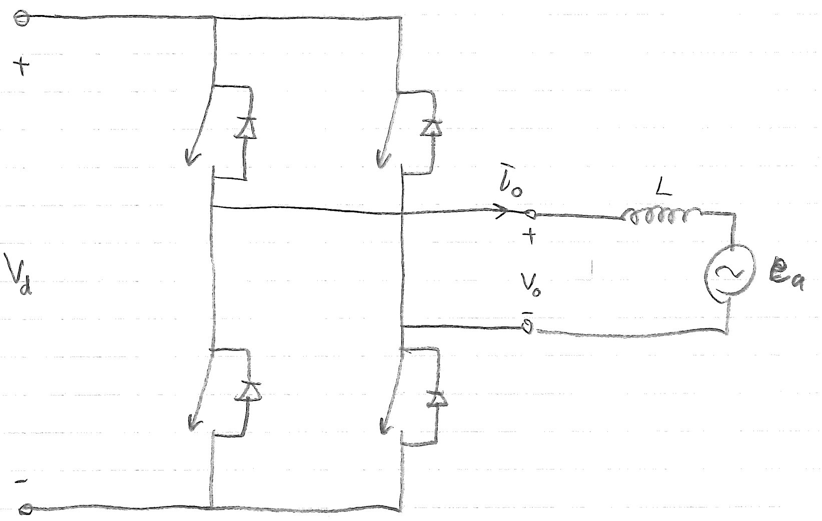
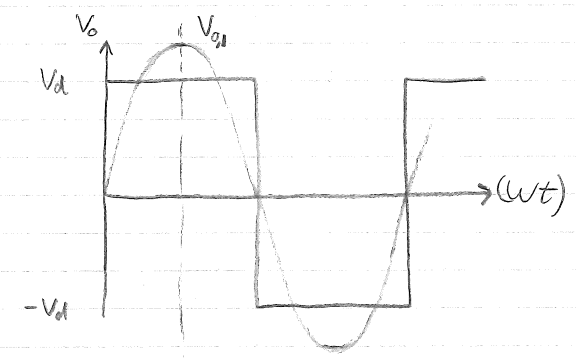
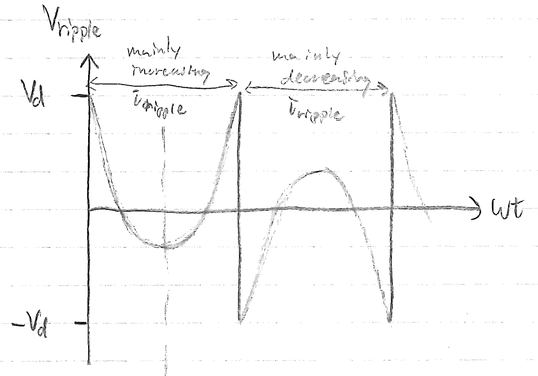
8-2 $\quad V_{o,1} = 220\,V$ at $47\,Hz$ $\quad L = 100\,mH$ $\quad$ 1-(1)

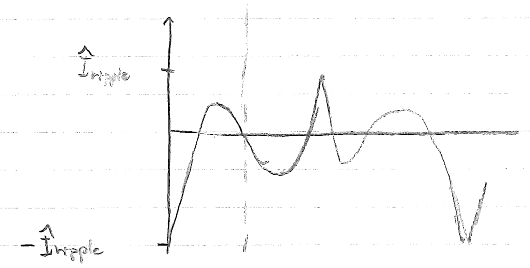
Square-Wave operation



Since e_a is sinusoidal the ripple voltage over the inductor is equal to $V_{ripple} = V_o - V_{o,1}$







Odd half wave function $\Rightarrow$

$$V_{o,1} = \frac{4}{\sqrt{2}\pi}\int_0^{\frac{\pi}{2}} V_d \sin(\omega t)\, d(\omega t) =$$

$$= \frac{4V_d}{\sqrt{2}\pi} \Rightarrow V_d = \frac{\sqrt{2}\pi}{4}\cdot 220 = \underline{244{,}4\,V}$$

$$V_L = L\frac{di_L}{dt} \Rightarrow$$

$$\omega L \int_0^{\hat{I}_{ripple}} di_o = \int_{\frac{\pi}{2}}^{\pi} V_d - \sqrt{2}V_{o,1}\sin(\omega t)\, d(\omega t) \Rightarrow$$

$$\hat{I}_{ripple} = \frac{1}{\omega L}\left(\left[V_d(\omega t) + \sqrt{2}V_{o,1}\cos(\omega t)\right]_{\frac{\pi}{2}}^{\pi}\right) =$$

$$= \frac{1}{\omega L}\left(\frac{\pi}{2}V_d - \sqrt{2}V_{o,1} + 0\right) = \frac{\pi V_d - 2\sqrt{2}V_{o,1}}{2\omega L}$$

$$\underline{\hat{I}_{ripple}} = \frac{\pi\cdot 244{,}4 - 2\sqrt{2}\,220}{2\cdot 2\cdot\pi\cdot 47\cdot 0{,}1} = \underline{2{,}46\,A}$$

