Wechselrichter mit eingeprägter Spannung (U–Wechselrichter)

1. Spannungssystem von U–Wechselrichter und Last:

Durch die Taktung erzeugt: Spannungen $u_{a0}(t),\ u_{b0}(t),\ u_{c0}(t)$ mit Bezugspunkt 0

Für die Summe der Spannungen gilt immer: $u_{a0}(t) + u_{b0}(t) + u_{c0}(t) \neq 0$

Für die Lastspannungen muß jedoch gelten: $\Sigma u(t) = 0$

$$u_{ab}(t) + u_{bc}(t) + u_{ca}(t) = 0 \qquad \text{und} \qquad u_a(t) + u_b(t) + u_c(t) = 0$$

Verkettete Spannungen:
$$\begin{aligned} u_{ab}(t) &= u_{a0} - u_{b0} = u_a - u_b \\ u_{bc}(t) &= u_{b0} - u_{c0} = u_b - u_c \\ u_{ca}(t) &= u_{c0} - u_{a0} = u_c - u_a \end{aligned}$$

Damit gilt für die Strangspannungen der Last (Bezugspunkt M):

$$u_{ab} - u_{ca} = (u_a - u_b) - (u_c - u_a) = 2\,u_a - (u_b + u_c) = 3\,u_a$$

$$u_a(t) = \frac{u_{ab} - u_{ca}}{3}; \qquad u_b(t) = \frac{u_{bc} - u_{ab}}{3}; \qquad u_c(t) = \frac{u_{ca} - u_{bc}}{3}$$

Spannung u_{M0} zwischen den Mittelpunkten M und 0:

$$u_{a0} = u_a + u_{M0}; \qquad u_{b0} = u_b + u_{M0}; \qquad u_{c0} = u_c + u_{M0}$$

$$u_a + u_b + u_c = 0 \quad \Longrightarrow \quad u_{M0}(t) = \frac{1}{3} \cdot (u_{a0} + u_{b0} + u_{c0})$$

2. Grundschwingungen der Spannungen:

Symmetrisches blockförmiges System mit Blocklänge δ und Amplitude $A_\sqcap$ (Übung 4):

Effektivwert: $U_{(1)} = \frac{2\sqrt{2}}{\pi} \cdot \sin\frac{\delta}{2} \cdot A_\sqcap$ bzw. Amplitude: $\hat{U}_{(1)} = \frac{4}{\pi} \cdot \sin\frac{\delta}{2} \cdot A_\sqcap$

Fall a): $\hat{U}_{a0(1)} = \frac{4}{\pi} \cdot \sin\frac{\pi}{2} \cdot \frac{U_d}{2} = \frac{2}{\pi} \cdot U_d = 0,637 \cdot U_d$

$$\hat{U}_{a(1)} = \frac{4}{\pi} \cdot \left(\sin\frac{\pi}{2} + \sin\frac{\pi}{6}\right) \cdot \frac{U_d}{3} = \frac{2}{\pi} \cdot U_d = \hat{U}_{a0(1)}$$

$$\hat{U}_{ab(1)} = \frac{4}{\pi} \cdot \sin\frac{\pi}{3} \cdot U_d = \frac{2\sqrt{3}}{\pi} \cdot U_d = \sqrt{3} \cdot \hat{U}_{a(1)} = 1,103 \cdot U_d$$

Fall c): $\hat{U}_{a0(1)} = \frac{4}{\pi} \cdot \left(\sin\frac{\pi}{2} \cdot \frac{U_d}{2} - \sin\alpha \cdot U_d\right) = \frac{2}{\pi} \cdot (1 - 2\sin\alpha) \cdot U_d = 0,307 \cdot U_d$

$$\hat{U}_{ab(1)} = \frac{4}{\pi} \cdot \left(\sin\frac{\pi}{3} - \sin(\frac{\pi}{6} + \alpha) + \sin(\frac{\pi}{6} - \alpha)\right) \cdot U_d$$

$$= \frac{4}{\pi} \cdot \left(\sin\frac{\pi}{3} - 2\cos\frac{\pi}{6} \cdot \sin\alpha\right) \cdot U_d = \frac{2\sqrt{3}}{\pi} \cdot (1 - 2\sin\alpha) \cdot U_d$$

