SULIT

UNIVERSITI MALAYSIA PERLIS

Peperiksaan Akhir Semester Pertama
Sidang Akademik 2025/2026

Februari 2026

EMJ32304 – Power Electronic 1
[Elektronik Kuasa 1]

Masa : 3 jam

Please make sure that this question paper has **EIGHT (8)** printed pages including this front page before you start the examination.
*[Sila pastikan kertas soalan ini mengandungi **LAPAN (8)** muka surat yang bercetak termasuk muka hadapan sebelum anda memulakan peperiksaan ini.]*

This question paper has **FOUR (4)** questions. Answer **ALL QUESTIONS**. Each question contributes 15 marks.
*[Kertas soalan ini mengandungi **EMPAT (4)** soalan. Jawab **SEMUA SOALAN**. Markah bagi tiap-tiap soalan adalah 15 markah.]*

Note: Some formulas are given in the Appendix.
[Nota: Beberapa formula diberikan dalam lampiran.]

Dicetak oleh Unit Peperiksaan & Pengijazahan, Bahagian Pengurusan Akademik, Pusat Pengurusan Akademik UniMAP

Question 1
[Soalan 1]

You are a junior electrical engineer working at Jati Combustion System Sdn Bhd, a company that designs compact heating solutions for industries. One of the heater modules uses a single-phase controlled half-wave rectifier to regulate the heating power. The system is supplied from a 230 V_{rms}, 50 Hz AC source, and the rectifier uses a thyristor for phase-angle control, as shown in **Figure 1**. The heater usually is resistive. However, some customers require an RL-type load due to additional inductive wiring and protection coils. **Analyse** the following problem:
*[Anda ialah seorang jurutera elektrik junior yang bekerja di Jati Combustion System Sdn. Bhd., sebuah syarikat yang mereka bentuk sistem pemanasan kompak untuk kegunaan industri. Salah satu modul pemanas menggunakan penerus separuh gelombang terkawal fasa tunggal untuk mengawal kuasa pemanasan. Sistem ini dibekalkan daripada sumber AT 230 V_{rms}, 50 Hz, dan penerus tersebut menggunakan tyristor untuk kawalan sudut-fasa, seperti ditunjukkan dalam **Rajah 1**. Pemanas tersebut pada asasnya bersifat resistif. Bagaimanapun, sesetengah pelanggan memerlukan beban jenis RL disebabkan oleh pendawaian tambahan beraruhan dan gegelung perlindungan. **Analisakan** permasalahan berikut:]*

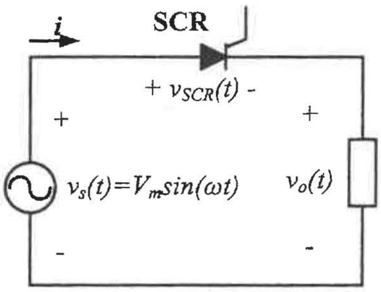

Figure 1
[Rajah 1]

(a) **Customer A** requests that the heater receive an average output voltage of 70 V for low-power operation, and the resistance, R, is 20 Ω. Determine the delay angle, α, required to control the average output voltage, the power absorbed by the header, and the power factor.
*[**Pelanggan A** meminta agar pemanas menerima voltan keluaran purata sebanyak 70 V untuk operasi kuasa rendah, dan nilai rintangan R ialah 20 Ω. Tentukan sudut lengah, α, yang diperlukan untuk mengawal voltan keluaran purata tersebut, kuasa yang diserap oleh pemanas, dan faktor kuasa.]*

(6 Marks/ *Markah*)

(b) **Customer B** requests the same heater but with an additional inductive coil installed as a load with R = 20 Ω and L = 80 mH. With the same delay angle, α as obtained in **Question 1(a)**, determine the time-varying expression for the current *i(t)*, the average current, power absorbed by the load, and the power factor.
*[**Pelanggan B** meminta pemanas yang sama tetapi dengan tambahan gegelung beraruhan sebagai beban dengan R = 20 Ω dan L = 80 mH. Dengan menggunakan sudut lengah, α yang sama seperti diperoleh dalam **Soalan 1(a)**, tentukan ungkapan masa berubah bagi arus i(t), arus purata, kuasa yang diserap oleh beban, dan faktor kuasa.]*

(9 Marks/ *Markah*)

Question 2
[Soalan 2]

(a) You are assigned to perform an **analysis** of output parameter of a full-bridge single-phase inverter circuit using a unipolar pulse-width-modulation (PWM) switching scheme. The inverter output voltage, V_o and load voltage, V_{load} waveforms are shown in **Figure 2**. Given the fundamental frequency, $f = 50$ Hz and series load combination of $R = 20\ \Omega$ and $L = 35$ mH, modulation index, $m_a = 0.9$ and switching frequency, $f_{sw} = 550$ Hz, determine the output power (W) and total harmonic distortion of output current (%THD_i).

