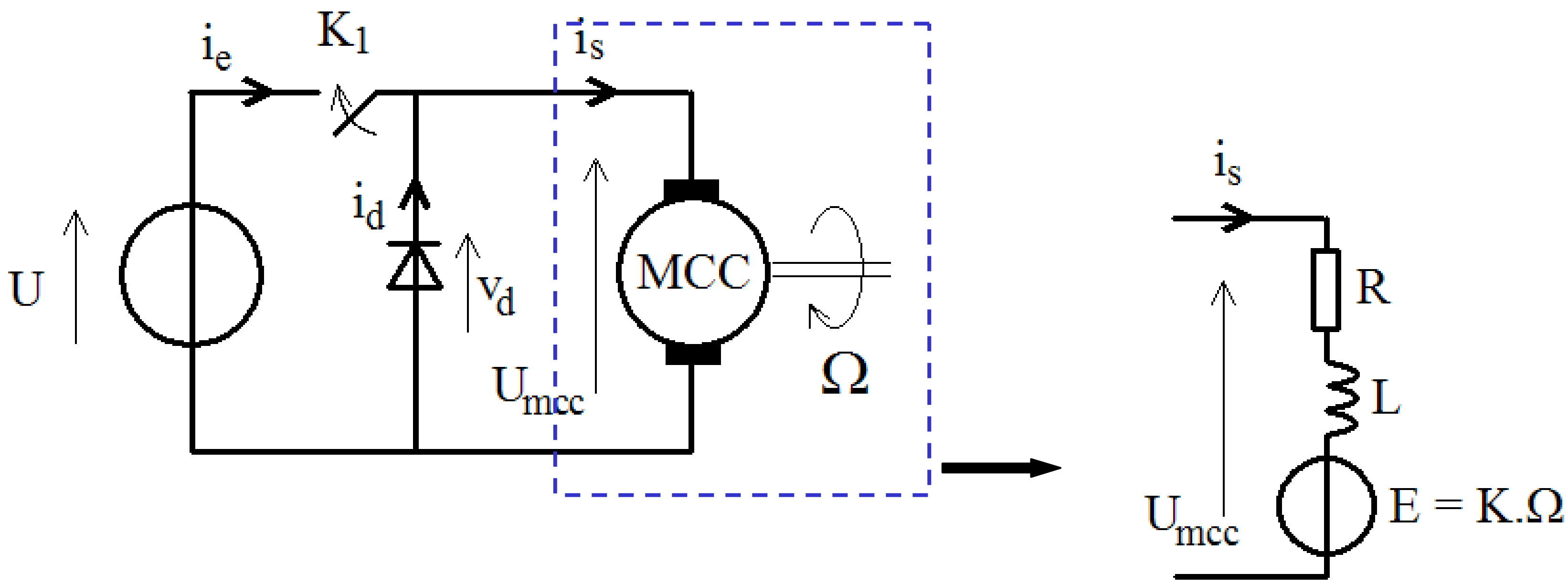
Hacheur série
=
abaisseur de tension



Hacheur parallèle
=
élévateur de tension

III.2 Hacheur série

Exemple : entraînement d'une MCC

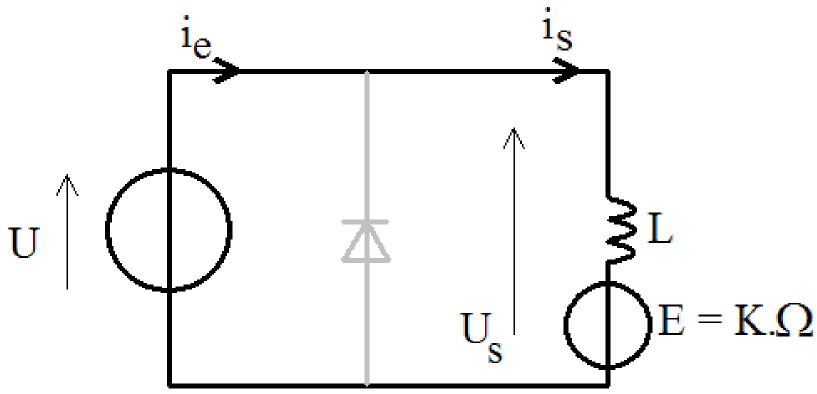


Hypothèse :