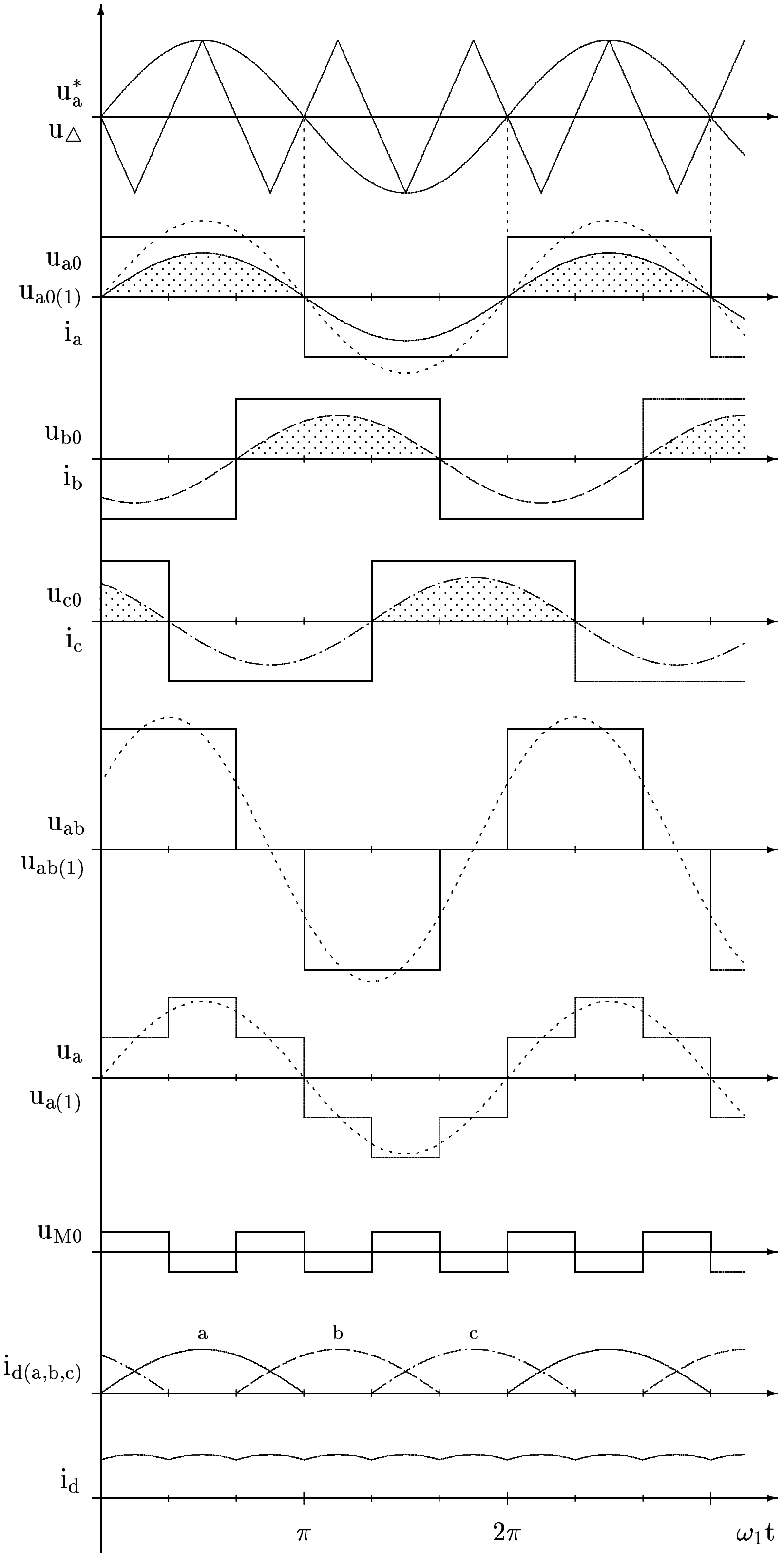
3. Mittelwerte des Zwischenkreisstroms:

Fall a): $I_d = \frac{3}{\pi} \cdot \int\limits_{\pi/3}^{2\pi/3} \sqrt{2} \cdot I_a \cdot \sin\omega_1 t \cdot d\,\omega_1 t = \frac{3}{\pi} \cdot \sqrt{2} \cdot I_a \cdot 2\cos\frac{\pi}{3} = \frac{3\sqrt{2}}{\pi} \cdot I_a$

Fall c): $I_d = \frac{6}{\pi} \cdot \int\limits_{\pi/3}^{\pi/2-\alpha} \sqrt{2} \cdot I_a \cdot \sin\omega_1 t \cdot d\,\omega_1 t = \frac{6}{\pi} \cdot \sqrt{2} \cdot I_a \cdot \left(\cos\frac{\pi}{3} - \cos(\frac{\pi}{2} - \alpha)\right)$

$$= \frac{6}{\pi} \cdot \sqrt{2} \cdot I_a \cdot (0,5 - \sin\alpha) = \frac{3\sqrt{2}}{\pi} \cdot (1 - 2\sin\alpha) \cdot I_a$$

a) Grundfrequenztaktung, Laststrom in Phase ($\varphi_1 = 0$)



Amplituden

$\hat{U}_a^* = 1$

$\hat{U}_\triangle = 1 \quad \left(\widehat{=}\,\hat{U}_{a(1)max}\right)$

$A_\sqcap = \dfrac{U_d}{2}$

$\hat{I}_a = \sqrt{2} \cdot I_a$

$A_\sqcap = \dfrac{U_d}{2}$

$\hat{I}_b = \sqrt{2} \cdot I_b$

$A_\sqcap = \dfrac{U_d}{2}$

$\hat{I}_c = \sqrt{2} \cdot I_c$

$A_\sqcap = U_d$

$\hat{U}_{ab(1)} = \dfrac{2\sqrt{3}}{\pi} \cdot U_d$

$A_\sqcap = \dfrac{U_d}{3}, \quad \dfrac{2\,U_d}{3}$

$\hat{U}_{a(1)} = \hat{U}_{a0(1)} = \dfrac{2}{\pi} \cdot U_d$

$A_\sqcap = \dfrac{U_d}{6}$

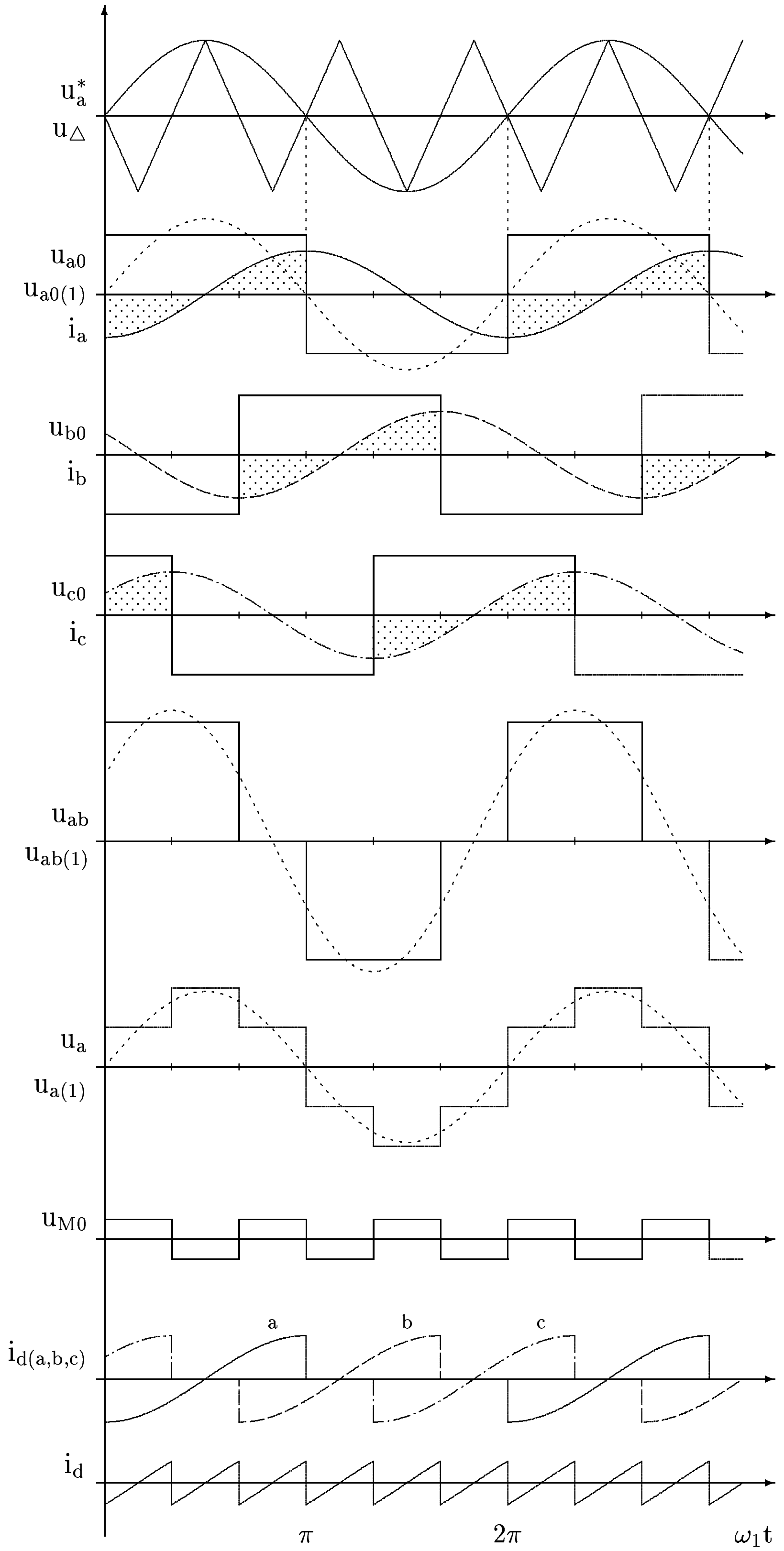
Mittelwert

$I_d = \dfrac{3\sqrt{2}}{\pi} \cdot I_a = 1,35 \cdot I_a$

$$P_L = 3 \cdot U_{a(1)} \cdot I_a \cdot \cos\varphi_1 = \frac{3\sqrt{2}}{\pi} \cdot U_d \cdot I_a = 1,35 \cdot U_d \cdot I_a$$

