UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF MARINE ENGINEERING TECHNOLOGY

FINAL EXAMINATION
SEPTEMBER 2016 SEMESTER

COURSE CODE	:	LEB30103
COURSE NAME	:	POWER ELECTRONICS
PROGRAMME NAME (FOR MPU: PROGRAMME LEVEL)	:	BACHELOR OF ENGINEERING TECHNOLOGY IN MARINE ELECTRICAL AND ELECTRONICS
DATE	:	16^{TH} JANUARY 2016
TIME	:	02.00 PM – 05.00 PM
DURATION	:	3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please CAREFULLY read the instructions given in the question paper.
2. This question paper has information printed on both sides of the paper.
3. This question paper consists of TWO (2) sections; Section A and Section B.
4. Answer ALL questions in Section A. For Section B, answer TWO (2) questions.
5. Please write your answers on the answer booklet provided.
6. Answer all questions in English language ONLY.

THERE ARE 10 PAGES OF QUESTIONS, INCLUDING THIS PAGE.

PART A (Total: 40 marks)

INSTRUCTION: Answer ALL questions.
Please use the answer booklet provided.

Question 1 (CLO1)

a. Explain about the gate drivers and theirs importance to Power Electronics

[5 marks]

b. Determine the parameters need to be consider, while selecting IGBT.

[4 marks]

c. Explain about the snubber circuit. List of two (2) of their examples.

[5 marks]

d. Converters are classified by the relationship between input and output as shown in **Figure 1**. State the four basic types of power converter, provide names in common usage and briefly explain their examples respectively.

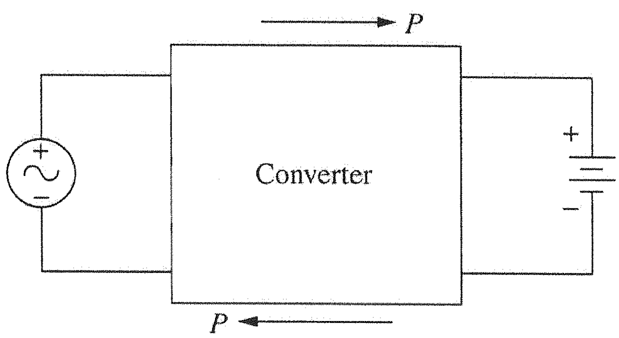


Figure 1

[6 marks]

Question 2 (CLO 2)

a. Sketch the waveform for the circuit shown in Figure 2 below by using **APPENDIX 1.**

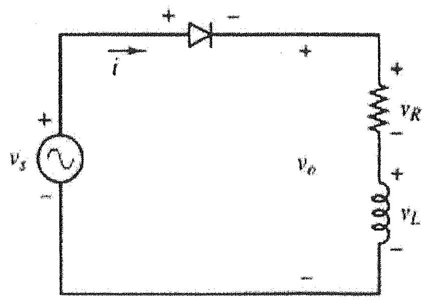


Figure 2

[7 marks]

b. The operational conditions for the fully controlled AC-to-DC converter shown in Figure 3 below and given in table 1.

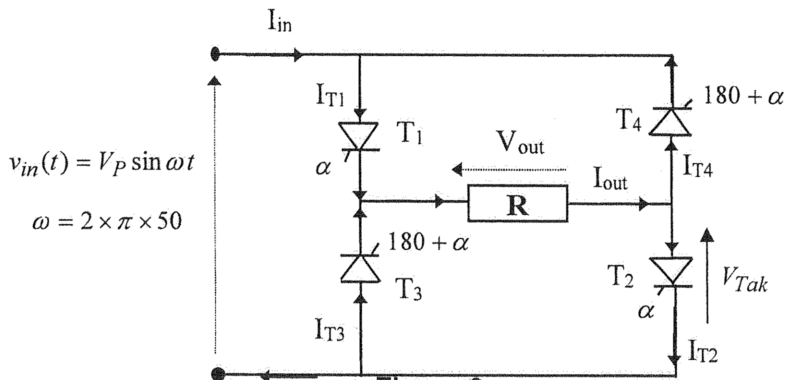


Figure 3

Table 1

$V_{in,rms}$	R	α
240	20Ω	40°

(i) Explain briefly the operation of single phase full-wave controlled rectifier with R load as shown in Figure 3.

[3 marks]

(ii) Refer figure 3, determine using **APPENDICES 2,3** and **4** as appropriate:

(a) The SCR rms current rating required [2 marks]

(b) The output power [3 marks]

(c) The input power factor [1 mark]

(d) The input volt-amperes [2 marks]

(e) Determine the input line 3rd Harmonic rms current [2 marks]

PART B (Total: 60 marks)

INSTRUCTION: Answer only THREE (3) questions.

Please use the answer booklet provided.

Question 3 (CLO 5)

a. Show that average output voltage of a DC-to-DC boost converter is given by expression:

$$V_O(av) = \frac{Vs}{(1-D)}$$

Where *Vs* is the dc source voltage and *D* is the duty cycle. Prove the equation above.