*[Anda ditugaskan untuk membuat satu **analisa** parameter keluaran bagi sebuah litar penukar satu-fasa titian-penuh yang menggunakan skim pensuisan modulasi-lebar-pulsa (PWM) unipolar. Gelombang-gelombang voltan keluaran penukar, V_o dan voltan beban, V_{load} seperti yang ditunjukkan dalam **Rajah 2**. Diberi frekuensi asas, $f = 50$ Hz dan kombinasi beban sesiri $R = 20\ \Omega$ dan $L = 35$ mH, indeks modulasi, $m_a = 0.9$ dan frekuensi pensusisan, $f_{sw} = 550$ Hz, tentukan kuasa keluaran (W) dan jumlah herotan harmonik arus keluaran (%THD_i).]*

(8 Marks/ *Markah*)

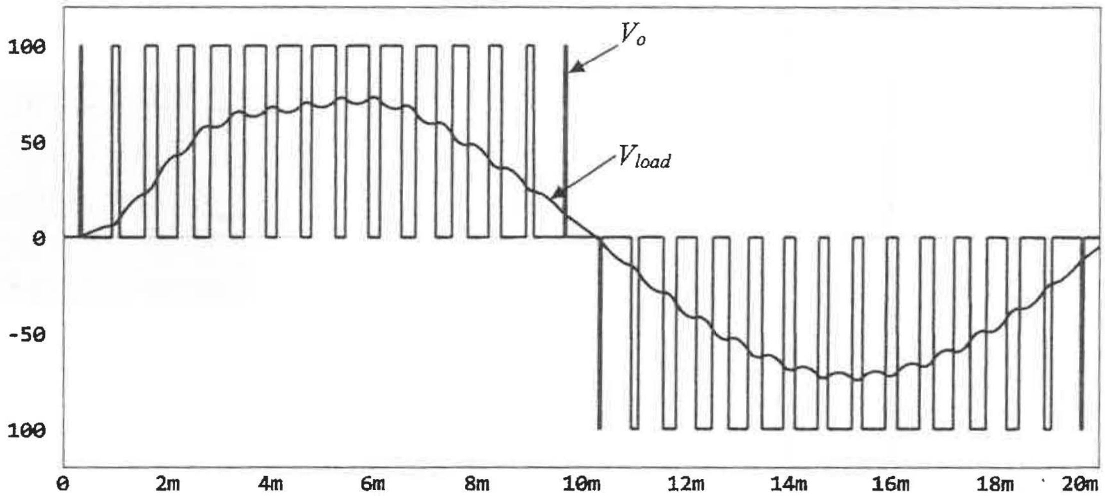

Figure 2
[Rajah 2]

Table 2: Normalised Fourier Coefficients V_n/V_{dc} for unipolar PWM
[Jadual 2: Pekali V_n/V_{dc} Fourier Ternormal bagi unipolar PWM]

	m_a=1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
$n=1$	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10
$n=2m_f\pm1$	0.18	0.25	0.31	0.35	0.37	0.36	0.33	0.27	0.19	0.10
$n=2m_f\pm3$	0.21	0.18	0.14	0.10	0.07	0.04	0.02	0.01	0.00	0.00

(b) The PWM switching scheme of the inverter circuit in **Question 2(a)** is then replaced by square-wave switching scheme. Repeat the task as specified in **Question 2(a)** You may consider harmonic, n^{th} up to 9 in your calculation. State your findings.

*[Skim pensuisan PWM bagi litar penukar di **Soalan 2(a)** kemudiannya ditukar kepada skim pensuisan segiempat-gelombang. Ulang tugasan yang dispeksifikasi dalam **Soalan 2(a)**. Anda boleh mengambilkira turutan harmonik, n^{th} sehingga 9 dalam pengiraan anda. Nyatakan penemuan anda.]*

(7 Marks/ *Markah*)

Question 3
[Soalan 3]

(a) A remote solar-powered communication repeater station requires a stable 60 V DC bus to power RF amplifiers and telemetry equipment. The solar panel provides 24 V under nominal sunlight conditions. To ensure reliable operation even under fluctuating irradiance, a robust boost DC-DC converter must be designed to maintain the required bus voltage. You are assigned to **design** a boost converter for this system. The station requires 150 W output, and the converter must operate in continuous conduction mode (CCM) at a switching frequency of 75 kHz. The specified constraints should be applied with a maximum inductor current ripple of 40% of the average inductor current, and the maximum output voltage ripple of 1% of the output voltage

[Sebuah stesen pengulang komunikasi jauh yang dikuasakan oleh tenaga suria memerlukan bas AT 60 V yang stabil untuk membekalkan kuasa kepada penguat RF dan peralatan telemetri. Panel solar membekalkan 24 V di bawah keadaan cahaya matahari nominal. Untuk memastikan operasi yang boleh dipercayai walaupun ketika tahap penyinaran berubah-ubah, sebuah penukar AT-AT jenis boost yang teguh perlu direkabentuk bagi mengekalkan voltan bas yang diperlukan. Anda ditugaskan untuk ***merekabentuk*** *penukar boost bagi sistem ini. Stesen tersebut memerlukan keluaran 150 W, dan penukar mesti beroperasi dalam mod pengaliran berterusan (CCM) pada frekuensi suis 75 kHz. Kekangan yang ditetapkan perlu diaplikasikan dengan arus puncak-peraruh maksimum ialah 40% daripada arus purata peraruh dan gelombang voltan keluaran maksimum ialah 1% daripada voltan keluaran.]*

(i) Determine the duty cycle of the system.
[Tentukan kitaran tugas bagi sistem tersebut.]

(2 Marks/ *Markah*)

(ii) Select the inductor value that guarantees the converter to operate under CCM conditions.
[Pilih nilai pengaruh yang menjamin penukar beroperasi dalam keadaan mod pengaliran berterusan.]