$$P_d = U_d \cdot I_d = \frac{3\sqrt{2}}{\pi} \cdot U_d \cdot I_a$$

b) Grundfrequenztaktung, Laststrom um $\varphi_1 = 90°$ nacheilend



Amplituden

$\hat{U}_a^* = 1$

$\hat{U}_\triangle = 1 \quad \left(\hat{=}\,\hat{U}_{a(1)max}\right)$

$A_\sqcap = \frac{U_d}{2}$

$\hat{I}_a = \sqrt{2} \cdot I_a$

$A_\sqcap = \frac{U_d}{2}$

$\hat{I}_b = \sqrt{2} \cdot I_b$

$A_\sqcap = \frac{U_d}{2}$

$\hat{I}_c = \sqrt{2} \cdot I_c$

$A_\sqcap = U_d$

$\hat{U}_{ab(1)} = \frac{2\sqrt{3}}{\pi} \cdot U_d$

$A_\sqcap = \frac{U_d}{3}, \quad \frac{2\,U_d}{3}$

$\hat{U}_{a(1)} = \hat{U}_{a0(1)} = \frac{2}{\pi} \cdot U_d$

$A_\sqcap = \frac{U_d}{6}$

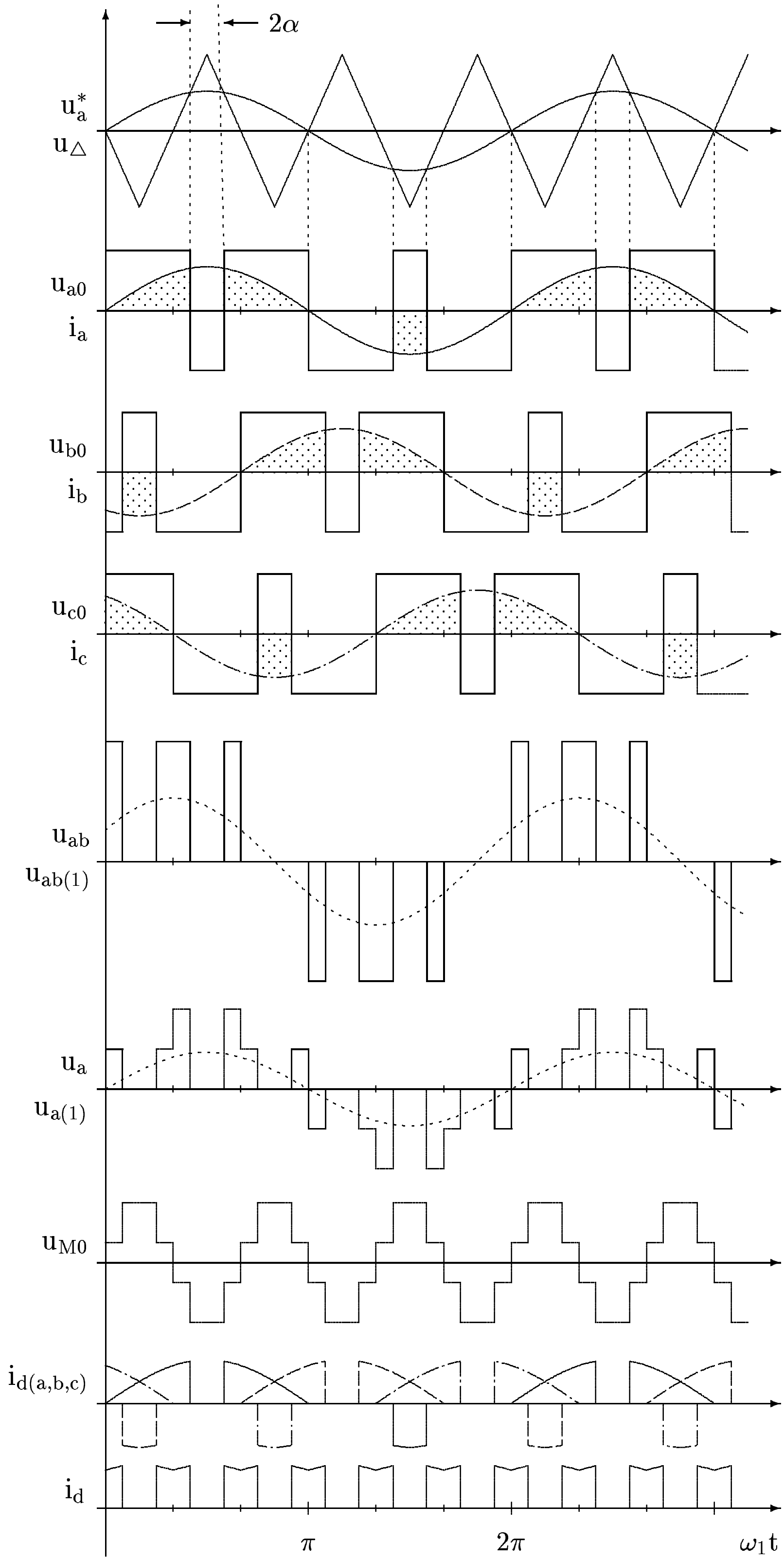
Mittelwert

$I_d = 0$