[6 marks]

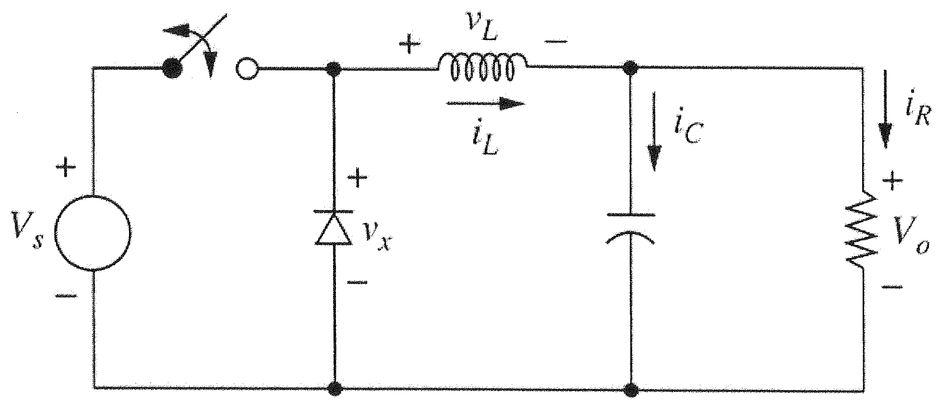


Figure 4

b. The buck converter of **Figure 4** has an input of 50 V and the output of 25 V. The switching frequency is 100 kHz, and the output power to a load resistor 125 W.

i. Determine the duty ratio.

[2 marks]

ii. Determine the value of inductance to limit the peak inductor current to 6.25 A

[4 marks]

iii. Determine the value of capacitance to limit the output voltage ripple to 0.5%.

[3 marks]

iv. Sketch the graph for maximum and minimum inductor current

[3 marks]

v. Sketch the graph output voltage for this DC buck converter and include the value output voltage ripple.

[2 marks]

Question 4 (CLO 3)

The Figure 5 shows the switching patterns for amplitude and harmonic control of the full bridge inverter with the dc source is 125 V, the load is a series RL connection with R= 10 and L= 20 mH, and the switching frequency is 60 Hz. By referring to

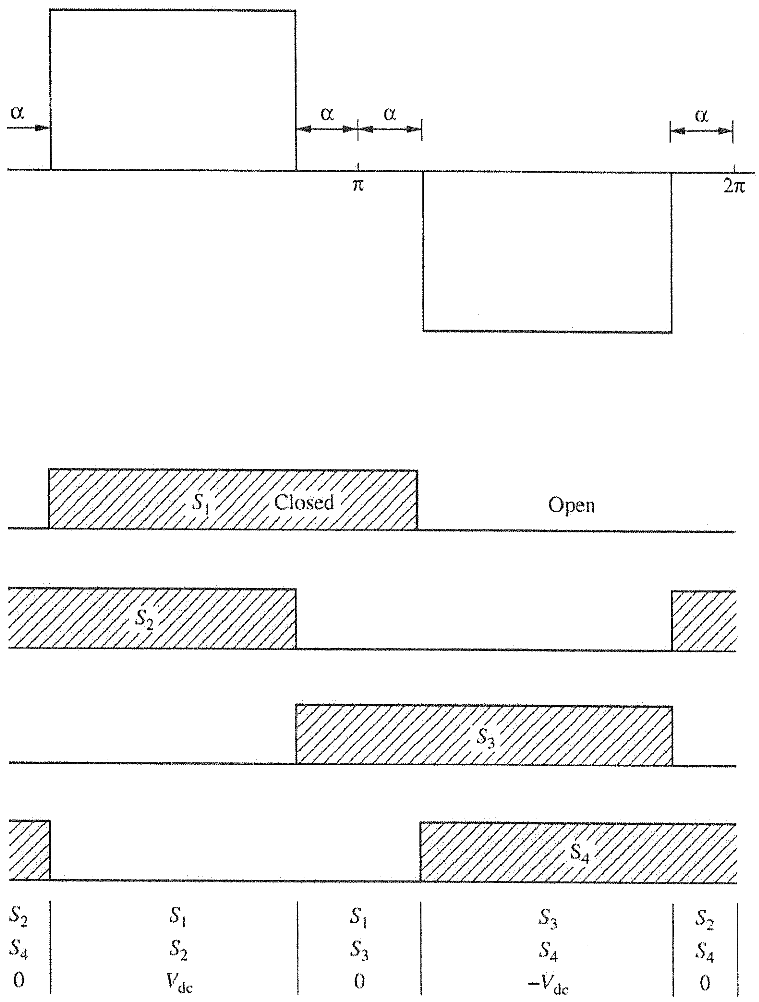


Figure 5

i. Determine the value of α to produce an output with an amplitude of 90 V at the fundamental frequency.

[4 marks]

ii. Determine the THD of the load current

[7 marks]

iii. Explain three (3) reasons why need to consider harmonics

[3 marks]

b. **Table 2** below shows the reading for Fourier series quantities taken from harmonics waveform. Analyze total Harmonic Distortion for current (THDi) and total Harmonic Distortion for voltage (THDv)

Table 2

n	f(Hz)	Vn(V)	Zn(Ω)	In(A)
1	60	127	13.7	9.27
3	180	0	30	0
5	300	25.5	48.2	0.53
7	420	18.2	66.7	0.27
9	540	0	85.4	0
11	660	11.6	104	0.11

[6 marks]

Question 5 (CLO 4)

a. List of two (2) ways operating modes of DC Motor in variable speed drive (VSD) applications. Discuss briefly ***regenerative braking*** operating mode operation.

[3 marks]

b. Consider a 500V, 10kW, 20A rated-DC Motor with armature resistance of $R_a = 1\Omega$ when supplied at 500V, the unloaded motor runs at 1040rev/min, drawing a current of 0.8A.