(2 Marks/ *Markah*)

(iii) Determine the output capacitor value to satisfy the ripple limit.
[Tentukan nilai penguat keluaran untuk memenuhi had gelombang yang ditetapkan.]

(2 Marks/ *Markah*)

(iv) Sketch the steady-state waveforms of pulse, inductor current, and output voltage. Please clearly indicate slopes, peak value, and conduction intervals.
[Lakarkan bentuk gelombang keadaan mantap bagi denyut, arus peraruh, dan voltan keluaran. Sila nyatakan dengan jelas kecerunan, nilai puncak, dan selang pengaliran.]

(3 Marks/ *Markah*)

..../6-

(b) An industrial sensor node must operate from a 12 V battery but requires a stable 48 V rail for powering an isolated analog measurement front-end. To maximize uptime, the converter must maintain high efficiency and stable continuous conduction mode (CCM) operation even as the battery voltage fluctuates. **Design** a buck-boost converter to deliver 48 V at 2.5 A, operating at a switching frequency of 100 kHz, with inductor current ripple $\leq$ 20% of average inductor current and output voltage ripple $\leq$ 0.5% of output voltage. Select a suitable inductor value and indicate the maximum and minimum inductor current values. Calculate the minimum required output capacitor value.

[Sebuah nod sensor industri mesti beroperasi dari bateri 12 V tetapi memerlukan rail 48 V yang stabil untuk membekalkan kuasa kepada bahagian hadapan pengukuran analog yang diasingkan. Untuk memaksimumkan masa operasi, penukar mesti mengekalkan kecekapan tinggi dan operasi mod pengaliran berterusan (CCM) yang stabil walaupun voltan bateri berubah-ubah. ***Rekabentukkan*** *satu penukar buck-boost untuk membekalkan 48 V pada 2.5 A, beroperasi pada frekuensi suis 100 kHz, dengan gelombang arus peraruh $\leq$ 20% daripada arus purata peraruh dan gelombang voltan keluaran $\leq$ 0.5% daripada voltan keluaran. Pilih nilai peraruh yang sesuai dan nyatakan nilai arus peraruh maksima dan minima. Kirakan nilai penguat keluaran minima yang diperlukan.*

(6 Marks/ *Markah*)

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Question 4
[Soalan 4]

(a) The three-phase voltage source inverter shown in **Figure 4(a)** functions as the interfacing unit between photovoltaic generator and local three-phase load in a small-scaled power plant. The inverter operates under 120° conduction scheme. Given the fundamental frequency, f is 50 Hz, DC-link voltage, V_{DC} is 300 V and three-phase balanced loads, $R_a = R_b = R_c$ is 35 Ω. **Determine** the expression of the instantaneous phase voltage, v_{an} in Fourier series considering harmonic components up to the 11th order.

*[Penukar sumber voltan tiga-fasa ditunjukkan dalam **Rajah 4(a)** berfungsi sebagai unit pengantara antara generator fotovolta dan beban local tiga-fasa didalam sebuah jana kuasa berskala kecil. Penukar beroperasi dibawah skim konduksi 120°. Diberi frekuensi asas, f is 50 Hz, voltan-AT, V_{AT} adalah 300 V dan beban tiga-fasa seimbang, $R_a = R_b = R_c$ adalah 35 Ω. **Tentukan** ungkapan voltan-fasa seketika, v_{an} dalam siri Fourier dengan mengambilkira komponen harmonik sehingga tertib ke-11.]*

(3 Marks/ *Markah*)

(b) The inverter depicted in **Question 4(a)** is subjected to unbalanced load conditions arising from malfunctioned circuit breaker, resulting in the distorted phase voltage waveforms, v_{an}, v_{bn} and v_{cn} as illustrated in **Figure 4(b)**. Given one phase of the three-phase loads, R_c has a resistance of 60 Ω, determine the inverter line-to-line voltages (v_{ab}, v_{bc} and v_{ca}). Your **analysis** shall include a comprehensive assessment of the equivalent switching circuits for each conduction interval over one complete cycle (from 0 to 2π).

*[Penukar yang diterangkan dalam **Soalan 4(a)** menghadapi keadaan beban tidak seimbang akibat kerosakan pemutus litar yang menyebabkan herotan pada gelombang-gelombang voltan fasa v_{an}, v_{bn} and v_{cn} seperti yang ditunjukkan dalam **Rajah 4(b)**. Diberi salah satu beban tiga-fasa, R_c adalah 60 Ω, tentukan penukar voltan talian-ke-talian (v_{ab}, v_{bc} and v_{ca}). **Analisis** anda hendaklah merangkumi penilaian terperinci terhadap litar setara pensuisan dalam setiap selang pengaliran sepanjang satu kitar lengkap (dari 0 hingga 2π).]*

(12 Marks/ *Markah*)

