1. a) The output waveform will be a square wave with the same frequency as the fundamental of the control voltage (intended output frequency of the DC-AC converter).

   b) The speed of the induction motor is mainly dependent on the frequency of the input voltage.

   c) A power bipolar transistor have a lower current amplification factor B compared to a small signal bipolar transistor.

   d) The switch-mode DC-AC converter can feed energy back into the voltage source.

   e) IGBT = Insulated Gate Bipolar Transistor

2. a) First find out if it is discontinuous or continuous current conduction mode. Output voltage and switching ratio D is given. For continuous current conduction mode the output voltage should then be $V_O = D\,V_d$, but here $V_O = 3$ V and $D\,V_d = 12*0.1 = 1.2$ V. Therefore, the circuit is operating in discontinuous mode.

   Steady state: $(V_d - V_O)D\,T_S = V_O\,\Delta\,T_S \Rightarrow \Delta = (V_d - V_O)D / V_O = (12-3) * 0.1 / 3 = 0.3$.

   The i_L current (defined as current through inductor directed to the left) is starting from zero at time 0, increase for 0.1 T_S, then decrease for 0.3 T_S back to zero. The rest 0.6 T_S will have $i_L = 0$. The average output current

$$I_O = \int_0^{T_S} i(t)\,dt = \frac{i_{Lmax}}{2}\frac{0.4\,T_S}{}\frac{1}{T_S} = \frac{i_{Lmax}}{5}$$

$$i_{Lmax} = \frac{(V_d - V_O)D\,T_S}{L} = \frac{(12-3)\cdot 0.1}{18\cdot 10^{-6}\cdot 50\cdot 10^{3}} = 1\,\mathrm{A}$$

$$I_O = \frac{i_{Lmax}}{5} = \frac{1}{5} = 0.2\,\mathrm{A}$$

   b) Input power must match output power, otherwise will the circuit dissipate or generate power. Therefore $V_d\,I_d = V_O\,I_O \Rightarrow I_d = V_O\,I_O / V_d = 3*0.2/12 = 50$ mA

   c) Task missing additional requirement: Increasing D will increase output current and/or output voltage.

   Assuming same output voltage: Apply voltages to continuous conduction mode equation $\Rightarrow D = V_O/V_d = 3/12 = 0.25$

   Assuming same output current (I_{LB} from equation 7-18):

$$I_{LB} = \frac{T_S V_O}{2\mathrm{L}}(1-D) \Rightarrow D = 1 - \frac{I_{LB} 2L}{T_S V_O} = 1 - \frac{0.2\cdot 2\cdot 18\cdot 10^{-6}}{\frac{1}{(50\cdot 10^{3})}\cdot 3} = 0.88$$

3. a) Ripple output voltage is based on current charging capacitor C, and the peak voltage will be reached when the current goes from positive to negative current (to the capacitor). First indicate symmetry point in the current, where charge and discharge of the capacitance is equal. Then indicate voltage increase from minimum. Ripple current initially low => small slope initially, then increase. Current reaches its maximum when current do a zero-crossing. Then have a decreasing slope again. Ripple current not symmetric => falling voltage shaped slightly different. See figure 7.10 in the book.

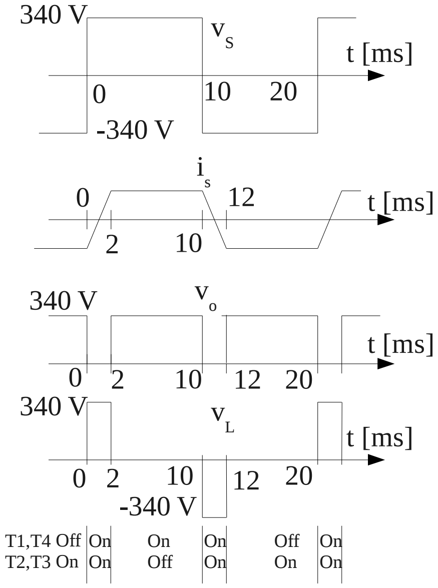
   b) Minimum size of C depend of amount of charge to store, and voltage produced due to this.

