KEMENTERIAN PENDIDIKAN TINGGI
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI

POLITEKNIK MALAYSIA
KUCHING SARAWAK

	ELECTRICAL ENGINEERING DEPARTMENT		
	DET40073 & POWER ELECTRONICS		
LECTURER NAME	FAIZAL BIN AHMAD		
TYPE OF ASSESSMENT	PRACTICAL WORK 2		
TOPIC	2 (AC TO DC CONVERTER)		
DURATION	2 HOURS 30 MINUTES		
DATE OF ASSESSMENT			
STUDENT'S INFORMATION	**NAME**	**REGISTRATION NO.**	**TICK STUDENT**
TOTAL MARKS	**CLO 2**		**/100**
	CLO 3		**/10**

POLITEKNIK MALAYSIA
KUCHING SARAWAK

DET40073 – POWER ELECTRONICS

PRACTICAL WORK 2 - SINGLE PHASE CONTROLLED RECTIFIER

CLO 2	Construct converters circuits and make observation on displayed waveforms using appropriate methods and equipments.	PLO 5	DP1: Cannot be resolved without extensive practical knowledge as reflected in DK5 and DK6 supported by theoretical knowledge defined in DK3 and DK4 DP2: Involve several issues, but with few of these exerting conflicting constraints DP3: Can be solved in standardized ways
CLO 3	Demonstrate the ability to practice leadership skills to complete assigned power electronics tasks.	PLO 9	DK DP NA (Not Related)

A. OBJECTIVES

i. Construct and explain the operation of single-phase AC to DC using single phase half wave controlled rectifier and single phase full wave controlled rectifier bridge circuit.
ii. Explain the operation of single phase half wave controlled rectifier and single phase full wave controlled rectifier.
iii. Determine the input voltage (Vs), inductor current (Io) and output voltage (Vo) waveforms.
iv. Calculate the input voltage (Vs), inductor current (Io) and output voltage (Vo).

B. LEARNING OUTCOME

Construct converters circuits and make observation on displayed waveforms using appropriate methods and equipments.

C. TOPIC SUMMARY/ THEORY

Controlled rectifiers are line commutated ac to dc power converters which are used to convert a fixed voltage, fixed frequency ac power supply into variable dc output voltage. The input supply fed to a controlled rectifier is ac supply at a fixed rms voltage and at a fixed frequency. By employing phase controlled thyristors in the controlled rectifier circuits, the variable dc output voltage and variable dc (average) output current can be obtain by varying the trigger angle (phase angle) at which the thyristors are triggered.

The thyristors are forward biased during the positive half cycle of input supply and can be turned ON by applying suitable gate trigger pulses at the thyristor gate leads. The thyristor current and the load current begin to flow once the thyristors are triggered (turned ON) say at $\omega t = \alpha$. The load current flows when the thyristors conduct from $\omega t = \alpha$ to β . The output voltage across the load follows the input supply voltage through the conducting thyristor. At $\omega t = \beta$, when the load current falls to zero, the thyristors turn off due to AC line (natural) commutation. In some bridge controlled rectifier circuits the conducting thyristor turns off, when the other thyristor is (other group of thyristors are) turned ON.

The thyristor remains reverse biased during the negative half cycle of input supply. The type of commutation used in controlled rectifier circuits is referred to AC line commutation or Natural commutation or AC phase commutation. When the input ac supply voltage reverses and becomes negative during the negative half cycle, the thyristor becomes reverse biased and hence turns off.

There are several types of single phase controlled rectifier:

1. Single Phase Half Wave Controlled Rectifier
2. Single Phase Full Wave Controlled Rectifier

i. Single Phase Half Wave Controlled Rectifier

Single-phase half wave controlled rectifier circuits will use silicon controlled rectifier (SCR) instead of the diode. Furthermore, the circuits are also known as phase-controlled converters. Controlled SCR rectifiers have a wide range of industrial and residential applications, especially applications in which power flows in both directions.

Let us consider the circuit in Figure 4.1(a) with a resistive load. During the positive half-cycle of input voltage, the thyristor anode is positive with respect to its cathode and the thyristor is said to be *forward biased*. When thyristor T_1 is fired at $\omega t = \alpha$, thyristor T_1 conducts and the input voltage appears across the load. When the input voltage starts to be negative at $\omega t = \pi$, the thyristor is anode is negative with respect to its cathode and the thyristor T_1 is said to be *reverse biased*; and it is turned off.The time after the input voltage starts to go positive until the thyristor is fired at $\omega t = \alpha$ is called the ***delay or firing angle*** α.

