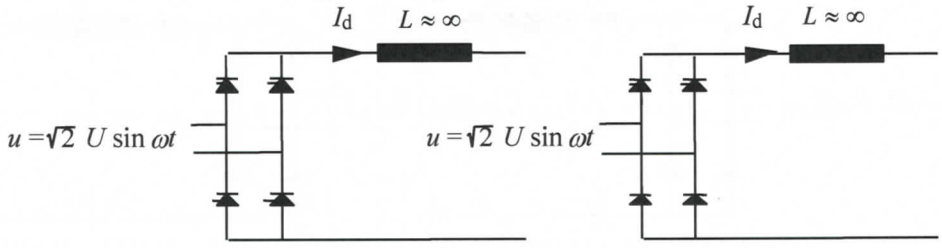
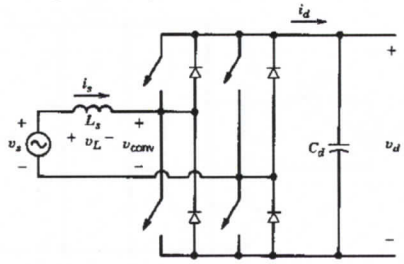
S - 81.3110 Converter Techniques **Exam 17.3.2014**

1. Derive equations for the symmetrical 2-pulse rectifier (left side figure below) the following quantities: fundamental line-current in relation to the rms of the line-current γ, power factor λ or sometimes *PF*, displacement power factor $\cos\phi_1$ or sometime *DPF* (only fundamental component). Calculate their values when the control angle α is 30° or 60°. DC current can be assumed ideal. How the case changes when the right hand side converter is used? Written explanation without math is enough in this part of the answer.



2. Squirrel cage motor is supplied from a pulse width modulated inverter. In one operating point the line-to-line voltage of the motor comprises of two pulses within a half cycle and the control principle is constant flux. Calculate the frequencies on which the minimum and maximum values of the 7th harmonic occur, $f < 50$Hz. The nominal line-to-line voltage of the motor is 400 V and it is also voltage supplying the six pulse diode rectifier of the frequency converter. Nominal frequency of the motor is 50 Hz.

3. Explain shortly the operating principle of the converter shown below. Draw the phasor diagram of the system and use it to calculate reference amplitude of v_{conv1} and its angle as a function of the line current, when the power taken from the power systems varies between 0 - 6 kW and reactive power is zero. Rms voltage of the power system is 230 V, inductance 20 mH and resistance 0,1 Ω. Explain without mathematics what changes if the converter supplies all the time 1 kVA reactive power to the power system.



4. The line frequency apparent power of a six-pulse thyristor rectifier $S = 20$ MVA and the line-to-line rms voltage is 110 kV. For compensation and filtering purposes there is a filter for the 5th harmonic with parameters: $X_0 = \omega_5 L = 480\ \Omega$ and quality factor $Q = X_0 / R_f = 50$. Short circuit power of the power system $S_k = 590$ MVA and system can be assumed to be reactive. Calculate the 5th harmonic voltage without and with the filter. What is the effect of the quality factor Q on the harmonic voltage? When calculating harmonics, the effect of commutation is neglected and dc current can be assumed ideal.

5. Principles of the use of snubber circuits in converters.

Fourier-sarja:

$$f(t) = F_0 + \sum_{n=1}^{\infty} [a_n \cos(n\omega t) + b_n \sin(n\omega t)] \tag{1}$$

$$a_n = \frac{1}{\pi} \int_0^{2\pi} f(t) \cos(n\omega t) \mathrm{d}\omega t\,, \quad n = 0, 1, 2, ..., \infty \tag{2}$$

$$b_n = \frac{1}{\pi} \int_0^{2\pi} f(t) \sin(n\omega t) \mathrm{d}\omega t\,, \quad n = 1, 2, ..., \infty \tag{3}$$

$$F_0 = \frac{1}{2} a_0 = \frac{1}{2} \cdot \frac{1}{\pi} \int_0^{2\pi} f(t) \cos(0) \mathrm{d}\omega t = \frac{1}{2\pi} \int_0^{2\pi} f(t) \mathrm{d}\omega t \tag{4}$$

Trigonometrisia muunnoksia:

$$\sin x \, \sin(x - y) = \frac{1}{2} [\cos y - \cos(2x - y)] \tag{5}$$

$$\sin x \, \cos y = \frac{1}{2} [\sin(x - y) + \sin(x + y)] \tag{6}$$

$$\sin x \, \sin y = \frac{1}{2} [\sin(x - y) - \cos(x + y)] \tag{7}$$

$$\cos x \, \cos y = \frac{1}{2} [\cos(x - y) + \cos(x + y)] \tag{8}$$

$$\sin^2 x + \cos^2 x = 1 \tag{9}$$

$$\tan x = \frac{\sin x}{\cos x} \tag{10}$$

$$\sin^2 x = \frac{1}{2} (1 - \cos 2x) \tag{11}$$

$$\cos^2 x = \frac{1}{2} (1 + \cos 2x) \tag{12}$$

$$\sin^3 x = \frac{1}{4} (3 \sin x - \sin 3x) \tag{13}$$

$$\cos^3 x = \frac{1}{4} (\cos 3x - 3 \cos x) \tag{14}$$

$$\sin 2x = 2 \sin x \cos x \tag{15}$$

$$\cos 2x = \cos^2 x - \sin^2 x = 2 \cos^2 x - 1 = 1 - 2 \sin^2 x \tag{16}$$

$$\sin(x \pm y) = \sin x \cos y \pm \cos x \sin y \tag{17}$$
$$\cos(x \pm y) = \cos x \cos y \mp \sin x \sin y \tag{18}$$

$$\sin x + \sin y = 2 \sin\left(\frac{x+y}{2}\right) \cos\left(\frac{x-y}{2}\right) \tag{19}$$
$$\sin x - \sin y = 2 \cos\left(\frac{x+y}{2}\right) \sin\left(\frac{x-y}{2}\right) \tag{20}$$
$$\cos x + \cos y = 2 \cos\left(\frac{x+y}{2}\right) \cos\left(\frac{x-y}{2}\right) \tag{21}$$
$$\cos x - \cos y = -2 \sin\left(\frac{x+y}{2}\right) \sin\left(\frac{x-y}{2}\right) \tag{22}$$

Eulerin lause:

$$e^{\mathrm{j}x} = \cos x + \mathrm{j} \sin x \tag{23}$$

$$\cos x = \frac{1}{2}\left(\mathrm{e}^{\mathrm{j}x} + \mathrm{e}^{-\mathrm{j}x}\right) \tag{24}$$
$$\sin x = \frac{1}{\mathrm{j}2}\left(\mathrm{e}^{\mathrm{j}x} - \mathrm{e}^{-\mathrm{j}x}\right) \tag{25}$$