Se page 222 fig 8-19 a

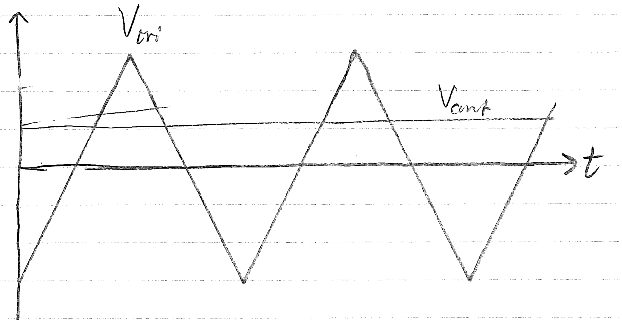
8-3 $m_f = 21$ and $m_a = 0{,}8$ bipolar voltage switching

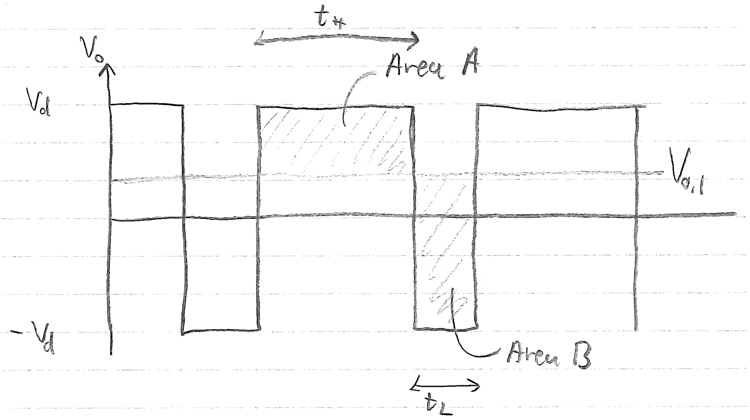
$m_f = \frac{f_s}{f_1}$ $\hat{V}_{o,1} = m_a V_d$

We have a PWM generator $\Rightarrow$ $V_{control} > V_{tri}$ T_{a+} on

$V_{control} < V_{tri}$ T_{a+} on

Since m_f is large we approximate $V_{control}(t) = \hat{V}_c \sin(\omega t)$ to be constand during one switching period $\Rightarrow$





Since we have approximated the control signal to be constant during one switching period we can also approximate the fundamental to be constant during one switching period $\Rightarrow$ Area A increases the ripple current and Area B decrease the ripple current

$$A(t) = t_H \left(V_d - m_a V_d \sin(\omega t) \right)$$

$$B(t) = t_L \left(V_d + m_a V_d \sin(\omega t) \right)$$

$$t_L = \frac{T_s}{2}\left(1 - \frac{\hat{V}_c \sin(\omega t)}{\hat{V}_{tri}}\right) = \frac{T_s}{2}\left(1 - m_a \sin(\omega t)\right)$$

$$t_H = T_s - t_L = T_s - \frac{T_s}{2} + \frac{T_s}{2} m_a \sin(\omega t) = \frac{T_s}{2}\left(1 + m_a \sin(\omega t)\right)$$

$\Rightarrow$

$$A(t) = \frac{T_s}{2}\left(1+m_a\sin(\omega t)\right)\left(V_d - m_a V_d \sin(\omega t)\right) = \frac{V_d T_s}{2}\left(1 - m_a^2 \sin^2(\omega t)\right)$$

$$B(t) = \frac{T_s}{2}\left(1-m_a\sin(\omega t)\right)\left(V_d + m_a V_d \sin(\omega t)\right) = \frac{V_d T_s}{2}\left(1 - m_a^2 \sin^2(\omega t)\right)$$