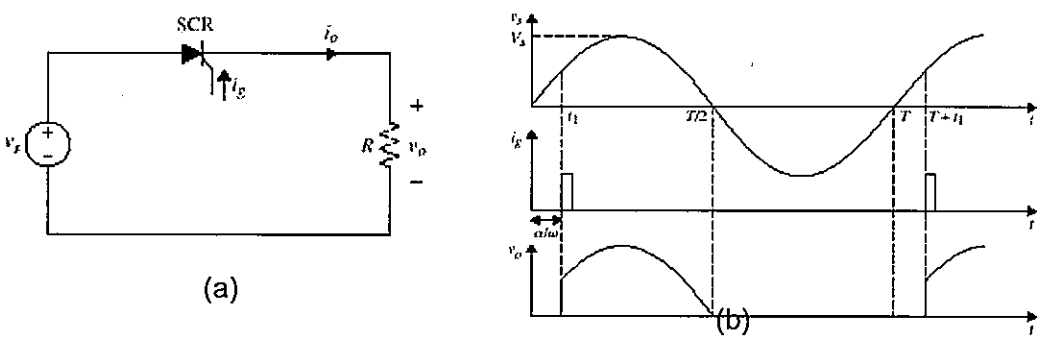


Figure 2.1 - Single-phase half wave controlled rectifier circuit with a resistive load.

Figure 3.1(b) shows the waveforms for input voltage, output voltage, load current, and gate current. This converter not normally used in industrial applications because its output has high ripple content and low ripple frequency. If V_m is the peak input voltage, the average output voltage V_{dc} can be found from,

$$V_{dc} = \frac{V_m}{2\pi}(1+\cos\alpha)$$

ii. Single-Phase Half Wave Controlled Rectifier with Resistive and Inductive Load

Figure 4.2(a) shows a single-phase half wave controlled with an inductive-resistive load. During the positive half-cycle of input voltage, the SCR is *forward biased*. When SCR T_1 is fired at $\omega t = \alpha$, SCR T_1 conducts and the input voltage appears across the load. The output voltage is the sum of voltage across resistor (V_R) and the voltage across inductor (V_L).

When v_s changes from a positive to a negative value, the current through the load does not fall to zero value at the instant wt = β radians, since the load contains an inductor and the SCRs continue to conduct, with the inductor acting as a source. When the input voltage starts to be negative at wt = $\pi + \beta$, the SCR is in the blocking condition so the output voltage is zero ($i_L = 0$ and $V_L = 0$) until $\omega t = 2\pi$. The average output voltage *Vdc* can be found from:

$$V_{dc} = \frac{V_m}{2\pi}\left[\cos(\alpha) - \cos(\beta)\right]$$

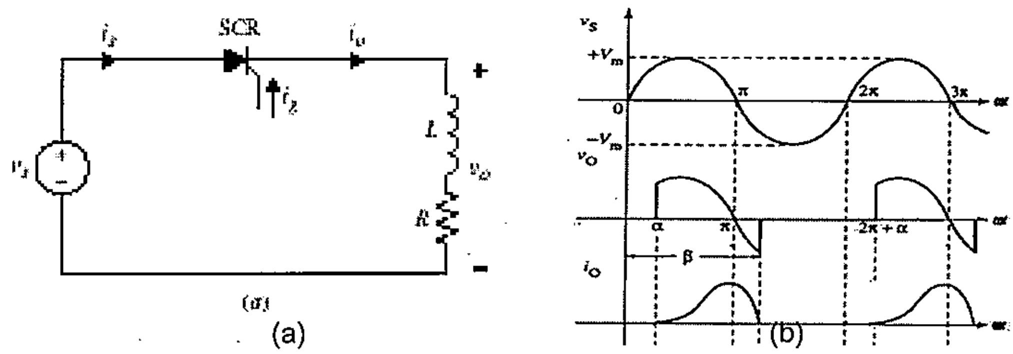
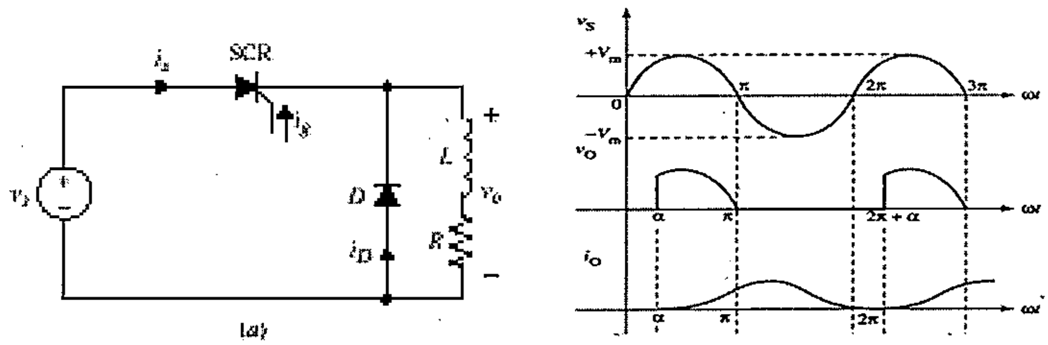