(i) Estimate the full load speed at rated values

[2 marks]

(ii) Estimate the no-load speed at 250V

[2 marks]

c. The speed of a separately excited DC Motor is controlled by a single phase full wave converter at armature side. The field circuit is controlled by a single phase semi-converter that is set to maximum possible value. The ac supply to the armature and field converters in one phase, 230V, 50Hz. The armature resistance, $R_a = 0.25\Omega$, field resistance, $R_f = 140\Omega$ and the motor voltage constant is $K_V = 1.125V/A/rad/s$. The load torque is $T_L = 60N.m$ at 1000rpm. The friction and no load losses are negligible. The inductance of the armature and field current continuous and ripple free. Determine:

(i) The motor Back EMF, E_g

[4 marks]

(ii) The delay angle of the converter in the armature circuit, α_a

[4 marks]

(iii) If the load torque, T_L decrease to 45N.m at 1100rpm, calculate (i) and (ii)

[5 marks]

QUESTION 6

a. The full-bridge resonant inverter of **Figure 6** has a 8 Ω resistive load that requires a 1200-Hz, 100-V rms sinusoidal voltage. The THD of the load voltage must be no more than 10 percent. Determine the required dc input and suitable values for Land C.

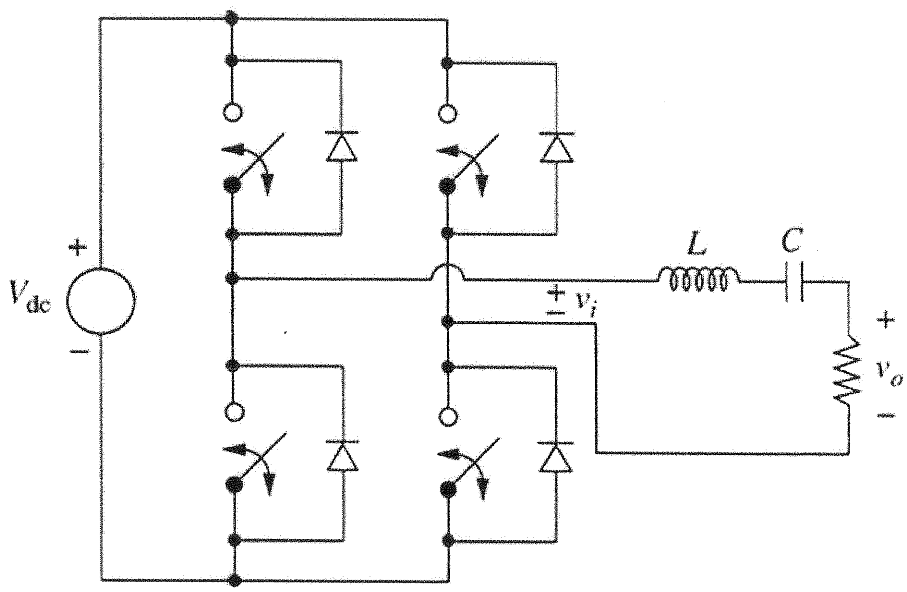


Figure 6

[10 marks]

(CLO3, CLO 5)

b. The circuit illustrated in **Figure 7** shows an inverter circuit which converts a DC Power into AC power at desired output voltage and frequency. Switch pair in each leg, i.e. S1 S4, S3 S6 and S5 S2 are turned-on with a time interval of 180°. It means that switches S1 conducts for 180° and switch S4 for the next 180° of a cycle. This six-step three-phase inverter has an adjustable dc input. The load is a balanced Y connection with a series RLcombination in each phase, with R = 5Ω and L = 50 mH. The output frequency is to be varied between 30 and 60 Hz. **Determine the range of the dc input voltage required to maintain the fundamental-frequency component of current at 10 A rms.**

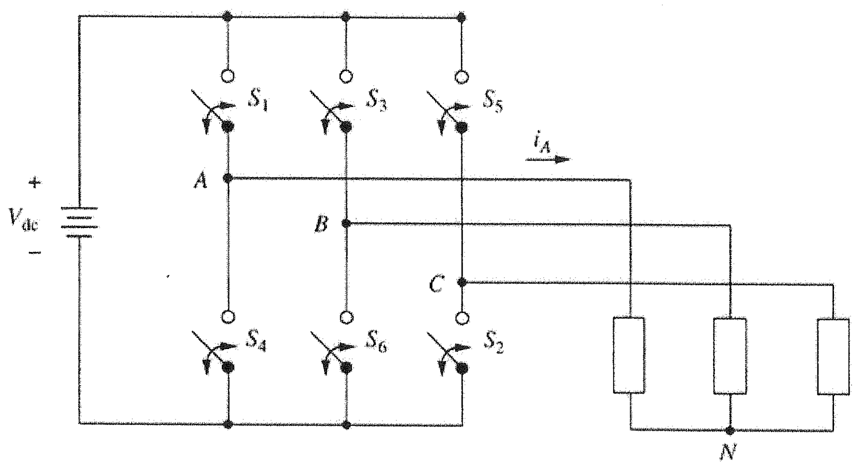


Figure 7

[10 marks]
(CLO 4)

