Problems of Chapter 2

1. Single phase half-wave diode rectifier is connected to 220 V, 50 Hz supply to feed 5Ω pure resistor. Draw load voltage and current and diode voltage drop waveforms along with supply voltage. Then, calculate (a) The rectification efficiency. (b) Ripple factor of load voltage. (c) Peak Inverse Voltage (PIV) of the diode.

2. The load of the rectifier shown in problem 1 is become 5Ω pure resistor and 10 mH inductor. Draw the resistor, inductor voltage drops, and, load current along with supply voltage. Then, find an expression for the load current and calculate the conduction angle, $\beta$. Then, calculate the DC and rms value of load voltage.
- In the rectifier shown in the following figure assume \( V_S = 220V \), 50Hz, \( L = 10mH \) and \( E_d = 170V \). Calculate and plot the current an the diode voltage drop along with supply voltage, \( V_s \).

- Assume there is a freewheeling diode is connect ed in shunt with the load of the rectifier shown in problem 2. Calculate the load curr ent during two periods of supply voltage. Then, draw the inductor, resistor, load voltages and diode currents along with supply voltage.
The voltage \( v \) across a load and the current \( i \) into the positive polarity terminal are as follows:

\[
v(\omega t) = V_d + \sqrt{2} V_1 \cos(\omega t) + \sqrt{2} V_1 \sin(\omega t) + \sqrt{2} V_3 \cos(3\omega t)
\]

\[
i(\omega t) = I_d + \sqrt{2} I_1 \cos(\omega t) + \sqrt{2} I_3 \cos(3\omega t - \phi)
\]

Calculate the following:

(a) The average power supplied to the load.
(b) The \textit{rms} value of \( v(t) \) and \( i(t) \).
(c) The power factor at which the load is operating.

Center tap diode rectifier is connected to 220 V, 50 Hz supply via unity turns ratio center-tap transformer to feed 5\( \Omega \) resistor load. Draw load voltage and currents and diode currents waveforms along with supply voltage. Then, calculate (a) The rectification efficiency. (b) Ripple factor of load voltage. (c) Transformer Utilization Factor (TUF) (d) Peak Inverse Voltage (PIV) of the diode. (e) Crest factor of supply current.

Single phase diode bridge rectifier is connected to 220 V, 50 Hz supply to feed 5\( \Omega \) resistor. Draw the load voltage, diodes currents and calculate (a) The rectification efficiency. (b) Ripple factor of load voltage. (c) Peak Inverse Voltage (PIV) of the diode.
٨- If the load of rectifier shown in problem 7 is changed to be 5Ω resistor in series with 10mH inductor. Calculate and draw the load current during the first two periods of supply voltage waveform.

\[ V_L, L \]

٩- If the load of problem 7 is changed to be 45 A pure DC. Draw diode diodes currents and supply currents along with supply voltage. Then, calculate (a) The rectification efficiency. (b) Ripple factor of load voltage. (c) Peak Inverse Voltage (PIV) of the diode. (d) Input power factor.

١٠- Single phase diode bridge rectifier is connected to 220V, 50Hz supply. The supply has 4 mH source inductance. The load connected to the rectifier is 45 A pure DC current. Draw, output voltage, diode currents and supply current along with the supply voltage. Then, calculate the DC output voltage, THD of supply current and input power factor, and, input power factor and THD of the voltage at the point of common coupling.
Three-phase half-wave diode rectifier is connected to 380 V, 50 Hz supply via 380/460 V delta/way transformer to feed the load with 45 A DC current. Assuming ideal transformer and zero source inductance. Then, draw the output voltage, secondary and primary currents along with supply voltage. Then, calculate (a) Rectification efficiency. (b) Crest factor of secondary current. (c) Transformer Utilization Factor (TUF). (d) THD of primary current. (e) Input power factor.
12- Solve problem 11 if the supply has source inductance of 4 mH.

