A one-quadrant dc chopper with 200 V supply voltage and 5 kHz switching frequency controls the power of 10 Ω heater. For $\lambda = 1/4$ by ignoring circuit losses

a) Calculate the period and ton

b) Calculate the load current while the transistor is on

c) Find the average and rms value of the transistor

d) Find the input power of the dc chopper

a) $T_s = \frac{1}{f_s} = \frac{1}{5 \cdot 10^{-3}} = 200\ \mu s$

$D = \frac{T_{on}}{T_s} = \frac{1}{4} \Rightarrow t_{on} = 50\ \mu s.$

b) $I_o = \frac{V_s}{R \rightarrow load} = \frac{200}{10} = 20\ A.$

$I_o = I_{Load}$

c) $I_{TAV} = D \cdot I_o = \frac{1}{4} \cdot 20 = 5\ A.$

$I_{TRMS} = \sqrt{D} \cdot I_o = \sqrt{\frac{1}{4}} \cdot 20 = 10\ A$

d) $P_i = V_s \cdot I_{TAV} = 200 \cdot 5 = 1\ kW.$

Example

A dc motor with 250 V input voltage is controlled via a dc chopper with 1 kHz operational frequency. The data for the motor is given as following for nominal operation: $P = 1750\,W$, $n = 1000$ rpm, $U = 200V$, $I_a = 10\,A$, $R_a = 2\,\Omega$, $P_{loss} = 0$, I_{field} is constant (Torque, constant).

a) If $D = \frac{3}{5}$ at single quadrant dc chopper, For nominal torque value, Find out, E_a Back e.m.f, number of revulution (n), Motor input power, torque and efficiency of motor.

Solution

$E_a + R_a \cdot I_a = U$ (motor voltage)

$U_o = D \cdot 250 \rightarrow$ input voltage of dc chopper

$U_o = \frac{3}{5} \cdot 250 = 150V.$ [output voltage dc chopper and input voltage of dc motor]

$E_a = U_o - I_a \cdot R_a = 150 - 2 \cdot 10 = 130\ V.$

$E_a = k \cdot \Phi \cdot n \rightarrow$ (I_{field} = constant, means Φ constant)

$E_a = C \cdot n$

$$\frac{E_{a_n}}{E_a} = \frac{n_n}{n} \Rightarrow \quad E_{a_n} = 200 - 2 \cdot 10 = 180V.$$

$n = 1000$

$$\frac{180}{130} = \frac{1000}{n} \Rightarrow n = 722.2 \text{ rpm}$$

$P_i = U_o \cdot I_a = 150 \cdot 10 = 1500\ W.$

$P_o = P_{mech} \cong E_a \cdot I_a = 130 \cdot 10 = 1300\ W$

$$\eta = \% \frac{P_{in}}{P_o} = \frac{1300}{1500} = \% 86.$$

$$P_o = P_{mech} = T \cdot \omega = T \cdot \frac{2 \cdot \pi \cdot n}{60}$$

$$T = \frac{1300}{2 \cdot \pi \cdot \frac{722.2}{60}} = 17.19 \text{ Nm.}$$

b) Let's assume that the dc motor is controlled by a two quadrant dc chopper and it rotates at 500 rpm. Find out the D, Ton an T values for braking with nominal torque value.

$n = 500$ rpm.

$$\frac{E_{a_n}}{E_a} = \frac{n_n}{500} = \frac{180}{E_a} = \frac{1000}{500} \Rightarrow E_a = 90V$$

For braking $E > U$ means $E_a = U + R_a \cdot I_a$

$$E_a = 90 = U + 2 \cdot 10 \Rightarrow U = 70 V.$$

70V is the output voltage of the dc chopper

We know the input voltage of the dc chopper

$$250 = D \cdot 70 \Rightarrow D = 0.36$$

$$T = \frac{1}{f} = \frac{1}{1000} = 1 \text{ ms} \qquad T_{on} = D \cdot T = 0.36 \text{ms}$$