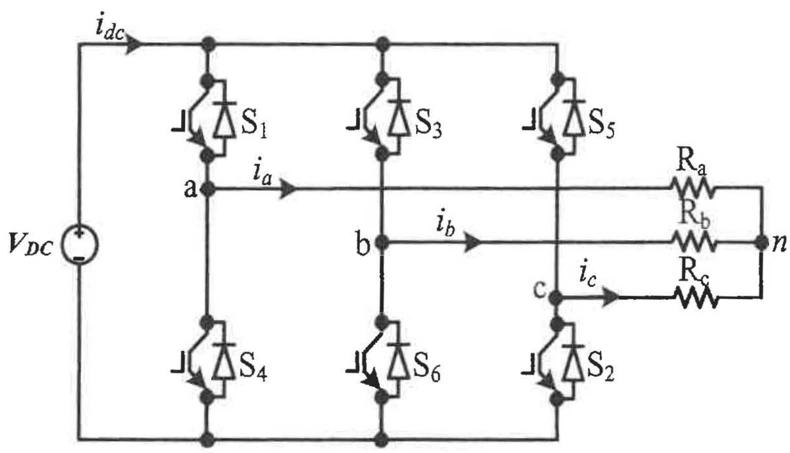

Figure 4(a)
[Rajah 4(a)]

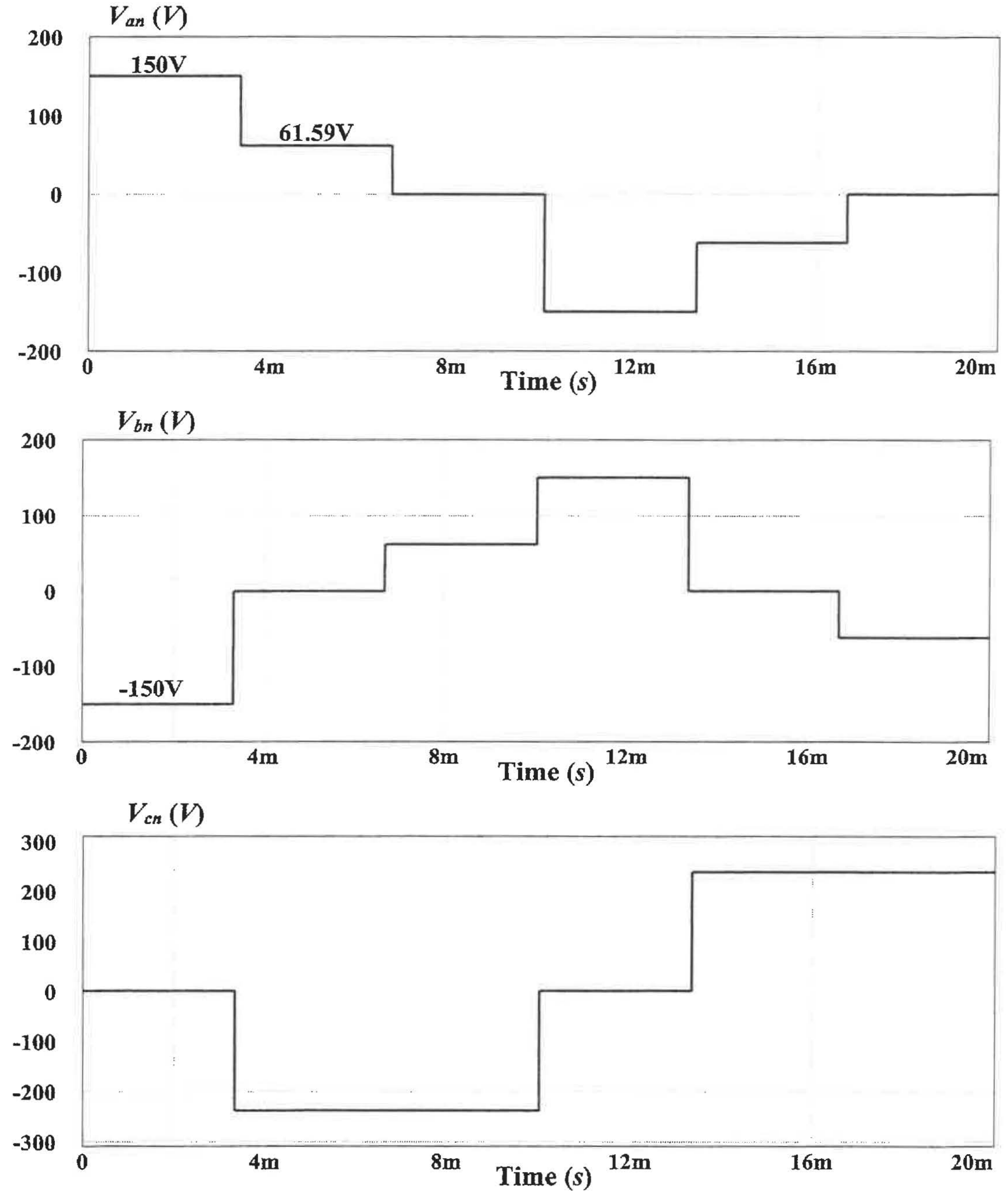

Figure 4(b)
[Rajah 4(b)]

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APPENDIX
[LAMPIRAN]

Please make sure that this appendix book has **TEN (10)** printed pages and this front page before you start the examination.
*[Sila pastikan buku lampuran ini mengandungi **SEPULUH (10)** muka surat yang bercetak dan muka hadapan sebelum anda memulakan peperiksaan ini.]*

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Appendix 1
[Lampiran 1]

MATHEMATICAL FORMULAE

Power Computations

Fourier Series

$$f(t) = a_0 + \sum_{n=1}^{\infty}\left[a_n \cos(n\omega_0 t) + b_n \sin(n\omega_0 t)\right] = a_0 + \sum_{n=1}^{\infty} C_n \cos(n\omega_0 t + \theta_n)$$