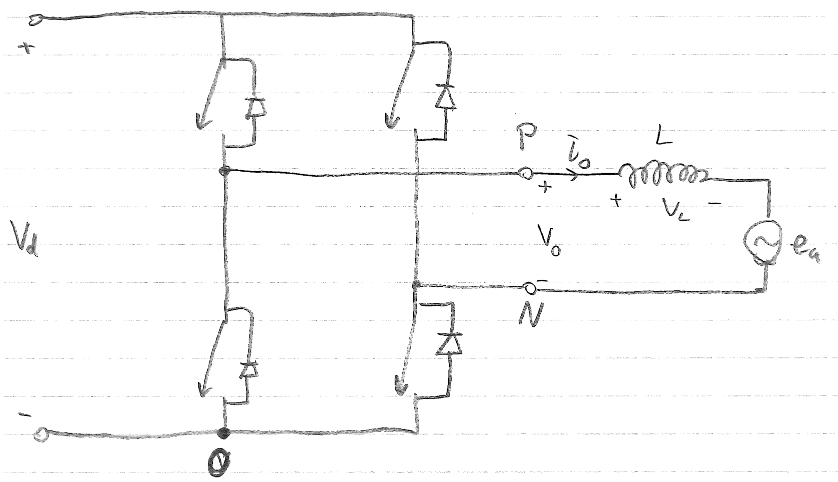
$\Rightarrow$ Area A = Area B as they should be. We see that the areas are greates at $t=0$. Therefore the ripple current will also be ~~greatest~~ greates at $t=0$ $\Rightarrow$

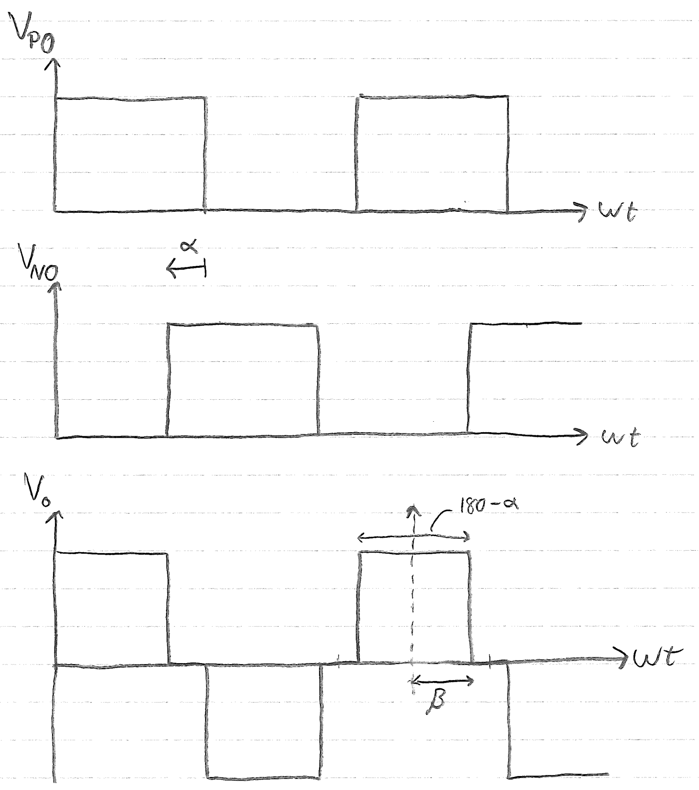
$$\hat{I}_{ripple,p-p} = \frac{A(t=0)}{L} = \frac{V_d}{2f_s L} = \frac{\sqrt{2}V_{a1}}{2 m_f f_1 m_a L} = \frac{\sqrt{2}\,220}{2\cdot 21\cdot 47\cdot 0{,}8\cdot 0{,}1} = 1{,}97A \Rightarrow$$

Peak ripple current $= \frac{1{,}97}{2} = \underline{\underline{0{,}985\ A}}$

8-4 Voltage Cancellation see page 218.