$P_L = 3 \cdot U_{a(1)} \cdot I_a \cdot \cos\varphi_1 = 0 \quad (\text{da} \quad \cos\varphi_1 = 0)$

$P_d = U_d \cdot I_d = 0 \quad (\text{da} \quad I_d = 0)$

c) Dreifachtaktung, Zwischenpulsweite $2\alpha = 30°$, $\varphi_1 = 0$



Amplituden

$$\hat{U}_a^* = \frac{1 - 6\alpha/\pi}{\cos\alpha} = 0,518$$

$$\hat{U}_\triangle = 1 \quad \left(\hat{=}\,\hat{U}_{a(1)\max}\right)$$

$$A_\sqcap = \frac{U_d}{2}$$

$$\hat{I}_a = \sqrt{2} \cdot I_a$$

$$A_\sqcap = \frac{U_d}{2}$$

$$\hat{I}_b = \sqrt{2} \cdot I_b$$

$$A_\sqcap = \frac{U_d}{2}$$

$$\hat{I}_c = \sqrt{2} \cdot I_c$$

$$A_\sqcap = U_d$$

$$\hat{U}_{ab(1)} = \frac{2\sqrt{3}}{\pi} \cdot \underbrace{(1 - 2\sin\alpha)}_{0,482} \cdot U_d$$