RMS of function f(t)

$$F_{rms} = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} f^2(t)dt}$$

$$F_{rms} = \sqrt{\sum_{n=0}^{\infty} F_{n,rms}^2} = \sqrt{a_0^2 + \sum_{n=1}^{\infty}\left(\frac{C_n}{\sqrt{2}}\right)^2}$$

Instantaneous Power

$p(t) = v(t)i(t)$

Average/real power:

$$P = \frac{1}{T}\int_{t_0}^{t_0+T} p(t)dt = \frac{1}{T}\int_{t_0}^{t_0+T} v(t)i(t)dt$$

If $v(t)=V_{dc}$ — $P = V_{dc}I_{avg}$

If $i(t)=I_{dc}$ — $P = V_{avg}I_{dc}$

If $v(t)$ and $i(t)$ are sinusoidal waveforms — $P = V_{rms}I_{rms}\cos(\theta - \phi)$, $pf = \cos(\theta - \phi)$

If $v(t)$ and $i(t)$ are nonsinusoidal periodic waveforms

$$P = V_0 I_0 + \sum_{n=1}^{\infty}\left(\frac{V_{n,max}I_{n,max}}{2}\right)\cos(\theta_n - \phi_n)$$

Power in a resistor

$$P = \frac{V^2_{rms}}{R} = I^2_{rms}R$$

Apparent power

$$S = V_{rms}I_{rms}$$

Uncontrolled Rectifier

Voltage/Current/Power:

Average output voltage: $V_{o,avg} = \frac{V_m}{2\pi}\int_0^{\pi} \sin(\omega t)d(\omega t) = 0.318V_m \Big|_{halfwave}$

RMS output voltage: $V_{o,rms} = V_m\sqrt{\frac{1}{2\pi}\int_0^{\pi} \sin^2(\omega t)d(\omega t)} = \frac{V_m}{2}\Big|_{halfwave}$

Output current: $I_o = \frac{V_o}{R} = \frac{V_m}{\pi R}\Big|_{halfwave}$

RMS output curmet: $I_{o,rms} = \frac{V_{o,rms}}{R} = \frac{V_m}{2R}\Big|_{halfwave}$

Power: $P = \frac{1}{2\pi}\int_0^{\pi} \frac{V_m^2}{R}\sin^2(\omega t)d(\omega t) = I_{o,rms}^2 R = \frac{V_{o,rms}^2}{R}\Big|_{halfwave}$

power factor: $pf = \frac{P}{V_{s,rms}I_{o,rms}}$

Average output voltage: $V_{o,avg} = \frac{V_m}{\pi}\int_0^{\pi} \sin(\omega t)d(\omega t) = \frac{2V_m}{\pi} = 0.637V_m \Big|_{fullwave}$

RMS output voltage: $V_{o,rms} = V_m\sqrt{\frac{1}{\pi}\int_0^{\pi} \sin^2(\omega t)d(\omega t)} = \frac{V_m}{\sqrt{2}}\Big|_{fullwave}$

Average output current: $I_{o,avg} = \frac{V_{o,avg}}{R} = \frac{2V_m}{\pi R}\Big|_{fullwave}$

RMS output current: $I_{o,rms} = \frac{V_m}{\sqrt{2}R} = \frac{I_m}{\sqrt{2}}\Big|_{fullwave}$

Power: $P = \frac{1}{\pi}\int_0^{\pi} \frac{V_m^2}{R}\sin^2(\omega t)d(\omega t) = I_{o,rms}^2 R = \frac{V_{o,rms}^2}{R}\Big|_{fullwave}$

Controlled Rectifier

Resistive Loads:

Average output voltage: $V_{o,avg} = \frac{1}{2\pi}\int_{\alpha}^{\pi} V_m \sin(\omega t) d(\omega t) = \frac{V_m}{2\pi}(1+\cos\alpha)\Big|_{halfwave}$

RMS output current: $V_{o,rms} = \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\pi}\left[V_m \sin(\omega t)\right]^2 d(\omega t)} = \frac{V_m}{2}\sqrt{1-\frac{\alpha}{\pi}+\frac{\sin 2\alpha}{2\pi}}\Big|_{halfwave}$

Output average current: $I_{o,avg} = \frac{V_{o,avg}}{R} = \frac{V_m}{2\pi R}(1+\cos\alpha)\Big|_{halfwave}$

Power: $P = \frac{V_{o,rms}^2}{R}$

Average output voltage: $V_{o,avg} = \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin(\omega t) d(\omega t) = \frac{V_m}{\pi}(1+\cos\alpha)\Big|_{fullwave}$

Average output current: $I_{o,avg} = \frac{V_{o,avg}}{R} = \frac{V_m}{R\pi}(1+\cos\alpha)\Big|_{fullwave}$

RMS output current: $I_{o,rms} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi}\left[V_m \sin(\omega t)\right]^2 d(\omega t)} = \frac{V_m}{R}\sqrt{\frac{1}{2}-\frac{\alpha}{2\pi}+\frac{\sin(2\alpha)}{4\pi}}\Big|_{fullwave}$

