1. a) The speed of a synchronous motor depends on the frequency of the driving voltage.
   b) A third winding is added to transformers in forward converters to allow the stored energy in the transformer to be removed.
   c) The voltage is reversed and there is a reverse current flowing through the diode at the same time. The current is linearly reduced down to zero.
   d) ZVS-CV = Zero Voltage Switching – Clamped Voltage
   e) The power factor PF = $(I_{s1}/I_s)*\cos(\varphi)$, where φ = angle between current and voltage fundamental components. For a resistive load, this can also be written as PF = $(V_{s1}/V_s)*\cos(\varphi)$. So the power factor does not depend on the voltage amplitude (depends on ratio between fundamental and total amplitude, not the absolute values).

2. a) Full rectifier, start angle 45 degrees. Peak voltage 220*sqrt(2) V.
   b) Average voltage = 1/(T/2) * integral from T/8 to T/2 of 220*sqrt(2) * sin(ωt) dt = 220*sqrt(2) / π * [-cos ωt] T/8 to T/2 = 220 * sqrt(2)/ π *(1+1/sqrt(2)) = 170 V

3. a) Assume V_s negative long enough to force i_L to zero. $V_L = 0$ because I_L fixed at 0. Then will I_0 go through the right diode, with $V_d = 0$. When V_s turns positive, I_0 still goes through right diode, => V_d still zero. V_L now 340 V, with the left diode conducting and with an increasing I_L current. Current grows as dI/dt = V_L/L = 340/136e-3 A/s. I_0 = 5A => I_L reach I_0 after T = I_O/(dI/dt) = $I_0 L/V_L$ = 5*136e-3/340 = 2 ms. When I_L reach I_0 then the right diode turns off and V_d reaches 340V, while V_L goes to zero.

   When V_s turns negative, then V_d drops to zero (starts to conduct current from I_0) as part of the I_0 current starts to go through that diode. The left diode still conducts, as I_L is non-zero. The V_L voltage is now -340V, and the I_L current thereby reduce at the same rate as it was increasing when V_s turned positive before. After 2 ms will I_L therefore reach zero, and the left diode turns off.
   b) From the description above: current commutation takes 2 ms.
   c) The V_d voltage is zero except from 2 ms into the cycle, and goes back to zero at 10 ms. The average output voltage is then 340*(10-2)/20 = 136V

4. a) Only 2 diodes conducting at the same time, assuming neglectable current commutation time. At most is 100 A running through each of them => $P_{diode,max}$ = 2*0.7*100 = 140 W.
   b) 90% efficiency. $P_{out} = P_{in} - P_{diode}$, efficiency = $P_{out}/P_{in} = P_{out}/(P_{out} + P_{diode})$ => 0.9=P_{out}/ $(P_{out}+P_{diode})$ => P_{out}*(1-0.9)=0.9P_{diode} => P_{out} = 0.9/0.1 * P_{diode} = 9*140W. I_{out} = 100A => V_{out} = 9*140/100 = 12.6V

5. a) Continuous conduction mode: $V_o = V_d$*D/(1-D) => D = $V_o/(V_o+V_d)$=3/(3+12) = 0.2
   b) Edge between continuous and discontinuous conduction mode: $I_{oB} = T_s V_o$/(2*L) * (1-D)^2 = 20e-6*3/(2*38.4e-6)*(1-0.2)^2 = 0.5A
   c) Power in must equal power out (assuming no losses in the converter) => $V_d * I_d = V_o * I_o$ => $I_d = V_o * I_o / V_d$ = 3*2/12 = 0.5A

6. Full bridge rectifier => cycle time of the input signal is 20 ms (2 pulses generated from

one cycle of the input voltage).

Fundamental frequency component of the current is zero, as the two pulses are identical.

Not symmetric in terms of f(-t) = f(t). It is therefore not possible to use any simplified versions of calculating the coefficients.

Find coefficients for the expression

$$i(t)=\frac{1}{2}a_0+a_1\cos(\omega t)+b_1\sin(\omega t)+a_2\cos(\omega t)+b_s\sin(\omega t)+a_3\cos(\omega t)+b_3\sin(\omega t)$$

$$\frac{1}{2}a_0=\text{average}=\frac{6\cdot 2}{10}=1.2\,A\text{(Not really part of the task)}$$

$$f(t)=f(t+T/2) \quad \Rightarrow \quad \text{no fundamental component}$$

$$a_1=\frac{1}{\pi}\int_0^{2\pi} i(t)\cos(\omega t)\,d(\omega t)=0$$

$$b_1=\frac{1}{\pi}\int_0^{2\pi} i(t)\sin(\omega t)\,d(\omega t)=0$$

$$a_2=\frac{1}{\pi}\int_0^{2\pi} i(t)\cos(2\omega t)\,d(\omega t)=0$$

$$b_2=\frac{1}{\pi}\int_0^{2\pi} i(t)\sin(2\omega t)\,d(\omega t)=0$$

$$a_3=\frac{1}{\pi}\int_0^{2\pi} i(t)\cos(3\omega t)\,d(\omega t)=0$$

$$b_3=\frac{1}{\pi}\int_0^{2\pi} i(t)\sin(3\omega t)\,d(\omega t)=0$$

NOTE: Task to complicated. Reduce minimum correct points to 26 and maximum points to 66. Task 6 gives at most 4 points, if student identifies that the fundamental component is zero and the 3rd harmonic also is zero.

General solution to task 6. Identify that f(t) = f(t+T/2)

$$a_h=\frac{1}{\pi}\int_0^{0.2\pi}\left(2-\frac{2\omega t}{0.2\pi}\right)\cos(h\omega t)\,d(\omega t)+\frac{1}{\pi}\int_{0.6\pi}^{\pi}(\omega t-0.6\pi)\frac{2}{0.4\pi}\cos(h\omega t)\,d(\omega t)+$$

$$\frac{1}{\pi}\int_{\pi}^{1.2\pi}\left(2-\frac{2(\omega t-\pi)}{0.2\pi}\right)\cos(h\omega t)\,d(\omega t)+\frac{1}{\pi}\int_{1.6\pi}^{2\pi}(\omega t-1.6\pi)\frac{2}{0.4\pi}\cos(\omega t)\,d(\omega t)=$$