$$V_d = \frac{\sqrt{2}\cdot 220}{0{,}8} = \underline{\underline{389\,V}}$$





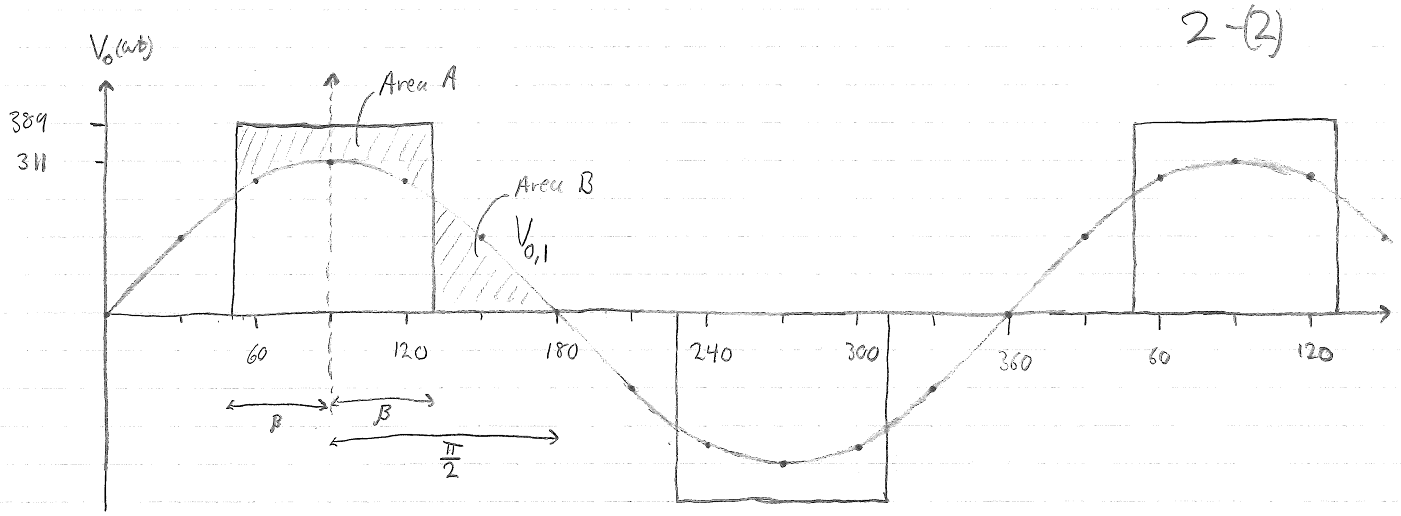
These are always square-wave voltages. By changing α we se that we can change the output voltage

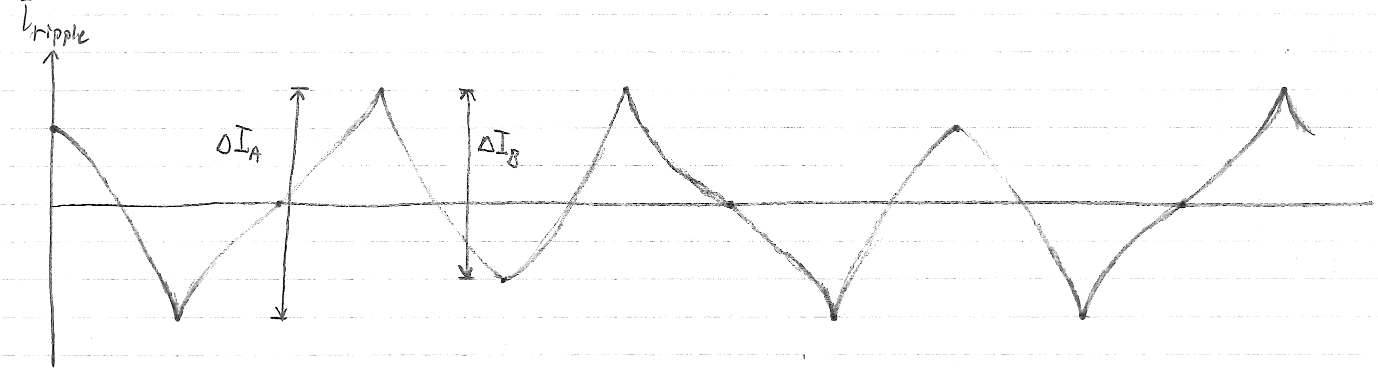
$$180-\alpha = 2\beta \Rightarrow \beta = 90 - \frac{\alpha}{2}$$

We have an even function ⇒

$$V_{o,1} = \frac{a_1}{\sqrt{2}} = \frac{2}{\sqrt{2}\pi}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} V_o(\omega t)\cos(\omega t)\,d(\omega t) = \frac{\sqrt{2}}{\pi}\int_{-\beta}^{\beta} V_d\cos(\omega t)\,d(\omega t) = \frac{2\sqrt{2}}{\pi}V_d\sin(\beta) \Rightarrow$$

$$\sin(\beta) = \frac{\pi}{2\sqrt{2}}\frac{V_{o,1}}{V_d} = \frac{\pi}{2\sqrt{2}}\frac{220}{389} = 0{,}628 \Rightarrow \beta = 38{,}9^\circ \Rightarrow \alpha =$$





We know that: $\Delta I_A = \frac{\text{Area } A}{L}$ and $\Delta I_B = \frac{\text{Area } B}{L} \Rightarrow$

$$\Delta I_A = \frac{1}{\omega L}\int_{-\beta}^{\beta}(V_d - \sqrt{2}V_{o,1}\cos(\omega t)\, d(\omega t) = \frac{2}{\omega L}\left(V_d \beta - \sqrt{2}V_{o,1}\sin(\beta)\right)$$

$$\Delta I_B = \frac{1}{\omega L}\int_{\beta}^{\frac{\pi}{2}}\sqrt{2}V_{o,1}\cos(\omega t)\, d(\omega t) = \frac{\sqrt{2}}{\omega L}V_{o,1}(1-\sin(\beta)$$

$$\Delta I_A = \frac{2}{2\pi 47 \cdot 0{,}1}\left(389 \cdot \frac{38{,}9° \cdot \pi}{180°} - \sqrt{2}\, 220\sin(38{,}9°)\right) = \underline{\underline{4{,}65\ A}}$$