END OF QUESTION

FORMULA'S

HALF-WAVE RECTIFIER

$$V_O = \frac{V_m}{\pi}$$

$$I_0 = \frac{V_0}{R} = \frac{V_m}{\pi R}$$

$$V_{RMS} = \frac{V_m}{2}$$

$$I_{RMS} = \frac{V_m}{2R}$$

$$V_o = \frac{V_m}{2\pi}[1+\cos\alpha]$$

$$V_{o(RMS)} = \frac{V_m}{2}\sqrt{1-\frac{\alpha}{\pi}+\frac{\sin(2\alpha)}{2\pi}}$$

FULL-WAVE RECTIFIER

$$V_O = \frac{2V_m}{\pi}$$

$$I_O = \frac{V_O}{R} = \frac{2V_M}{\pi R}$$

$$V_O = \frac{Vm}{\pi}(1+\cos\alpha)$$

$$I_O = \frac{V_O}{R} = \frac{V_m}{\pi R}(1+\cos\alpha)$$

BUCK AND BOOST CONVERTER

$$I_L = \frac{V_S}{(1-D)^2 R}$$

$$I_L = \frac{Vout}{R}$$

$$\frac{\Delta V_O}{V_O} = \frac{D}{RCF}$$

$$\frac{\Delta Vo}{Vo} = \frac{1-D}{8LCf^2}$$

$$I_D = I_O = \frac{V_O}{R}$$

$$I_{L(\max)} = I_L + \frac{\Delta i_L}{2}$$

$$I_{L(\min)} = I_L - \frac{\Delta i_L}{2}$$

RESONANT INVERTER

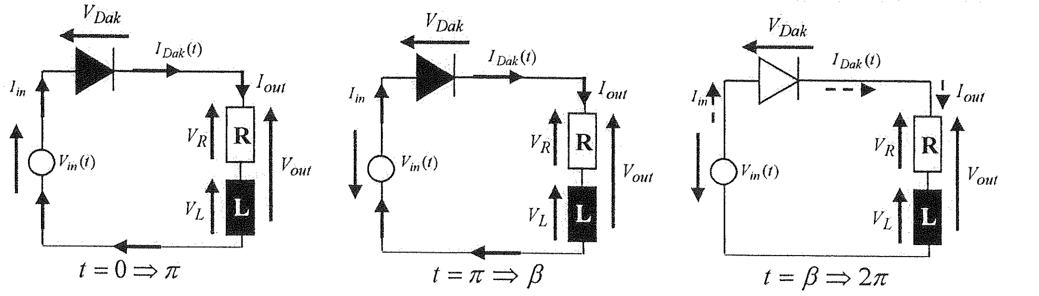
$$\frac{V_o}{V_i} = \frac{R}{\sqrt{R^2+\left(\omega L-\frac{1}{\omega C}\right)^2}} = \frac{1}{\sqrt{1+\left(\frac{\omega L}{R}-\frac{1}{\omega RC}\right)^2}}$$

$$\omega_o = \frac{1}{\sqrt{LC}} \qquad V_1 = \frac{4V_{dc}}{\pi}$$

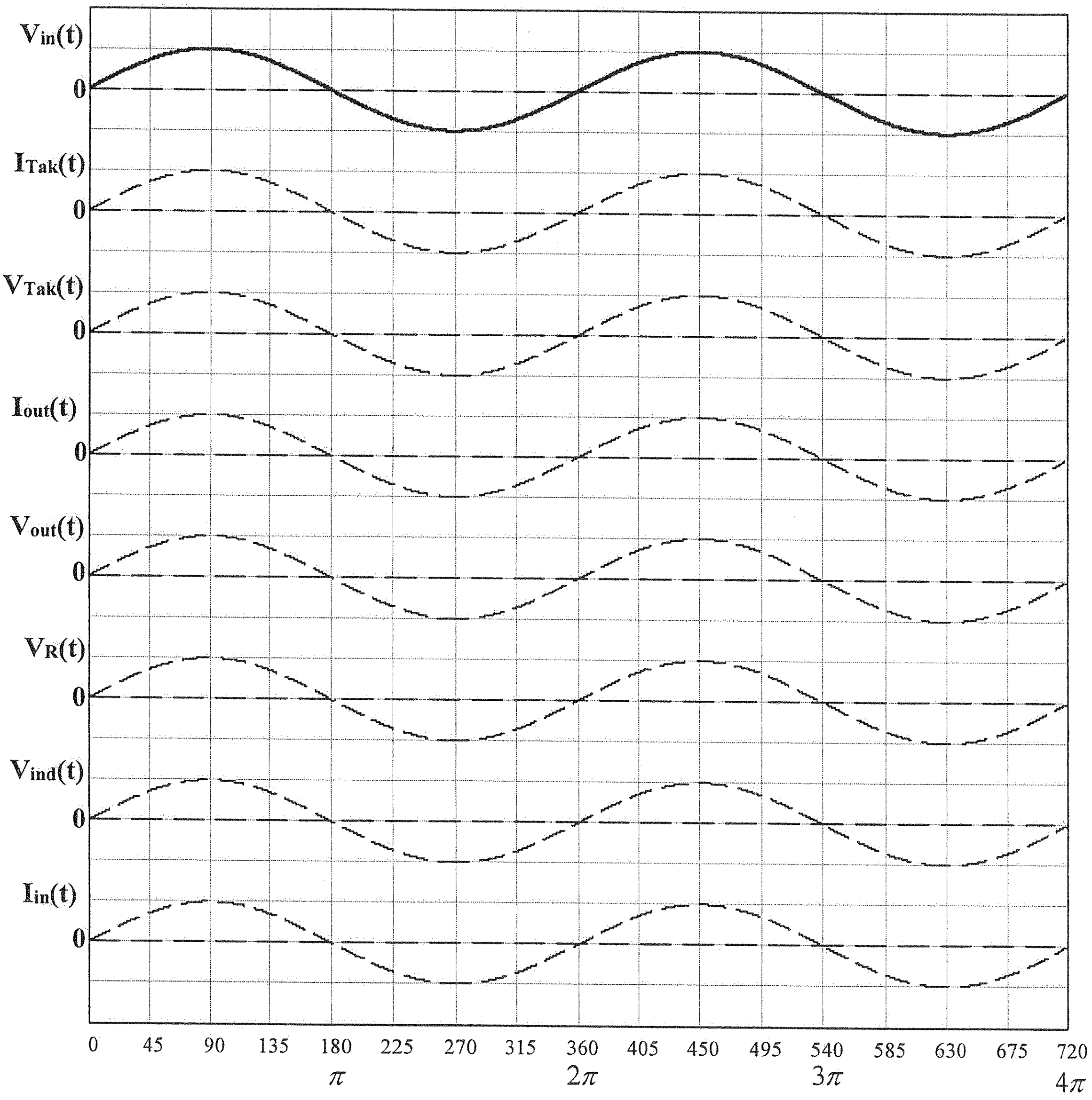
$$Q = \frac{\omega_o L}{R} = \frac{1}{\omega_o RC}$$