Figure 2.2 - Single-phase half wave controlled rectifier circuit with a resistive and inductive load

iii. Single-Phase Half Wave Controlled Rectifier with Resistive, Inductive Load and a Free-Wheeling Diode (FWD)



(b)

Figure 2.3 - Single-phase half wave controlled rectifier circuit with a resistive - inductive load and a free-wheeling diode (FWD)

Figure 4.3(a) shows a single-phase half wave controlled with an inductive-resistive load and free wheeling diode. The effect of this diode is to prevent a negative voltage appearing across the load. So in this situation freewheeling diode is used:

i. to supplies an alternate path for current to flow in the negative half-cycle
ii. to cut off the negative portion of instantaneous output voltage and smooth the output current ripple.

iv. Single-Phase Full Wave Controlled Bridge Rectifier with Resistive Load.

The circuit of a single-phase fully-controlled bridge rectifier circuit is shown in the figure 4.4 above. The circuit has four SCRs. It is preferable to state that the circuit has two pairs of SCRs, with S_1 and S_4 forming one pair and, S_2 and S_3 the other pair. For this circuit, the source is marked as V_s and it is a sinusoidal voltage source.

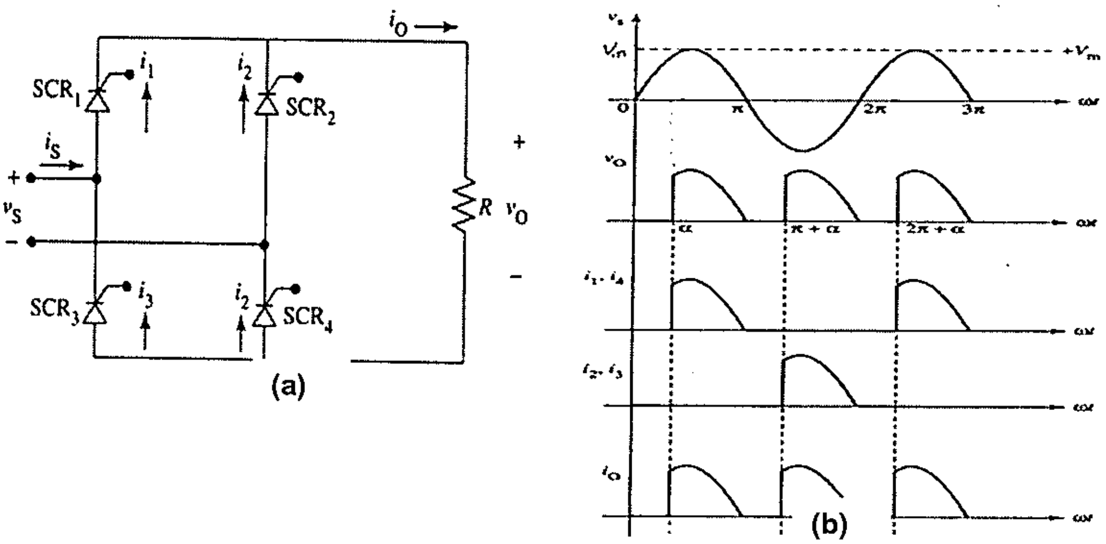


Figure 2.4 – Single-phase full wave bridge rectifier with resistive load
(a) Circuit Diagram (b) Output Waveform

When it is positive, SCRs S_1 and S_4 can be triggered and then current flows from v_s through SCR S_1, load resistor R, SCR S_4 and back into the source. In the next half-cycle, the other pair of SCRs conducts. Even though the direction of current through the source alternates from one half-cycle to the other half-cycle, the current through the load remains unidirectional.