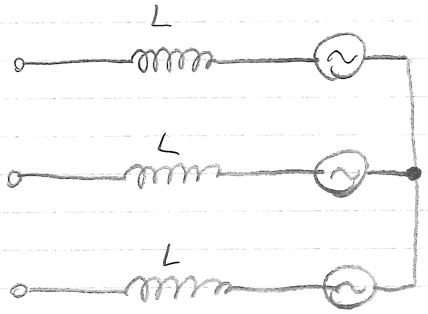
$$\Delta I_B = \frac{\sqrt{2}}{2\pi 47 \cdot 0{,}1}\, 220\left(1-\sin(38{,}9°)\right) = \underline{\underline{3{,}92\ A}}$$

$\Delta I_A > \Delta I_B \Rightarrow$

Peak ripple current $= \frac{\Delta I_A}{2} = \frac{4{,}65}{2} = \underline{\underline{2{,}33\ A}}$

8-8   Synchronous PWM $m_f = 39$, $m_a = 0{,}8$, $V_{LL} = 200\,V$ 52Hz

Three-phase load



$L = 100\,mH$

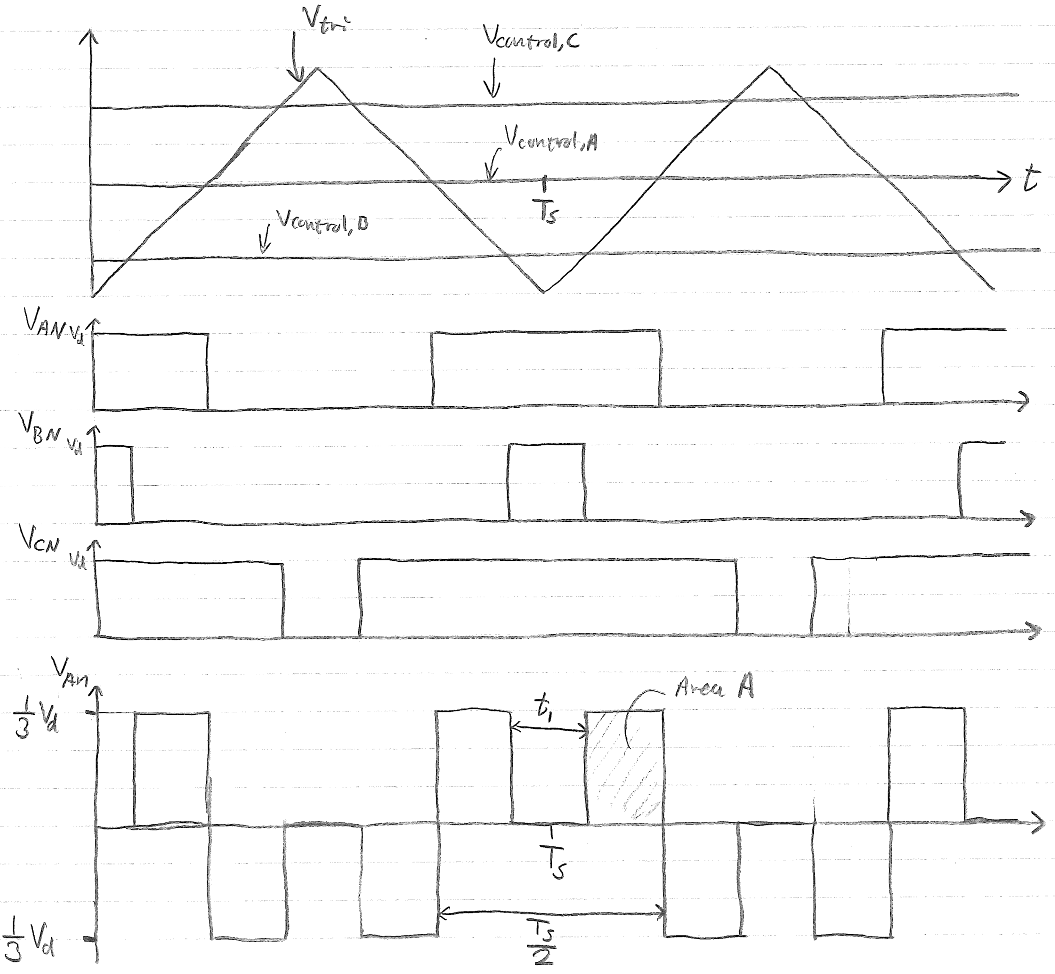
As we can see from figure 8-26 b the peak ripple current occurs near the zero-crossing points of V_{AN1}.