$$\frac{V_o}{V_i} = \frac{1}{\sqrt{1+Q^2\left(\frac{\omega}{\omega_o}-\frac{\omega_o}{\omega}\right)^2}}$$

POWER ELECTRONICS
WAVEFORM ANALYSIS
POWER CONVERTERS
H-W RECTIFICATION : R + L template



β
230°



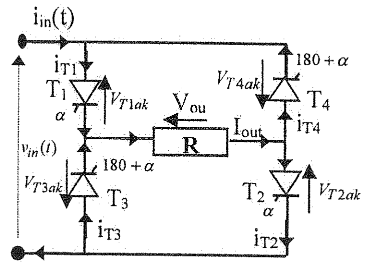
POWER ELECTRONICS

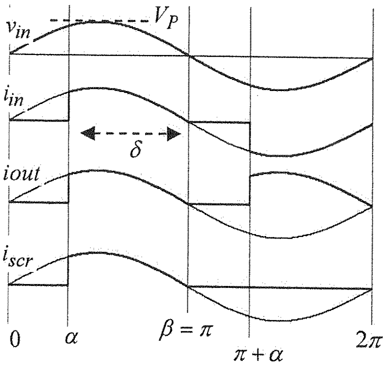
WAVEFORM ANALYSIS: PERFORMANCE CURVE

POWER CONVERTERS

FC-FW CONTROLLED RECTIFICATION : R

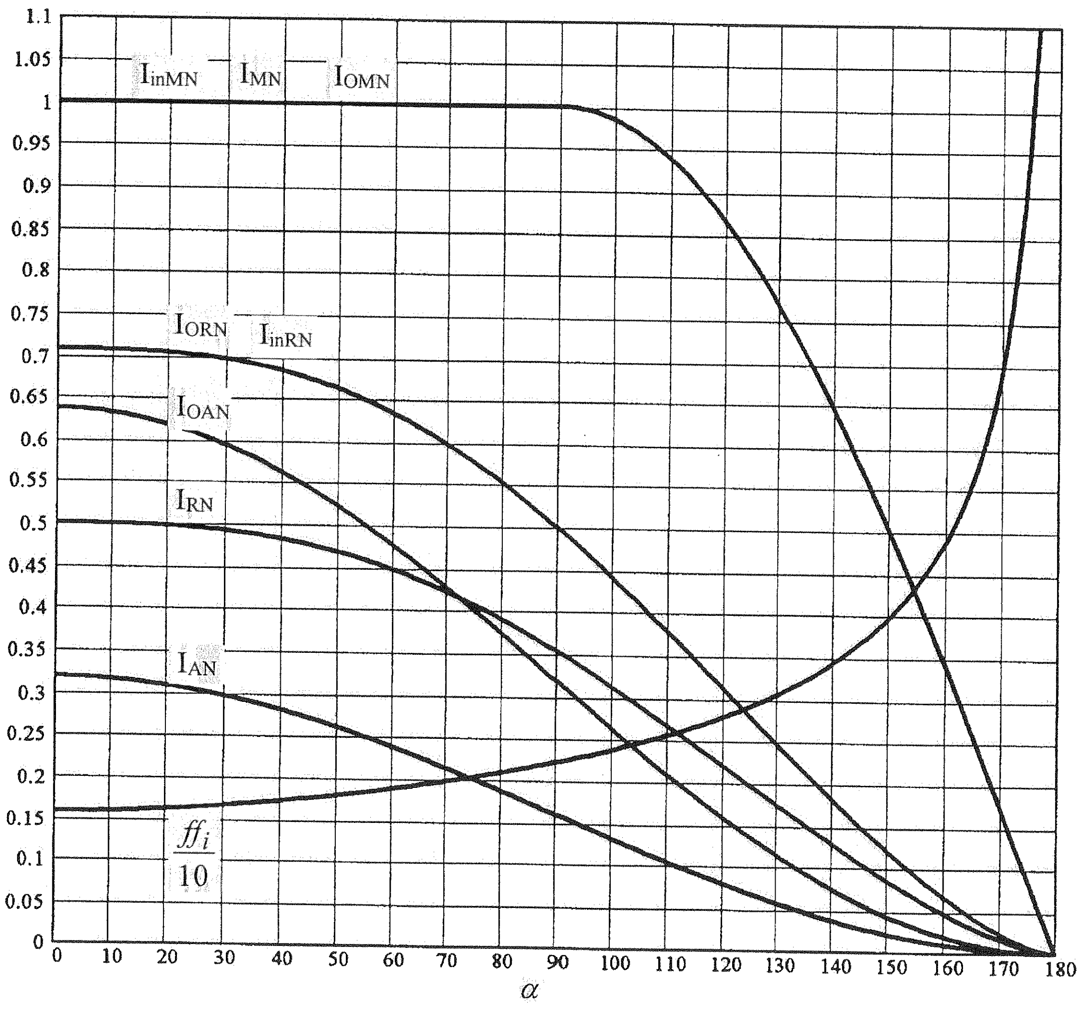
$I_{o(av)}$ SCALING FACTOR	I_{OAN}	*versus*	FIRING DELAY ANGLE α
$I_{o(rms)}$ SCALING FACTOR	I_{ORN}	*versus*	FIRING DELAY ANGLE α
$I_{o(M)}$ SCALING FACTOR	I_{OMN}	*versus*	FIRING DELAY ANGLE α
$I_{scr(av)}$ SCALING FACTOR	I_{AN}	*versus*	FIRING DELAY ANGLE α
$I_{scr(rms)}$ SCALING FACTOR	I_{RN}	*versus*	FIRING DELAY ANGLE α
CURRENT FORM FACTOR	ff_i	*versus*	FIRING DELAY ANGLE α