13- Three-phase full bridge diode rectifier is connected to 380V, 50Hz supply to feed 10Ω resistor. Draw the output voltage, diode currents and supply current of phase a. Then, calculate: (a) The rectification efficiency. (b) Ripple factor of load voltage. (c) Transformer Utilization Factor (TUF) (d) Peak Inverse Voltage (PIV) of the diode. (e) Crest factor of supply current.
Solve problem 13 if the load is 45A pure DC current. Then find THD of supply current and input power factor.

If the supply connected to the rectifier shown in problem 13 has a 5 mH source inductance and the load is 45 A DC. Find, average DC voltage, and THD of input current.
- Single phase diode bridge rectifier is connected to square waveform with amplitude of 200V, 50 Hz. The supply has 4 mH source inductance. The load connected to the rectifier is 45 A pure DC current. Draw, output voltage, diode currents and supply current along with the supply voltage. Then, calculate the DC output voltage, THD of supply current and input power factor.

- In the single-phase rectifier circuit of the following figure, \( L_s = 1 \) mH and \( V_d = 160V \). The input voltage \( v_s \) has the pulse waveform shown in the following figure. Plot \( i_s \) and \( i_d \) waveforms and find the average value of \( I_d \).
**Problems Of Chapter 3**

1. Single phase half-wave controlled rectifier is connected to 220 V, 50Hz supply to feed 10Ω resistor. If the firing angle $\alpha = 30^\circ$ draw output voltage and drop voltage across the thyristor along with the supply voltage. Then, calculate, (a) The rectification efficiency. (b) Ripple factor. (c) Peak Inverse Voltage (PIV) of the thyristor. (d) The crest factor $C_F$ of input current.

2. Single phase half-wave controlled rectifier is connected to 220 V, 50Hz supply to feed 5Ω resistor in series with 10mH inductor if the firing angle $\alpha = 30^\circ$.
   (a) Determine an expression for the current through the load in the first two periods of supply current, then find the DC and rms value of output voltage.
   (b) Draw the waveforms of load, resistor, inductor voltages and load current.

3. Solve problem 2 if there is a freewheeling diode is connected in shunt with the load.

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![Graphs of output voltage, thyristor reverse voltage, load, resistor, inductor voltages, and output current waveforms.](image)
single phase full-wave fully controlled rectifier is connected to 220V, 50 Hz supply to feed 5Ω resistor, if the firing angle $\alpha = 40^\circ$. Draw the load voltage and current, thyristor currents and supply current. Then, calculate (a) The rectification efficiency. (b) Peak Inverse Voltage (PIV) of the thyristor. (c) Crest factor of supply current.

In the problem 4, if there is a 5mH inductor is connected in series with the 5Ω resistor. Draw waveforms of output voltage and current, resistor and inductor voltages, thyristor currents, supply currents. Then, find an expression of load current, DC and rms values of output voltages.
- Solve problem 5 if the load is connected with freewheeling diode.

- Single phase full wave fully controlled rectifier is connected to 220V, 50 Hz supply to feed the load with 47 A pure dc current. The firing angle $\alpha = 40^\circ$. Draw the load voltage, thyristor, and load currents. Then, calculate (a) the rectification efficiency. (b) Ripple factor of output voltage. (c) Crest factor of supply current. (d) Use Fourier series to find an expression for supply current. (e) THD of supply current. (f) Input power factor.
A- Solve problem 7 if the supply has a 3 mH source inductance.

A- Single phase full-wave semi-controlled rectifier is connected to 220 V, 50Hz supply to feed 5Ω resistor in series with 5 mH inductor, the load is connected in shunt with freewheeling diode. Draw the load voltage and current, resistor voltage and inductor voltage diodes and thyristor currents. Then, calculate $V_{dc}$ and $V_{rms}$ of the load voltages. If the freewheeling diode is removed, explain what will happen?
The single-phase full wave controlled converter is supplying a DC load of 1 kW with pure DC current. A 1.5-kVA-isolation transformer with a source-side voltage rating of 120 V at 50 Hz is used. It has a total leakage reactance of 8% based on its ratings. The ac source voltage of nominally 120 V is in the range of -10% and +5%. Then, Calculate the minimum transformer turns ratio if the DC load voltage is to be regulated at a constant value of 100 V. What is the value of a when $V_S = 120\ V + 5\%$.