Power: $P = I_{o,rms}^2 R$

Buck Converter

Continuous Conduction Mode (CCM)	
Average output voltage	$V_o = V_s D$
Average inductor current	$I_L = I_o = \frac{V_o}{R}$
Maximum inductor current	$I_{max} = I_L + \frac{\Delta i_L}{2} = \frac{V_o}{R} + \frac{1}{2}\left[\frac{V_o}{L}(1-D)T\right] = V_o\left[\frac{1}{R} + \frac{(1-D)}{2Lf}\right]$
Minimum inductor current	$I_{min} = I_L - \frac{\Delta i_L}{2} = \frac{V_o}{R} - \frac{1}{2}\left[\frac{V_o}{L}(1-D)T\right] = V_o\left[\frac{1}{R} - \frac{(1-D)}{2Lf}\right]$
Minimum inductance for CCM	$L_{min} = \frac{(1-D)R}{2f}$
Peak-to-peak output voltage ripple	$\Delta V_o = \frac{V_o(1-D)}{8LCf^2}$
Peak-to-peak output voltage ripple due to ESR	$\Delta V_{o,ESR} = \Delta i_C r_C = \Delta i_L r_C$
Peak-to-peak inductor current ripple	$\Delta i_L = \left(\frac{V_o}{L}\right)(1-D)T$

Boost Converter

Continuous Conduction Mode (CCM)	
Average output voltage	$V_o = \frac{V_s}{1-D}$
Average inductor current	$I_L = \frac{V_s}{(1-D)^2 R} = \frac{V^2_o}{V_s R} = \frac{V_o I_o}{V_s}$
Maximum inductor current	$I_{max} = I_L + \frac{\Delta i_L}{2} = \frac{V_s}{(1-D)^2 R} + \frac{V_s DT}{2L}$
Minimum inductor current	$I_{min} = I_L - \frac{\Delta i_L}{2} = \frac{V_s}{(1-D)^2 R} - \frac{V_s DT}{2L}$
Minimum inductance for CCM	$L_{min} = \frac{D(1-D)^2 R}{2f}$
Peak-to-peak output voltage ripple	$\Delta V_o = \frac{DV_o}{RCf}$
Peak-to-peak output voltage ripple due to ESR	$\Delta V_{o,ESR} = \Delta i_C r_C = I_{L,max} r_C$
Peak-to-peak inductor current ripple	$\Delta i_L = \frac{V_s DT}{L}$

Buck-Boost Converter

Continuous Conduction Mode (CCM)	
Average output voltage	$V_o = -V_s\left[\frac{D}{1-D}\right]$
Average inductor current	$I_L = \frac{V^2_o}{V_s RD} = \frac{P_o}{V_s D} = \frac{V_s D}{R(1-D)^2}$
Maximum inductor current	$I_{max} = I_L + \frac{\Delta i_L}{2} = \frac{V_s D}{R(1-D)^2} + \frac{V_s DT}{2L}$
Minimum inductor current	$I_{min} = I_L - \frac{\Delta i_L}{2} = \frac{V_s D}{R(1-D)^2} - \frac{V_s DT}{2L}$
Minimum inductance for CCM	$L_{min} = \frac{(1-D)^2 R}{2f}$
Peak-to-peak output voltage ripple	$\Delta V_o = \frac{V_o DT}{RC} = \frac{V_o D}{RCf}$
Peak-to-peak output voltage ripple due to ESR	$\Delta V_{o,ESR} = \Delta i_C r_C = I_{L,max} r_C$
Peak-to-peak inductor current ripple	$\Delta i_L = \frac{V_s DT}{L}$

Single-phase Inverter

$$i_o(t) = \begin{cases} \frac{V_{dc}}{R} + \left(I_{min} - \frac{V_{dc}}{R}\right)e^{-t/\tau} \\ -\frac{V_{dc}}{R} + \left(I_{max} + \frac{V_{dc}}{R}\right)e^{(t-T/2)/\tau} \end{cases}$$

$$I_{max} = -I_{min} = \frac{V_{dc}}{R}\left[\frac{1-e^{-T/2\tau}}{1+e^{-T/2\tau}}\right]$$

$$v_o(t) = \sum_{n=1,3,5,..}^{\infty} V_n \sin n\omega t$$

$$V_{n,rms} = \frac{2V_{dc}}{\sqrt{2}n\pi}\bigg|\, halfwave \qquad V_{n,rms} = \frac{4V_{dc}}{\sqrt{2}n\pi}\bigg|\, fullwave$$

$$i_o(t) = \sum_{n=1,3,5,..}^{\infty} I_n \sin(n\omega t - \theta_n) \qquad \theta_n = \tan^{-1}\left(\frac{n\omega_o L}{R}\right)$$

$$I_n = \frac{V_n}{Z_n} \qquad Z_n = \sqrt{R^2 + (n\omega_o L)^2}$$

$$I_{dc} = \frac{V_{o1}}{V_{dc}} I_{o1} \cos\theta_1$$

$$P = \sum_{n=1,3,5,..}^{\infty} P_n = \sum_{n=1,3,5,..}^{\infty} I_{n,rms}^2 R = \sum_{n=1,3,5,..}^{\infty} \left(\frac{I_n}{\sqrt{2}}\right)^2 R$$

$$THD_v = \frac{\sqrt{V_{o,rms}^2 - V_{1,rms}^2}}{V_{1,rms}}$$

$$THD_i = \frac{\sqrt{I_{o,rms}^2 - I_{1,rms}^2}}{I_{1,rms}}$$

Pulse-width modulation (PWM)