- Résistance négligeable
- Période de découpage << L/R
- Vitesse constante (E = constante)

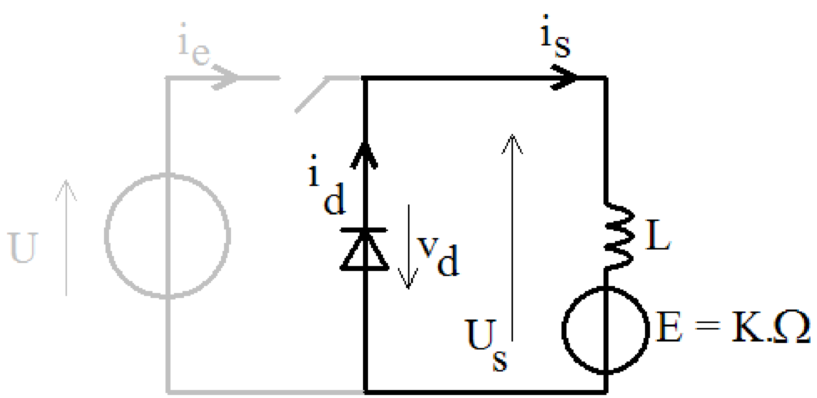
Fonctionnement

- $t = 0$ à $\alpha.T_d$ ⟶ K_1 fermé & D ouverte



$$U = L\,.\,\frac{di_s}{dt} + E$$

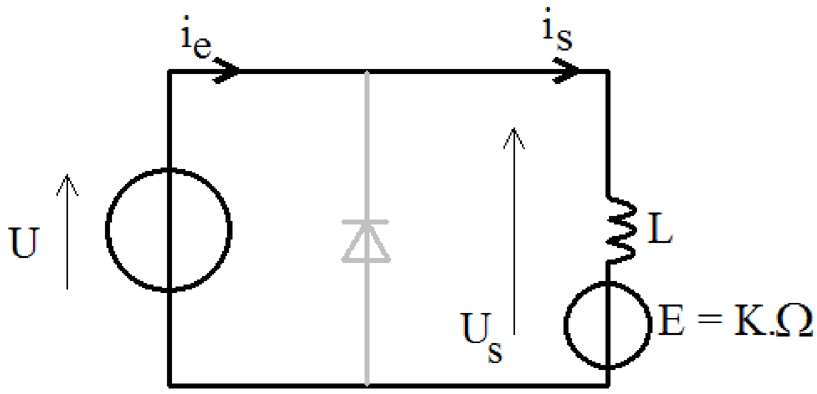
- $t = \alpha.T_d$ à T_d ⟶ K_1 ouvert & D fermée