$$T = T_{on} + T_{off} \Rightarrow T_{off} = 0.64 \text{ ms.}$$

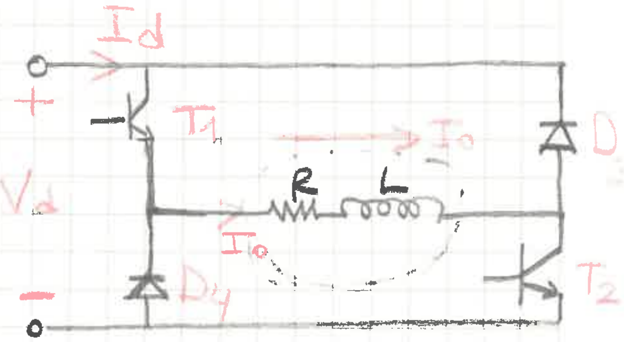
A two quadrant dc/dc converter (dc chopper) with 100 V. input voltage and 20 kHz operational frequency supplies to a dc motor with 10A nominal current value. By assuming the output current is constant;

a) If D= 7/10, find out the voltage across the load, the power of dc motor, diode and transistor currents.

b) If D= 2/10, what about the direction of power flow, please comment it

a)

$$U_o = \frac{1}{T}\left[\int_0^{T_{on}} U_d \cdot dt + \int_{T_{on}}^{T} -U_d \cdot dt\right]$$



$$D = \frac{T_{on}}{T}$$

$$U_o = \frac{1}{T}\cdot(2\cdot T_{on} - T)\cdot U_d$$

$$U_o = (2\cdot D - 1)\cdot U_d$$

$$I_o = I_T + I_D$$

$$I_d = I_T - I_D$$

$$I_T = D \cdot I_o$$

$$U_o = \left(2\cdot\frac{7}{10} - 1\right) 100 = 40\ V.$$

$$P_o = U_o \cdot I_o = 10\cdot 40 = 400\ W$$

$$I_T = \frac{7}{10}\cdot I_o = 7\ A.$$

$$I_D = 10 - 7 = 3A.$$

b) $$U_o = \left(2\cdot\frac{2}{10} - 1\right)\cdot 100 = -60\ V.$$

Negative operation mode

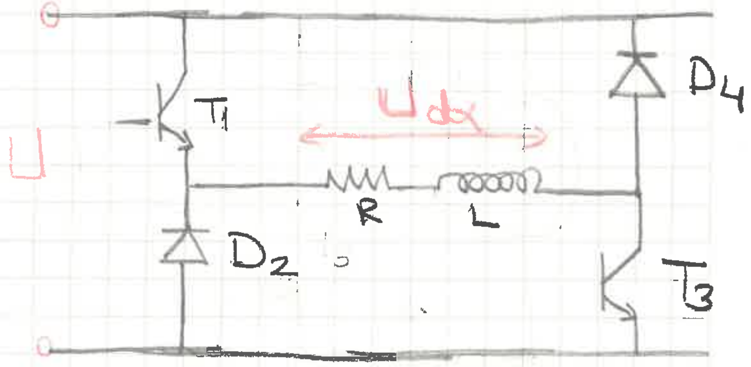
Power flow from dc motor to dc supply.

Example

A half-wave controlled and two phases rectifier with 110 V phase voltage controls a dc motor with 9.9 A. By assuming the load current continous, For $\alpha = 60°$;

a) Draw circuit and find out the motor voltage
b) Calculate the avarage current for each transistor
c) Calculate the rms current
d) Find out the active power drawn from network

Solution



a) $U_{d\alpha} = U_d \cdot \cos\alpha$.

$$U_d = s \cdot \frac{q}{\pi} \cdot \sqrt{2} \cdot U_{phase} \cdot \sin\frac{\pi}{q}$$

$s = 1$ for half-wave

$q = 2$ two phase

$$U_{d\alpha} = 1 \cdot \frac{2}{\pi} \cdot \sqrt{2} \cdot 110 \cdot \sin\frac{\pi}{2} \cdot \cos 60°$$

$U_{d\alpha} = 49.52$ V.

b) $I_{T\,AV} = \frac{1}{q} \cdot I_d$ (→ motor current) $= \frac{1}{2} \cdot 9.9$ A

$= 4.95$ A.

c) $I_{T\,rms} = \sqrt{\frac{1}{q}} \cdot I_d = 7$ A.

d) $P_s \cong P_{motor} = 49.52 \cdot 9.9 = 490.2$ W.