Since m_f is large, $V_{control,A}$, $V_{control,B}$ and $V_{control,C}$ can be assumed to be constant during one switching period. At the zero-crossing of $V_{control,A}$ =>

$V_{control,A} = 0$

$V_{control,B} = 0{,}8\,\hat{V}_{tri}\sin(0-120°) = -0{,}8\frac{\sqrt{3}}{2}\hat{V}_{tri} = -0{,}4\sqrt{3}\,\hat{V}_{tri}$

$V_{control,C} = 0{,}8\,\hat{V}_{tri}\sin(0+120°) = 0{,}4\sqrt{3}\,\hat{V}_{tri}$



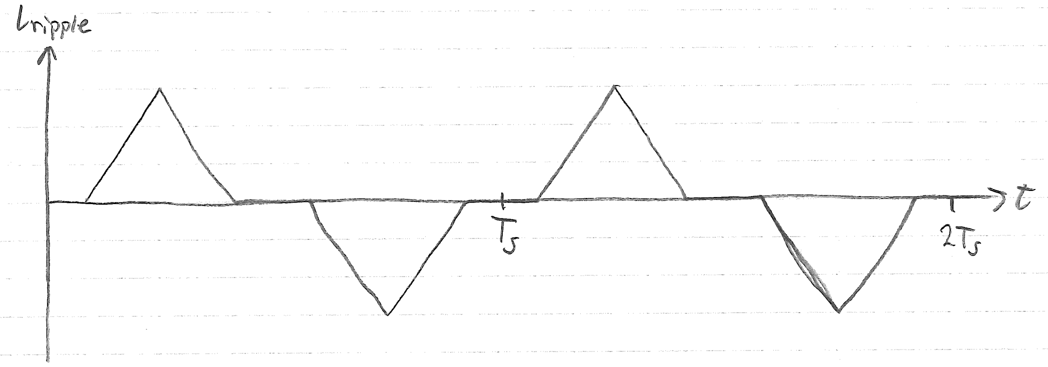
2-(2)

From 8-7 we know that

$$V_{An} = \frac{2}{3}V_{AN} - \frac{1}{3}(V_{BN} + V_{CN})$$

We also know that $V_{An,1} = 0 \Rightarrow$

$V_{ripple} = V_{An}$ it is this voltage that drives the ripple current $\Rightarrow$



$$\hat{i}_{ripple} = \frac{1}{L}\int_0^{\frac{T_s}{4}} V_{An}(t)\,dt = \frac{\text{Area } A}{L}$$

$$t_1 = \frac{T_s}{2}\left(1 - \frac{|V_{control,B}|}{\hat{V}_{tri}}\right) = \frac{T_s}{2}\left(1 - 0{,}4\sqrt{3}\right) \Rightarrow$$

$$\text{Area } A = \frac{1}{3}V_d\left(\frac{T_s}{4} - \frac{t_1}{2}\right) = \frac{1}{3}V_d\left(\frac{T_s}{4} - \frac{T_s}{4}\left(1 - 0{,}4\sqrt{3}\right)\right) = \frac{V_d T_s}{12}\,0{,}4\sqrt{3} \Rightarrow$$

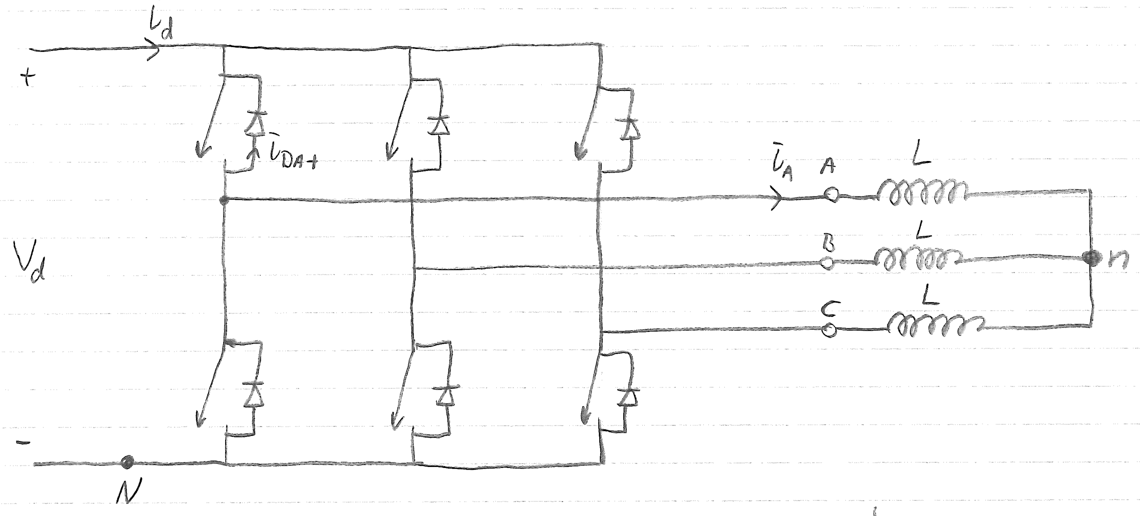
$$\hat{i}_{ripple} = \frac{0{,}4\sqrt{3}\,V_d}{12\,L\,f_s}$$