$$A_\sqcap = \frac{U_d}{3},\ \frac{2\,U_d}{3}$$

$$\hat{U}_{a(1)} = \frac{2}{\pi} \cdot (1 - 2\sin\alpha) \cdot U_d$$

$$A_\sqcap = \frac{U_d}{6},\ \frac{U_d}{2}$$

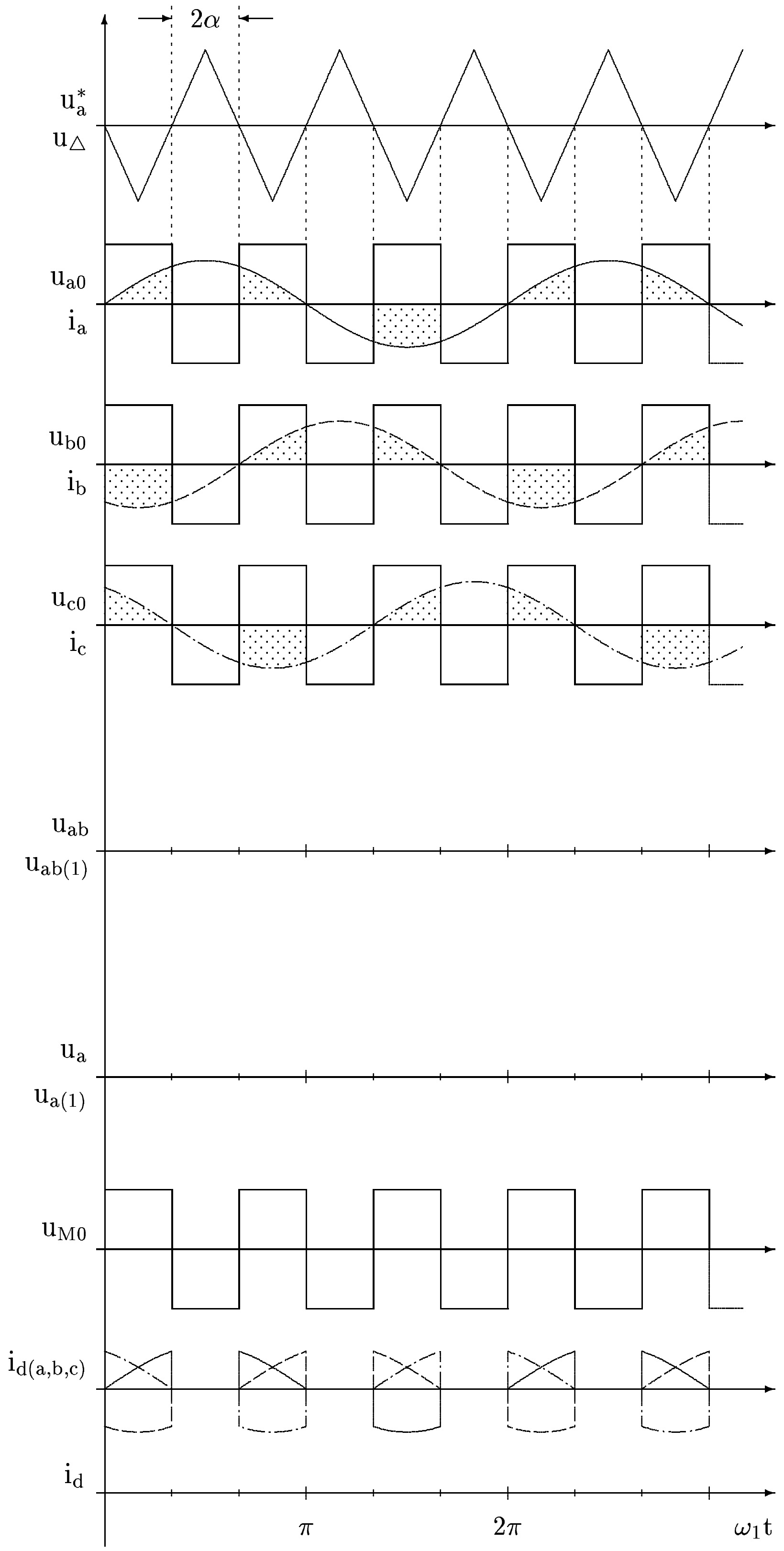
Mittelwert

$$I_d = \frac{3\sqrt{2}}{\pi} \cdot (1 - 2\sin\alpha) \cdot I_a$$

$$P_L = 3 \cdot U_{a(1)} \cdot I_a \cdot \cos\varphi_1 = \frac{3\sqrt{2}}{\pi} \cdot (1 - 2\sin\alpha) \cdot U_d \cdot I_a = 0,651 \cdot U_d \cdot I_a$$

$$P_d = U_d \cdot I_d = \frac{3\sqrt{2}}{\pi} \cdot (1 - 2\sin\alpha) \cdot U_d \cdot I_a$$

d) Dreifachtaktung, Zwischenpulsweite $2\alpha = 60°$, $\varphi_1 = 0$



Amplituden

$\hat{U}_a^* = 0$

$\hat{U}_\triangle = 1 \ \left(\hat{=}\, \hat{U}_{a(1)max}\right)$

$A_\sqcap = \dfrac{U_d}{2}$

$\hat{I}_a = \sqrt{2} \cdot I_a$

$A_\sqcap = \dfrac{U_d}{2}$

$\hat{I}_b = \sqrt{2} \cdot I_b$

$A_\sqcap = \dfrac{U_d}{2}$

$\hat{I}_c = \sqrt{2} \cdot I_c$

$u_{ab}(t) = 0$

$u_a(t) = 0$

$A_\sqcap = \dfrac{U_d}{2}$

$i_d(t) = 0$

$P_L = 3 \cdot U_{a(1)} \cdot I_a \cdot \cos\varphi_1 = 0 \quad (\text{da} \quad U_{a(1)} = 0)$

$P_d = U_d \cdot I_d = 0 \quad (\text{da} \quad I_d = 0)$