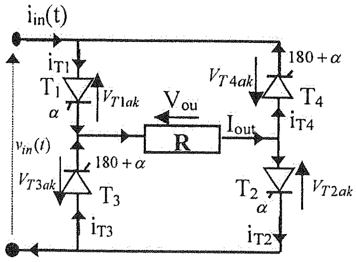


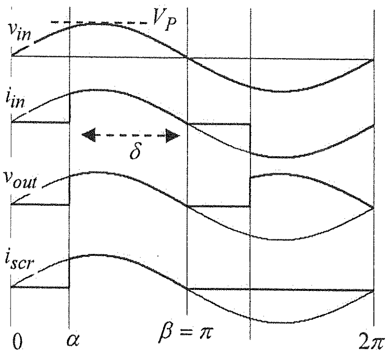


$$I_{out,av} = I_{OAN} \times \frac{V_P}{R}$$
$$I_{out,rms} = I_{ORN} \times \frac{V_P}{R}$$
$$I_{out,\max} = I_{OMN} \times \frac{V_P}{R} = I_{in,\max} = I_{scr,\max}$$
$$I_{scr,av} = I_{AN} \times \frac{V_P}{R}$$
$$I_{scr,rms} = I_{RN} \times \frac{V_P}{R}$$

$$I_{OAN} = \frac{1+\cos\alpha}{\pi} \Rightarrow \frac{2}{\pi} @ \alpha = 0$$
$$I_{ORN} = \sqrt{\frac{\pi-\alpha+\frac{1}{2}\sin 2\alpha}{2\pi}} \Rightarrow \frac{1}{\sqrt{2}} @ \alpha = 0$$
$$I_{OMN} = \sin\alpha \quad @\alpha \ge \frac{\pi}{2} \quad or \quad 1 \quad @\alpha \le \frac{\pi}{2}$$







POWER ELECTRONICS

WAVEFORM ANALYSIS: PERFORMANCE CURVE

POWER CONVERTERS

F-W CONTROLLED RECTIFICATION : R

$V_{o(av)}$	SCALING FACTOR	V_{OAN}	*versus*	FIRING DELAY ANGLE α
$V_{o(rms)}$	SCALING FACTOR	V_{ORN}	*versus*	FIRING DELAY ANGLE α
$V_{o(M)}$	SCALING FACTOR	V_{OMN}	*versus*	FIRING DELAY ANGLE α
P_o	SCALING FACTOR	P_{ON}	*versus*	FIRING DELAY ANGLE α
INPUT POWER FACTOR		pf	*versus*	FIRING DELAY ANGLE α