The main purpose of this circuit is to provide a variable dc output voltage, which is brought about by varying the firing angle. Let $V_s = V_m \sin wt$, with $0 < wt < 360^\circ$. If $wt = 30^\circ$ when S_1 and S_4 are triggered, then the firing angle is said to be 30°. The other pair is triggered when $wt = 210^\circ$.The average load voltage *V*dc is simply *twice* the half-wave average,

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

D. MATERIAL / TOOLS

i. Three Phase Isolation Transformer
ii. Power Diodes
iii. Power SCR
iv. Resistive Load (100 ohm)
v. Inductive Load (25 mH)
vi. Oscilloscope
vii. Apparatus Stand
viii. Cable Connector

E. GENERAL INSTRUCTION / SAFETY PROCEDURE

i. Wear suitable PPE where required.
ii. Identify location of Fire Exit, Fire Extinguisher, First Aid Kit box and HIRARC sheets.
iii. Avoid unsafe activities during practical work.
iv. Carefully follow the lecturers' instructions to avoid personal injury and damage to the equipment.
v. Check the hand tools and equipment in good working condition.
vi. Verify electrical power supply connection before powering up. Seek advice from lecturer when necessary or if the practical work procedures require you to do so.
vii. Never remove any component when the power is on.
viii. Read direction and procedure of the experiments very carefully.
ix. Always take precautions in handling measurements of voltage and current.

F. WORK INSTRUCTION / PROCEDURE

i. Single Phase Half Wave Controlled Rectifier With Resistive Load

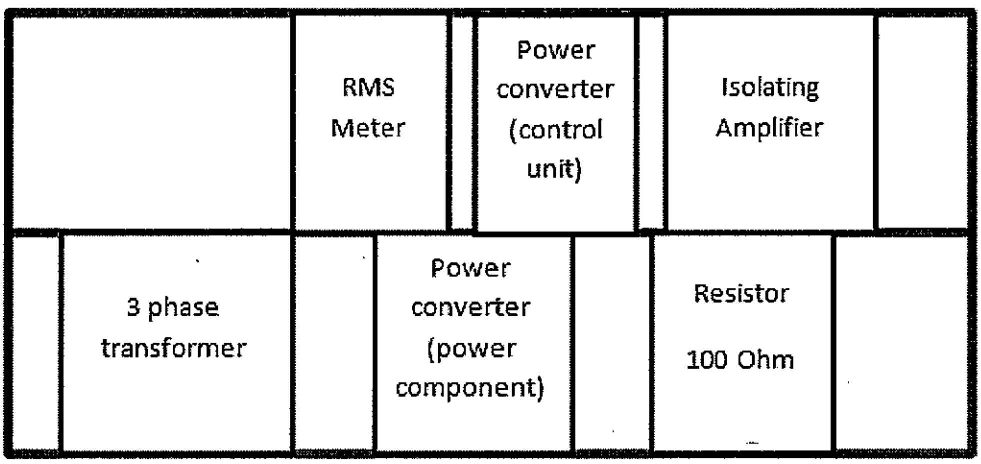


Figure 2.5: Apparatus arrangement

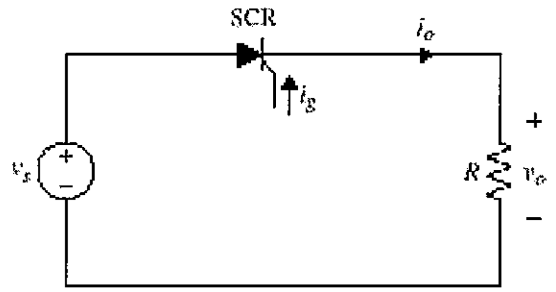


Figure 2.6 – Single Phase Half Wave Controlled Rectifier With Resistive Load Circuit

1. Arrange the apparatus as in the illustration in Figure 4.5.
2. Connect the circuit according to the circuit **diagram in figure 2.6** given.
3. Set the Power converter-control unit to:

   - Trigger delay angle α=180°
   - Rectifier step limit α_G=0°
   - Inverter step limit α_W=180°
   - Set the toggle swicth in lower position.