In the single-phase inverter of, $V_S = 120\ V$ at 50 Hz, $L_S = 1.2\ mH$, $L_d = 20\ mH$, $E_d = 88\ V$, and the delay angle $\alpha = 135^\circ$. Using PSIM, obtain $v_s$, $i_s$, $v_d$, and $i_d$ waveforms in steady state.

In the inverter of Problem 12, vary the delay angle $\alpha$ from a value of $165^\circ$ down to $120^\circ$ and plot $i_d$ versus $\alpha$. Obtain the delay angle $\alpha_c$, below which $i_d$ becomes continuous. How does the slope of the characteristic in this range depend on $L_S$?

In the three-phase fully controlled rectifier is connected to 460 V at 50 Hz and $m_{HL} = 0$. Calculate the commutation angle $\psi$ if the load draws pure DC current at $V_{dc} = 515V$ and $P_{dc} = 500\ kW$.

In Problem 13 compute the peak inverse voltage and the average and the rms values of the current through each thyristor in terms of $V_{LL}$ and $I_o$.

Consider the three-phase, half-controlled converter shown in the following figure. Calculate the value of the delay angle $\alpha$ for which $V_{dc} = 0.5V_{dm}$. Draw $v_d$ waveform and identify the devices that conduct during various intervals. Obtain the DPF, PF, and %THD in the input line current and compare results with a full-bridge converter operating at $V_{dc} = 0.5V_{dm}$. Assume $L_S$. 
Repeat Problem 15 by assuming that diode $D_f$ is not present in the converter.

The three-phase converter of Fig. 3.48 is supplying a DC load of 12 kW. A Y- Y connected isolation transformer has a per-phase rating of 5 kVA and an AC source-side voltage rating of 120 V at 50 Hz. It has a total per-phase leakage reactance of 8% based on its ratings. The AC source voltage of nominally 208 V (line to line) is in the range of -10% and +5%. Assume the load current is pure DC, calculate the minimum transformer turns ratio if the DC load voltage is to be regulated at a constant value of 300 V. What is the value of $\alpha$ when $V_{LL} = 208$ V +5%.

In the three-phase inverter of Fig. 3.63, $V_{LL} = 460$ V at 60 Hz, $E = 550$ V, and $L_S = 0.5$ mH. Assume the DC-side current is pure DC, Calculate $\alpha$ and $\gamma$ if the power flow is 55 kW.

Problems Of Chapter 4

1- In a single-phase full-bridge PWM inverter, the input dc voltage varies in a range of
295-325 V. Because of the low distortion required in the output $v_o$, $m_a \leq 1.0$

(a) What is the highest $V_{o1}$, that can be obtained and stamped on its nameplate as its voltage rating?

(b) Its nameplate volt-ampere rating is specified as 2000 VA, that is, $V_{o1,\text{max}}I_{o1,\text{max}} = 2000VA$, where $i_o$ is assumed to be sinusoidal. Calculate the combined switch utilization ratio when the inverter is supplying its rated volt-amperes.
2- Consider the problem of ripple in the output current of a single-phase full-bridge inverter. Assume $V_{ol} = 220\,\text{V}$ at a frequency of $47\,\text{Hz}$ and the type of load is as shown in Fig.18a with $L = 100\,\text{mH}$. If the inverter is operating in a square-wave mode, calculate the peak value of the ripple current.
3- Repeat Problem 2 with the inverter operating in a sinusoidal PWM mode, with $m_f = 21$ and $m_d = 0.8$. Assume a bipolar voltage switching.