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

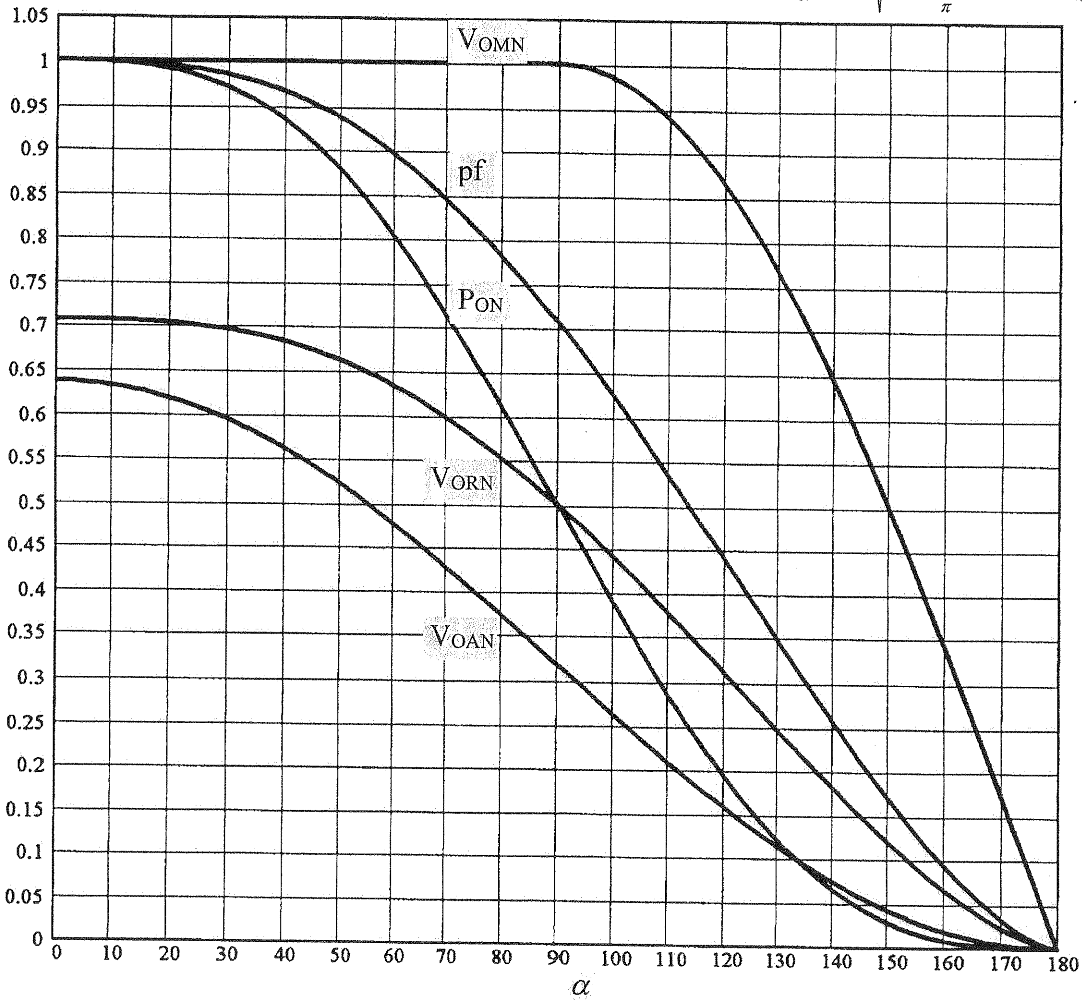
$$V_{ORN} = \sqrt{\frac{\pi-\alpha+\frac{1}{2}\sin 2\alpha}{2\pi}} \Rightarrow \frac{1}{\sqrt{2}}@\alpha = 0$$

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

$$P_{ON} = \frac{\pi-\alpha+\frac{1}{2}\sin 2\alpha}{\pi} \Rightarrow 1@\alpha = 0$$

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

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



APPENDIX 3

POWER ELECTRONICS

WAVEFORM ANALYSIS: PERFORMANCE CURVE

POWER CONVERTERS

FC-FW CONTROLLED RECTIFICATION : R

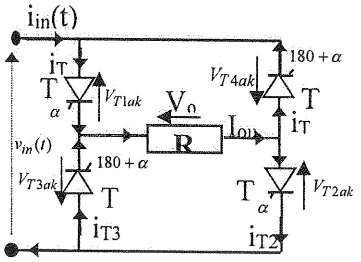
LINE CURRENT HARMONICS *versus* α

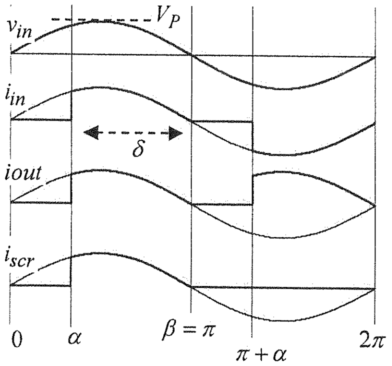
$I_{in(rms)}$ SCALING FACTOR I_{IRN} *versus* FIRING DELAY ANGLE α

$I_{infund(rms)}$ SCALING FACTOR I_{FRN} *versus* FIRING DELAY ANGLE α

$I_{inharm(rms)}$ SCALING FACTOR I_{HN} *versus* FIRING DELAY ANGLE α

FUNDAMENTAL 3rd 5th 7th 9th HARMONICS





$$I_{IRN} = \sqrt{\frac{\pi-\alpha+\frac{1}{2}\sin 2\alpha}{\pi}}$$

$$I_{IFRN} = \sqrt{\left[1-\frac{\alpha}{\pi}+\frac{\sin 2\alpha}{2\pi}\right]^2+\left[\frac{\cos 2\alpha-1}{4\pi}\right]^2}$$