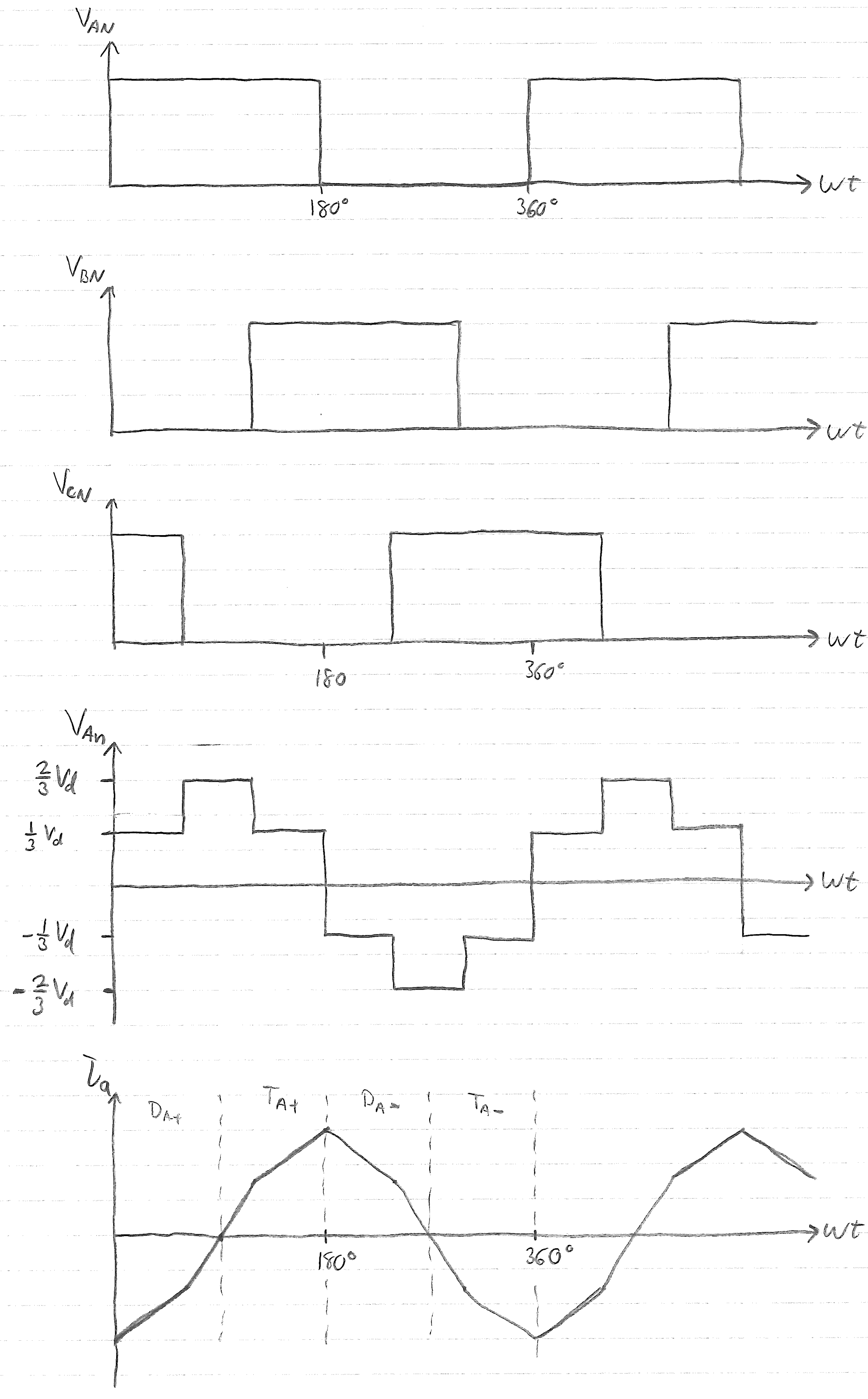
From equation 8-57 we know that

$$V_d = \frac{2\sqrt{2}}{\sqrt{3}\,m_a}V_{LL1} \Rightarrow$$

$$\underline{\hat{i}_{ripple}} = \frac{0{,}4\cancel{\sqrt{3}}\,2\sqrt{2}\,V_{LL1}}{\cancel{\sqrt{3}}\,m_a\,12\,L\,m_f\,f_1} = \frac{0{,}4\cdot 2\cdot\sqrt{2}}{12}\cdot\frac{200}{0{,}8\cdot 0{,}1\cdot 52\cdot 39} = \underline{\underline{0{,}116}}$$