4- Repeat Problem 2 but assume that the output voltage is controlled by voltage cancellation and $V_d$ has the same value as required in the PWM inverter of Problem 3.
5- Calculate and compare the peak values of the ripple currents in Problems 2 through 4.
THREE-PHASE

6- Consider the problem of ripple in the output current of a three-phase square-wave inverter. Assume \( V_{LL} = 220 \) V at a frequency of 52 Hz and the type of load is as shown in Fig.25a with \( L = 100 \) mH. Calculate the peak ripple current defined in Fig.26a.
7- Repeat Problem 6 if the inverter of Problem 6 is operating in a synchronous PWM mode with $m_f = 39$ and $m_a = 0.8$. Calculate the peak ripple current defined in Fig. 26b.
8- In the three-phase, square-wave inverter of Fig.24a, consider the load to be balanced and purely resistive with a load-neutral n. Draw the steady-state $v_{An}$, $i_{A+}$, and $i_d$ waveforms, where $i_{A+}$ is the current through $DA+$. 
9- Repeat Problem 8 by assuming that the toad is purely inductive, where the load resistance, though finite, can be neglected.
1- Consider a permanent-magnet dc servo motor with the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{\text{rated}}$</td>
<td>10 N·m</td>
</tr>
<tr>
<td>$n_{\text{rated}}$</td>
<td>3700 rpm</td>
</tr>
<tr>
<td>$k_f$</td>
<td>53V/1000 rpm</td>
</tr>
<tr>
<td>$R_p$</td>
<td>0.37 Ω</td>
</tr>
<tr>
<td>$\tau_e$</td>
<td>4.05 ms</td>
</tr>
<tr>
<td>$\tau_m$</td>
<td>11.7 ms</td>
</tr>
<tr>
<td>$k_T$</td>
<td>0.5 N·m/A</td>
</tr>
</tbody>
</table>

Calculate the terminal voltage $V_t$ in steady state if the motor is required to deliver a torque of 5 N·m at a speed of 1500 rpm.
13-2 \( G_1(s) = \frac{[\omega_m(s)/V_i(s)]}{s^2/\omega_n^2} \) is the transfer function of an unloaded and uncontrolled dc motor. Express \( G_1(s) \) given by Eq. 13-27 in the following form:

\[
G_1(s) = \frac{1/k_e}{1 + 2sD/\omega_n + s^2/\omega_n^2}
\]

Calculate \( D \) and \( \omega_n \) for the servomotor parameters given in Problem 13-1. Plot the magnitude and the phase of \( G_1(s) \) by means of a Bode plot.
13-3 Using the servomotor parameters given in Problem 13-1, calculate and plot the change in $\omega_m$ as a function of time for a step increase of 10 V in the terminal voltage of that uncontrolled, unloaded servomotor.
The servomotor of Problem 13-1 is driven by a full-bridge dc–dc converter operating from a 200-V dc bus. Calculate the peak-to-peak ripple in the motor current if a PWM bipolar voltage-switching scheme is used. The motor is delivering a torque of 5 N·m at a speed of 1500 rpm. The switching frequency is 20 kHz.
13-5 Repeat Problem 13-4 if a unipolar voltage-switching scheme is used.
13-6 In the servo drive of Problem 13-1, a PI regulator is used in the speed loop to obtain a transfer function of the following form in Fig. P13-6:

\[ F_{\omega}(s) = \frac{\omega(s)}{\omega^*(s)} = \frac{1}{1 + sD\omega_n + s^2\omega_n^2} \]

where \( D = 0.5 \) and \( \omega_n = 300 \text{ rad/s} \).

(a) Draw the Bode plot of the closed-loop transfer function \( F_{\theta}(s) = \frac{\theta(s)}{\theta^*(s)} \) if a gain \( k_p = 60 \) is used for the proportional position regulator in Fig. P13-6.

(b) What is the bandwidth of the above closed-loop system?

---

**Figure P13-6**
13-7 Consider the servomotor of Problem 13-1 in a speed-control loop. If an internal current loop is not used, the block diagram is as shown in Fig. P13-7a, where only a proportional control is used. If an internal current loop is used, the block diagram without the current limits is as shown in Fig. P13-7b, where \( \omega_n \) is 10 times that in part a.

![Block diagrams](image)

**Figure P13-7**

Design the controllers \( (K_v, K_i, K_p) \) to yield a control loop with slightly underdamped response \( (D = 0.7) \). Compare the two control schemes in terms of bandwidth and transient performance, assuming that the current limit is not reached in either of them.
Power Electronics (2)
Assignment