

MASSACHUSETTS INSTITUTE OF TECHNOLOGY



DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

6.622 Power Electronics Assessment #1

Due: Thursday March 2, 2023 at 11:00 pm (Cambridge time)

YOUR NAME

Solutions

YOUR KERBEROS ID

General Instructions:

1. You must complete this assessment on your own with no consultation or discussion with any other person, excepting 6.622 staff, of whom you may ask clarifying questions. Do not discuss your solutions with anyone until the solutions have been released.
2. You may use a calculator and review the course lectures, notes and textbook (Principles of Power Electronics) when completing this assessment. Please do not use other computational tools or reference materials.
3. Please do all of your work in the space provided. In particular, try to do your work for each question within the boundaries of the question, or on the additional pages at the end of the uploaded document, clearly marking those pages to indicate what problem they relate to. Place the answer to each question within the appropriate answer box.
4. The assessment must be completed and uploaded by the indicated date/time to receive credit.
5. Please make sure to show all of your work. This is important both for you to receive credit for a correct answer and to receive partial credit when an answer is wrong or incomplete.

Problem 1

Some types of rectifiers can only draw current from the grid over a limited portion of the line cycle. Consider the switched-mode rectifier system and associated waveforms shown in Fig. 1. For a line voltage $v_{ac}(t) = V_S \sin(\omega t)$, the rectifier line current $i_{ac}(t)$ is a sinusoid having peak amplitude GV_S for part of the line cycle, and zero for the remainder of the line cycle as defined by an angle β :

$$i_{ac} = \begin{cases} GV_S \sin(\omega t) & \beta < \omega t < \pi - \beta, \pi + \beta < \omega t < 2\pi - \beta \\ 0 & \text{otherwise} \end{cases}$$

- What average power is drawn from the ac line as a function of V_S , G , and β ?
- What is the power factor of the rectifier at its ac port (v_{ac} , i_{ac}) as a function of angle β ($0 \leq \beta < \pi/2$)?
- What is the distortion factor k_D and displacement factor k_θ for this rectifier?

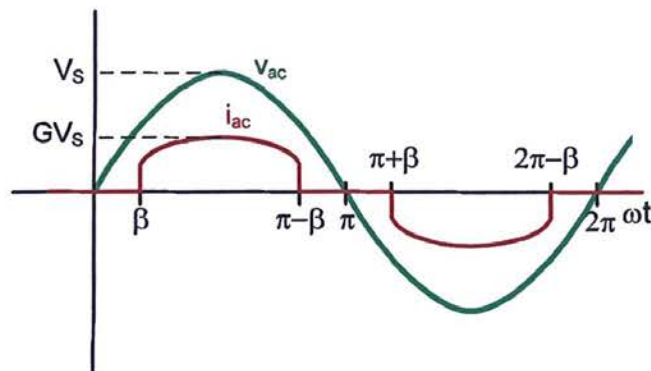
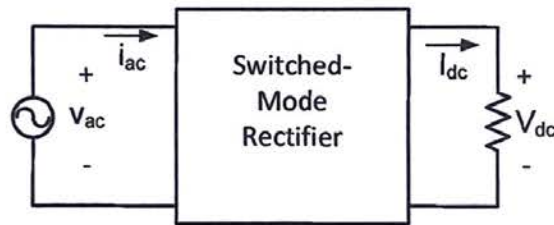


Figure 1 A “switched-mode” rectifier that only draws current over a limited portion of the line cycle and its associated ac waveforms.

$$\begin{aligned} (a) P_{av} &= \frac{1}{\pi} \int_{\beta}^{\pi-\beta} G V_s^2 \sin^2(\omega t) d(\omega t) \\ &= \frac{1}{\pi} \int_{\beta}^{\pi-\beta} G V_s^2 \left[\frac{1}{2} - \frac{1}{2} \cos(2\omega t) \right] d(\omega t) \\ &= \frac{G V_s^2}{2\pi} [\pi - 2\beta] - \frac{G V_s^2}{2\pi} \int_{\beta}^{\pi-\beta} \cos(2\omega t) d(\omega t) \\ &= \frac{G V_s^2}{2\pi} [\pi - 2\beta] - \frac{G V_s^2}{4\pi} \left[\sin(2\omega t) \Big|_{\beta}^{\pi-\beta} \right] \\ &= \frac{G V_s^2}{2\pi} [\pi - 2\beta] - \frac{G V_s^2}{4\pi} [\sin(2\pi - 2\beta) - \sin(2\beta)] \end{aligned}$$

$$P_{av} = \frac{G V_s^2}{2\pi} [\pi - 2\beta + \sin(2\beta)]$$

$$(b) V_{rms} = \frac{V_s}{\sqrt{2}}$$

$$\begin{aligned} I_{rms} &= \sqrt{\frac{1}{\pi} \int_{\beta}^{\pi-\beta} (G V_s)^2 \sin^2(\omega t) d(\omega t)} \\ &= \frac{G V_s}{\sqrt{2}} \cdot \sqrt{\frac{\pi - 2\beta + \sin(2\beta)}{\pi}} \end{aligned}$$

$$k_p = \frac{P_{av}}{V_{rms} I_{rms}}$$
$$= \frac{G V_s^2 [\pi - 2\beta + \sin(2\beta)]}{2\pi} \cdot \frac{\sqrt{2} \sqrt{\pi}}{G V_s \sqrt{\pi - 2\beta + \sin(2\beta)}} \cdot \frac{\sqrt{2}}{V_s}$$

$$k_p = \frac{\sqrt{\pi - 2\beta + \sin(2\beta)}}{\sqrt{\pi}}$$

(c) The fundamental of i_{ac} is in phase with v_{ac} . $k_p = k_d k_\theta$

$$\therefore k_\theta = 1$$

$$\therefore k_d = k_p = \frac{\sqrt{\pi - 2\beta + \sin(2\beta)}}{\sqrt{\pi}}$$

$$\begin{aligned} \text{Average power } P_{av} &= \frac{GV_s^2}{2} \cdot \frac{\pi - 2\beta + \sin(2\beta)}{\pi} \\ \text{Power Factor } k_p &= \frac{\sqrt{\pi - 2\beta + \sin(2\beta)}}{\sqrt{\pi}} \\ \text{Distortion Factor } k_d &= \frac{\sqrt{\pi - 2\beta + \sin(2\beta)}}{\sqrt{\pi}} \\ \text{Displacement Factor } k_\theta &= | \end{aligned}$$

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