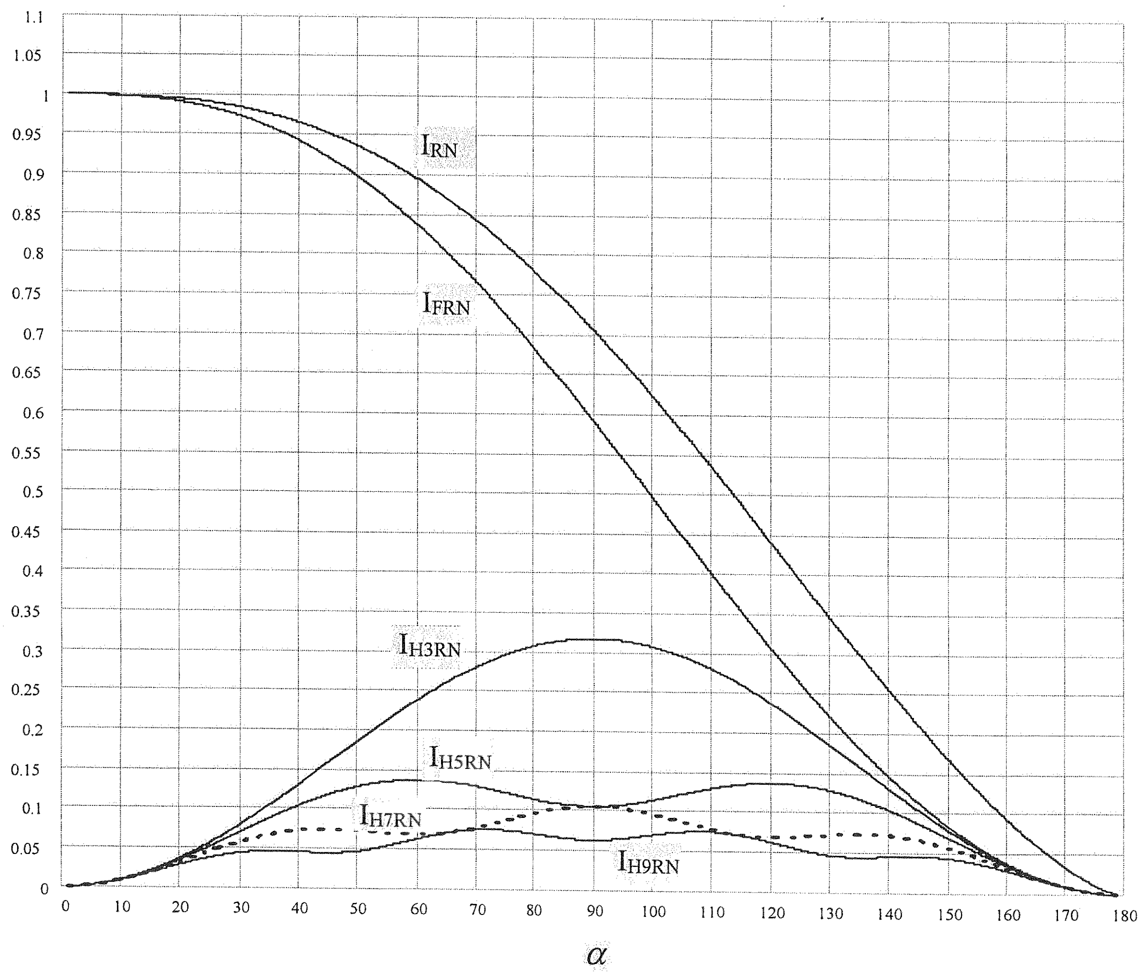
$$I_{IHRN} = \sqrt{\frac{1}{\pi^2}\left\{\left[\frac{\sin(n+1)\alpha}{n+1}\right]-\left[\frac{\sin(n-1)\alpha}{n-1}\right]\right\}^2+\frac{1}{\pi^2}\left\{\left[\frac{1-\cos(n-1)\alpha}{n-1}\right]-\left[\frac{1-\cos(n+1)\alpha}{n+1}\right]\right\}^2}$$

$$pf = \sqrt{\frac{\pi-\alpha+\frac{1}{2}\sin 2\alpha}{\pi}}$$

$$I_{in,rms} = I_{IRN}\times\frac{V_{in,rms}}{R}$$

$$I_{infund,rms} = I_{IFRN}\times\frac{V_{in,rms}}{R}$$

$$I_{inharm,rms} = I_{IHRN}\times\frac{V_{in,rms}}{R}$$



FORMULA'S

HALF-WAVE RECTIFIER

$$V_O = \frac{V_m}{\pi}$$

$$I_0 = \frac{V_0}{R} = \frac{V_m}{\pi R}$$

$$V_{RMS} = \frac{V_m}{2}$$

$$I_{RMS} = \frac{V_m}{2R}$$

$$V_o = \frac{V_m}{2\pi}[1 + \cos\alpha]$$

$$V_{o(RMS)} = \frac{V_m}{2}\sqrt{1 - \frac{\alpha}{\pi} + \frac{\sin(2\alpha)}{2\pi}}$$

BUCK AND BOOST CONVERTER

$$I_L = \frac{V_S}{(1-D)^2 R}$$

$$\frac{\Delta_O}{V_O} = \frac{D}{RCF}$$

$$I_D = I_O = \frac{V_O}{R}$$

$$I_{L(\max)} = I_L + \frac{\Delta i_L}{2}$$

$$I_{L(\min)} = I_L - \frac{\Delta i_L}{2}$$

$$V_o = V_s x D$$

FULL-WAVE RECTIFIER

$$V_O = \frac{2V_m}{\pi}$$

$$I_O = \frac{V_O}{R} = \frac{2V_M}{\pi R}$$

$$V_O = \frac{Vm}{\pi}(1 + \cos\alpha)$$

$$I_O = \frac{V_O}{R} = \frac{V_m}{\pi R}(1 + \cos\alpha)$$