$i_{Lmax}=6\,A \Rightarrow i_{Lripplemax}=3$ A Triangle shaped charging => total charge in half cycle is

$$\frac{\frac{T_S}{2}\, i_{Lripplemax}}{2}=\frac{\frac{20\cdot 10^{-6}}{2}\cdot 3}{2}=15\mu C, \quad Q=CU \quad \Rightarrow \quad C=\frac{Q}{U}=\frac{15\cdot 10^{-6}}{0.1}=150\mu F$$

c) ESR = Equivalent Series Resistance: => additional voltage across capacitor of 0.1*3A = 0.3V peak voltage (shaped and in phase with current waveform).

4. a) Inductor in series with voltage source. Voltage across the inductor non-zero when changing current direction. This happens when voltage flips, and the current from source drops below I_O. All diodes will then conduct. v_O will be the rectified version of v_S except directly after switch time where it will be zero. I_S will flow out of the source in the voltage direction except when voltage switch, where the output current will linearly change to the opposite direction with the output voltage being zero. v_L will be zero except directly after v_S switch, where it will be alternating +340 or -340 V for a part of the cycle.



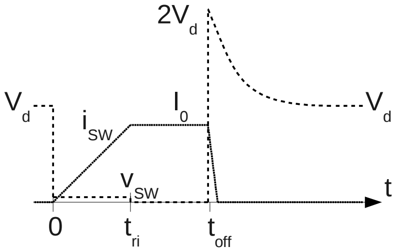
b) Average output voltage require the knowledge of how long the output voltage is zero. During the output voltage equal zero time, the voltage across the inductor is 340V. The current will change from $-I_0$ to $+I_0$, therefore the total current change in the inductor is $2I_0$.

$$2I_0=V_d\frac{T_{sw}}{L} \Rightarrow T_{sw}=2I_0\frac{L}{V_d}=\frac{2\cdot 10\cdot 34\cdot 10^{-3}}{340}=2\,\text{ms} \Rightarrow V_O=\frac{1}{T}\int_0^T v_O(t)\,dt=$$

$$=\frac{1}{10}\int_2^{10} 340\,dt=\frac{340\cdot 8}{10}=272\,\text{V}$$

c) Source displacement power factor = cos φ, where φ = fundamental voltage phase angle - fundamental voltage phase angle: zero-crossing current happens 1 ms after voltage zero-crossing => φ = 1/20 * 2 π => DPF = cos (1/20 * 2 π) = 0.95

5. a) Switch on at t=0, and switch off at t_{off}

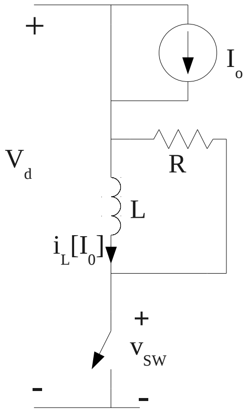


b) 5% of V_d across the switch at turn on leaves 95% of V_d across L. The current increase should still be same as defined by the switch.

$$L=\frac{v_L}{di_L/dt}=\frac{0.95V_d}{\Delta i_L/t_{ri}}=\frac{0.95\cdot 200}{10/4\cdot 10^{-6}}=76\mu H$$

c) At turn-off will the diode in parallel with I_O start to conduct when the i_{SW} starts to decrease.

The snubber diode starts to conduct, and the current now flows through R instead of the switch. Assuming the current fall time can be neglected compared to the LR time constant τ_{LR} at time t_{off}:



$$v_{sw}=V_d+RI_0$$
$$v_{sw}<2V_d$$
$$V_d+RI_0<2V_d$$
$$RI_0<2V_d-V_d=V_d$$
$$R<\frac{V_d}{I_0}=\frac{200}{10}=20\Omega$$
$$R<20\Omega$$