$$m_f = \frac{f_{sw}}{f_o}$$

$$m_a = \frac{V_{m,ref}}{V_{m,carrier}}$$

$$V_{1(peak)} = m_a V_{dc} \qquad 0 \le m_a \le 1$$

Three-phase Inverter

180 ° mode of conduction

$$v_{ab} = \sum_{n=1,5,7...}^{\infty} \frac{4V_{dc}}{n\pi} \sin\frac{n\pi}{3} \sin n\left(\omega t + \frac{\pi}{6}\right)$$

$$v_{bc} = \sum_{n=1,5,7...}^{\infty} \frac{4V_{dc}}{n\pi} \sin\frac{n\pi}{3} \sin n\left(\omega t - \frac{\pi}{2}\right)$$

$$v_{ca} = \sum_{n=1,5,7,..}^{\infty} \frac{4V_{dc}}{n\pi} \sin\frac{n\pi}{3} \sin n\left(\omega t - \frac{7\pi}{6}\right)$$

$$v_{an} = \sum_{n=1,5,7...}^{\infty} \frac{4V_{dc}}{\sqrt{3}n\pi} \sin\frac{n\pi}{3} \sin n(\omega t)$$

$$v_{bn} = \sum_{n=1,5,7,..}^{\infty} \frac{4V_{dc}}{\sqrt{3}n\pi} \sin\frac{n\pi}{3} \sin n\left(\omega t - \frac{2\pi}{3}\right)$$

$$v_{cn} = v_{an} = \sum_{n=1,5,7...}^{\infty} \frac{4V_{dc}}{\sqrt{3}n\pi} \sin\frac{n\pi}{3} \sin n\left(\omega t - \frac{4\pi}{3}\right)$$

120 ° mode of conduction

$$v_{ab} = \sum_{n=1,5,7,..}^{\infty} \frac{2\sqrt{3}V_{dc}}{n\pi} \sin\frac{n\pi}{3} \sin n\left(\omega t + \frac{\pi}{3}\right)$$

$$v_{bc} = \sum_{n=1,5,7,..}^{\infty} \frac{2\sqrt{3}V_{dc}}{n\pi} \sin\frac{n\pi}{3} \sin n\left(\omega t - \frac{\pi}{3}\right)$$

$$v_{ca} = \sum_{n=1,5,7,..}^{\infty} \frac{2\sqrt{3}V_{dc}}{n\pi} \sin\frac{n\pi}{3} \sin n(\omega t - \pi)$$

$$v_{an} = \sum_{n=1,5,7,..}^{\infty} \frac{2V_{dc}}{n\pi} \sin\frac{n\pi}{3} \sin n\left(\omega t + \frac{\pi}{6}\right)$$

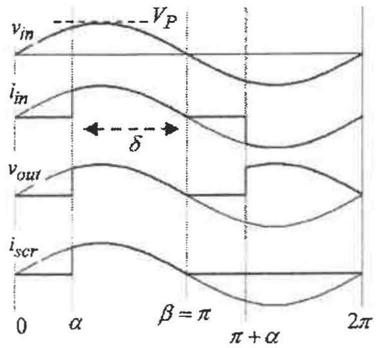
$$v_{bn} = \sum_{n=1,5,7...}^{\infty} \frac{2V_{dc}}{n\pi} \sin\frac{n\pi}{3} \sin n\left(\omega t - \frac{\pi}{2}\right)$$

$$v_{cn} = \sum_{n=1,5,7...}^{\infty} \frac{2V_{dc}}{n\pi} \sin\frac{n\pi}{3} \sin n\left(\omega t - \frac{7\pi}{6}\right)$$

Appendix 2
[Lampiran 2]