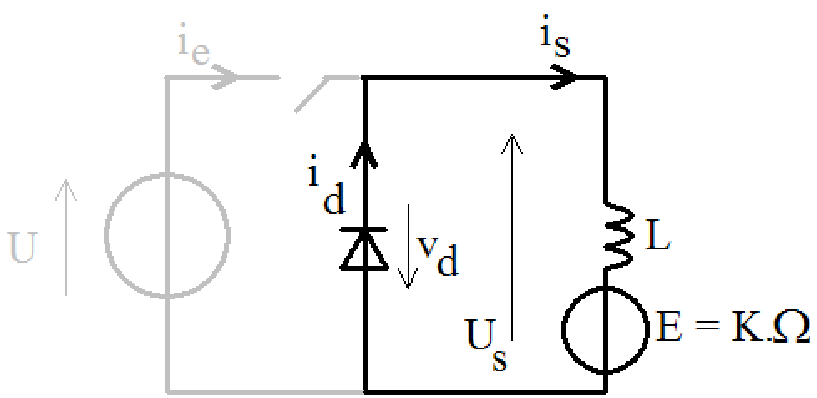
$$0 = L\,.\,\frac{di_s}{dt} + E$$

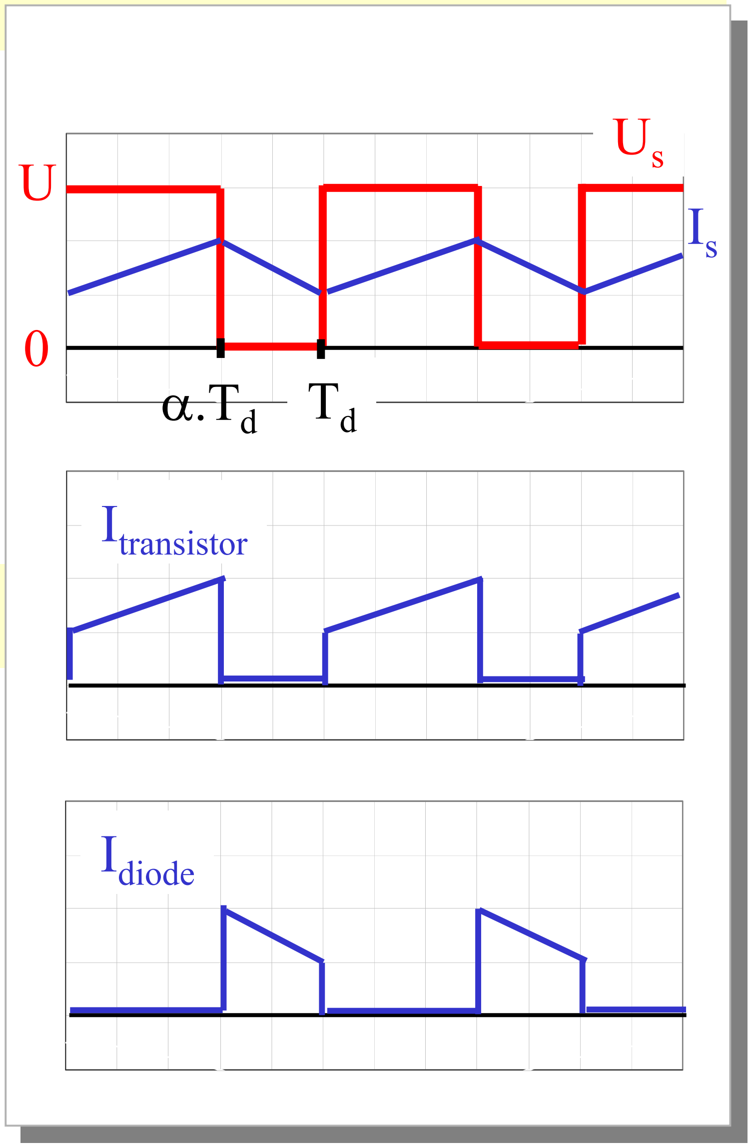
Fonctionnement

- $t = 0$ à $\alpha.T_d$ ⟶ K_1 fermé & D ouverte



- $t = \alpha.T_d$ à T_d ⟶ K_1 ouvert & D fermée





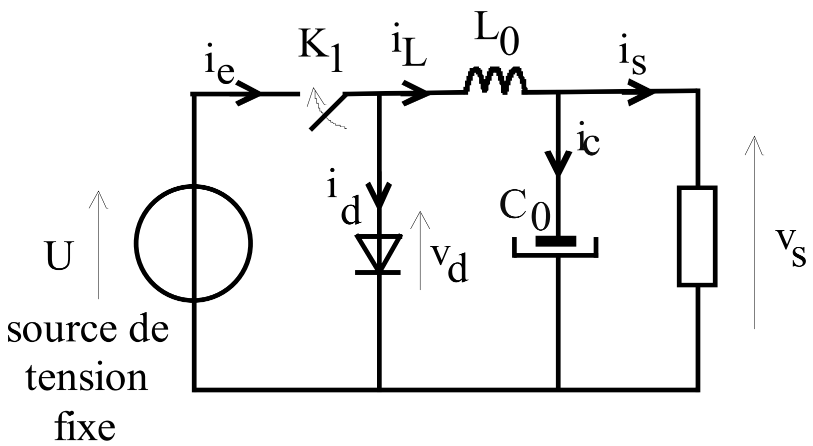
Tension moyenne

$$U_{s\ moyen} = \alpha . U$$

Ondulation de courant

$$\Delta i = \frac{U.(1-\alpha).\alpha}{L.f_d} \longrightarrow \Delta i\Big|_{max} = \frac{U}{4.L.f_d}$$

c. *Réalisation d'une source de tension à partir d'un hacheur série*



Filtrage LC

$$\Delta i = \frac{U.(1-\alpha)}{L.f_d}$$

$$\Delta V_c = \frac{\Delta_i}{8.C_0.f_d}$$