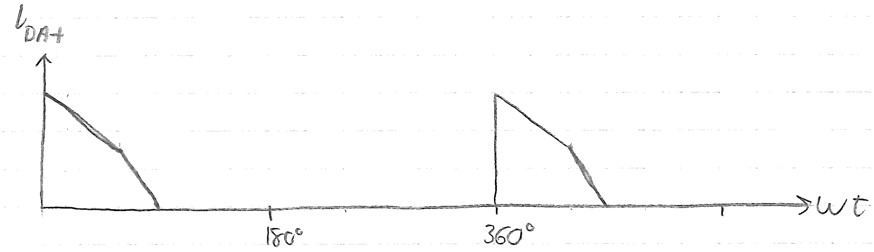
8-11

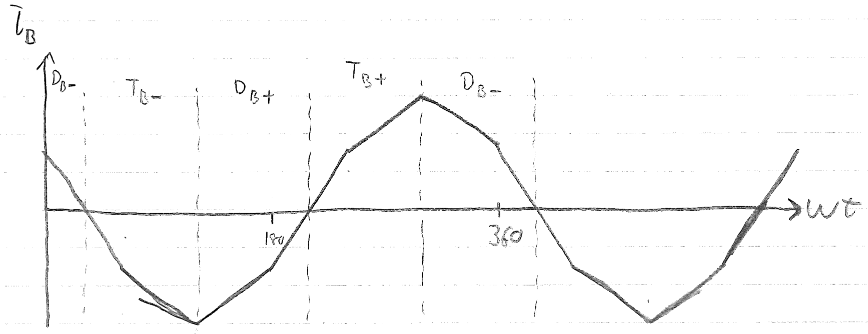


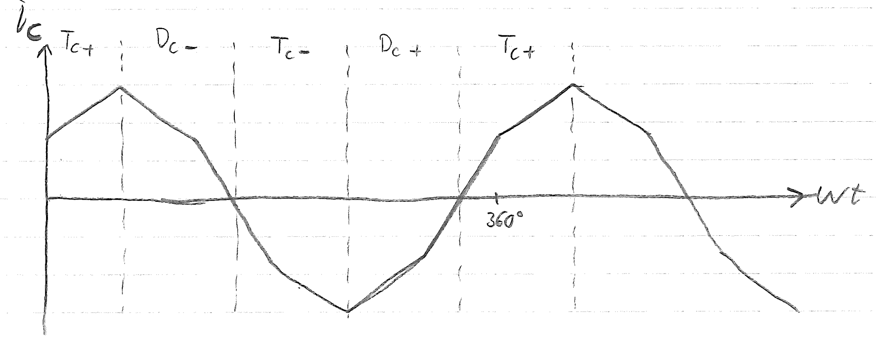


We have a three-phase balanced load $\Rightarrow$

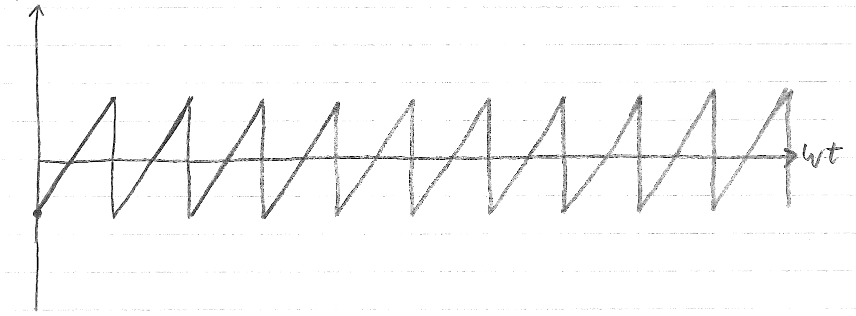
$$V_{An} = \frac{2}{3}V_{AN} - \frac{1}{3}\left(V_{BN} + V_{CN}\right)$$







$i_d = i_{TA+} - i_{DA+} + i_{TB+} - i_{DB+} + i_{TC+} - i_{DC+}$



We see that $I_d = 0$ as it should be since the load do not draw active power $P_{ac} = 0 = P_{in} = V_d \cdot 0$