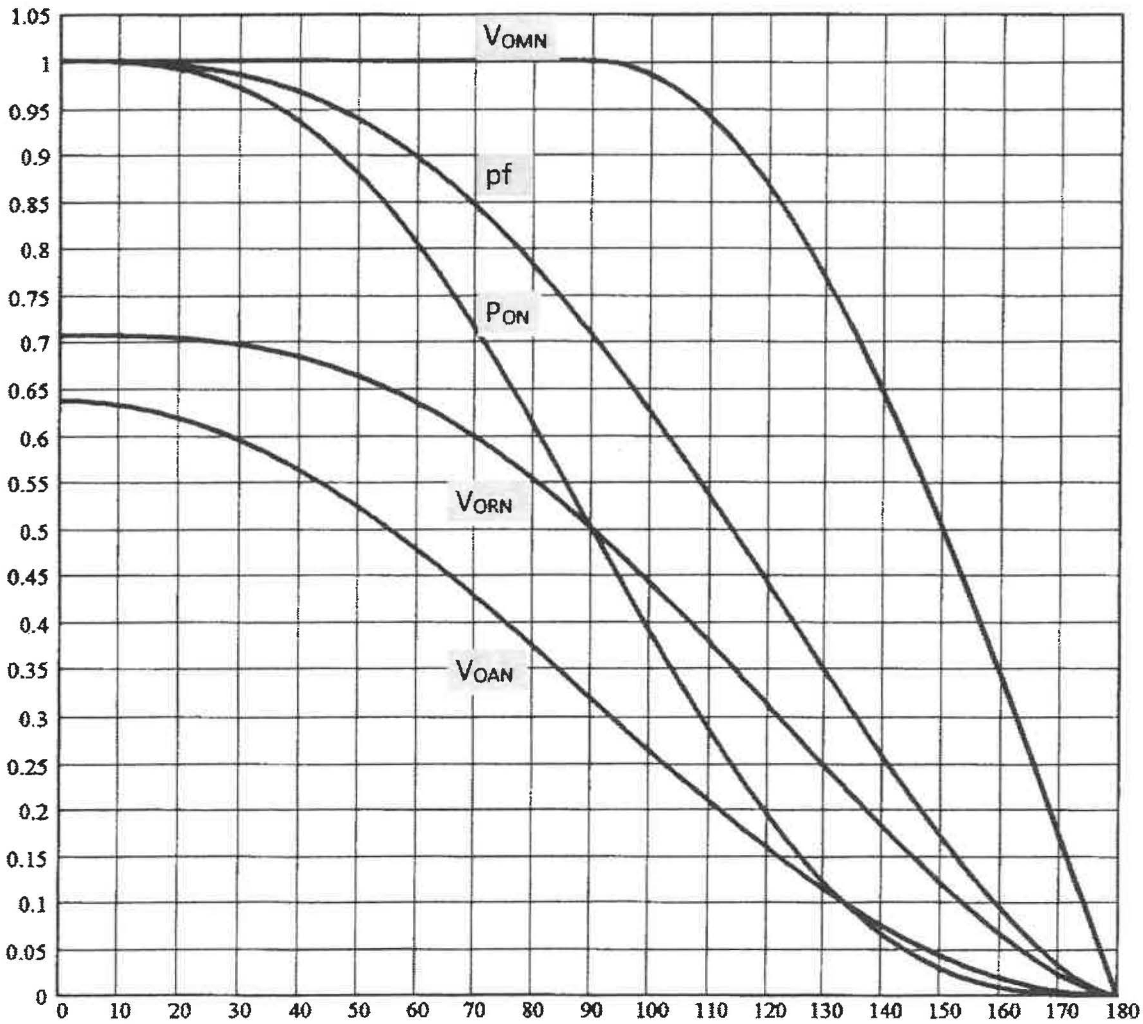
Please attached Appendix 2 together with the examination answer book.
[Sila kepilkan Lampiran 2 bersama dengan buku jawapan peperiksaan]

Index Number *[Nombor Index]*	Table Number *[Nombor Meja]*



$$V_{out,av} = V_{OAN} \times V_P$$
$$V_{out,rms} = V_{ORN} \times V_P$$
$$V_{out,\max} = V_{OMN} \times V_P$$
$$P_O = P_{ON} \times P_M$$
$$P_M = V_{in,rms} \times I_{in,rms(\alpha=0)}$$

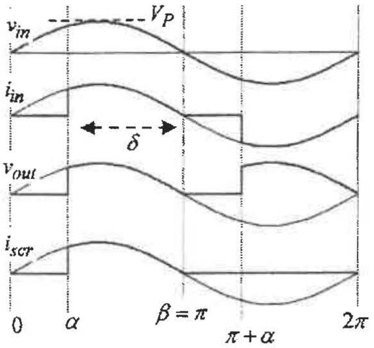
$$V_{OAN} = \frac{1+\cos\alpha}{\pi} \quad \Rightarrow \frac{2}{\pi} @ \alpha = 0$$
$$V_{ORN} = \sqrt{\frac{\pi-\alpha+\frac{1}{2}\sin 2\alpha}{2\pi}} \quad \Rightarrow \frac{1}{\sqrt{2}} @ \alpha = 0$$
$$V_{OMN} = \sin\alpha \quad @\alpha \geq \frac{\pi}{2} \quad or \quad 1 \quad @\alpha \leq \frac{\pi}{2}$$
$$P_{ON} = \frac{\pi-\alpha+\frac{1}{2}\sin 2\alpha}{\pi} \quad \Rightarrow 1 @ \alpha = 0$$
$$pf = \sqrt{\frac{\pi-\alpha+\frac{1}{2}\sin 2\alpha}{\pi}} \quad \Rightarrow 1 @ \alpha = 0$$



Appendix 3
[Lampiran 3]

Please attached Appendix 3 together with the examination answer book.
[Sila kepilkan Lampiran 3 bersama dengan buku jawapan peperiksaan]

Index Number *[Nombor Index]*	Table Number *[Nombor Meja]*



$$I_{out,av} = I_{OAN} \times \frac{V_P}{R}$$

$$I_{out,rms} = I_{ORN} \times \frac{V_P}{R}$$

$$I_{out,max} = I_{OMN} \times \frac{V_P}{R} = I_{in,max} = I_{scr,max}$$

$$I_{scr,av} = I_{AN} \times \frac{V_P}{R}$$

$$I_{scr,rms} = I_{RN} \times \frac{V_P}{R}$$

$$I_{OAN} = \frac{1+\cos\alpha}{\pi} \quad \Rightarrow \frac{2}{\pi} @ \alpha = 0$$

$$I_{ORN} = \sqrt{\frac{\pi - \alpha + \frac{1}{2}\sin 2\alpha}{2\pi}} \quad \Rightarrow \frac{1}{\sqrt{2}} @ \alpha = 0$$

$$I_{OMN} = \sin\alpha \quad @ \alpha \geq \frac{\pi}{2} \quad or \quad 1 \quad @ \alpha \leq \frac{\pi}{2}$$