4. Set α=0° step by step until α=180°. Measure V_o for each setting of α.
5. Fill in your result in **Table 1.**
6. **Plot the graph for V_o vs α according to result in table 1.**

α° (degree)	0	30	60	90	120	150	180
V_o (V)							

Table 1

7. **Sketch the Input and output voltage waveform for α=0, α=90 and α=180 deg.**

ii. Single Phase Half Wave Controlled Rectifier With Resistive and Inductive Load

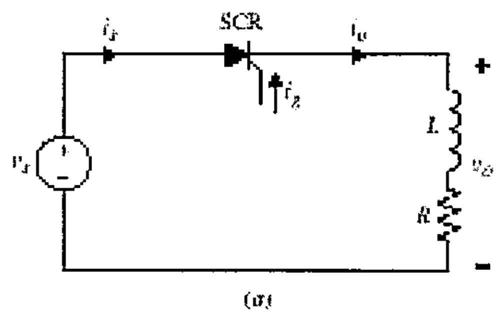


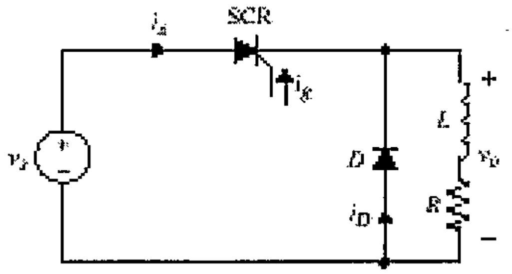
Figure 2.7 – Single Phase Half Wave Controlled Rectifier With Resistive and Inductive Load Circuit

1. Arrange the apparatus as in the illustration in Figure 2.5.
2. Connect the circuit according to the circuit **diagram in Figure 2.7** given.
3. Set the Power converter-control unit to:

- Trigger delay angle α=180°
- Rectifier step limit α_G=0°
- Inverter step limit α_W=180°
- Set the toggle swicth in lower position.

4. Set α=0°,90°,and 180°. Observe V_o waveform for each setting of α.
5. **Sketch the output voltage waveform for every α=0,90 and 180 deg.**

C. Single Phase Half Wave Controlled Rectifier With Resistive, Inductive Load and Freewheeling Diode



(a)

Figure 2.8 – Single Phase Half Wave Controlled Rectifier With R-L and Freewheeling Diode

Load Circuit

1. Arrange the apparatus as in the illustration in Figure 1.
2. Connect the circuit according to the circuit diagram in **Figure 2.8** given.
3. Set the Power converter-control unit to:

- Trigger delay angle α=180°
- Rectifier step limit α_G=0°
- Inverter step limit α_W=180°
- Set the toggle swicth in lower position.

4. Set α=0°, 90°and 180°. Observe V_o wafeform for each setting of α.
5. **Sketch the output wave for every α value.**

D. Single Phase Full Wave Controlled Bridge Rectifier

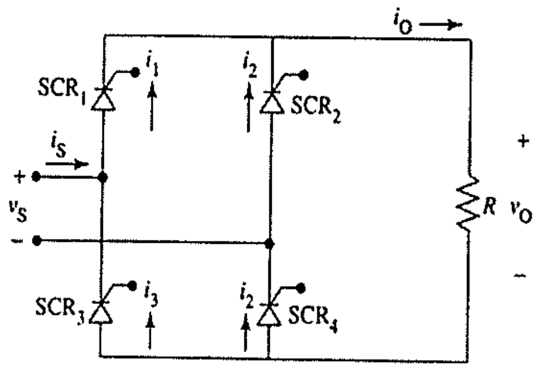


Figure 2.9 – Single Phase Full Wave Controlled Bridge Rectifier

1. Connect the circuit according to the circuit **diagram in figure 2.9** given.
2. Set α=0° step by step until α=180°. Measure V_o for each setting of α.
3. Fill in your result in table 1.
4. **Plot the graph for V_o vs α according to result in table 2.**

α° (degree)	0	30	60	90	120	150	180
V_o (V)							

Table 2

G. RESULT

A. Single Phase Half Wave Controlled Rectifier With Resistive Load

1. Fill the measured output voltage (Vo) in Table 1 for each setting of α.

(1 marks)

2. Sketch the waveform of input voltage (Vi) and output voltage (Vo) of the Single phase Half Wave Controlled Rectifier With Resistive Load when the firing angle, α is 0°,90⁰ and 180⁰.

(2 marks)

B. Single Phase Half Wave Controlled Rectifier With Resistive and Inductive Load

1. Sketch the waveform of input voltage (Vi), output voltage (Vo) and of the Single Phase Half Wave Controlled Rectifier With Resistive and Inductive Load for **α=0⁰ ,90 0 and 180⁰ deg.**

(2 marks)

C. Single Phase Half Wave Controlled Rectifier With Resistive, Inductive Load and Freewheeling Diode

1. Sketch the waveform of input voltage (Vi) and output voltage (Vo) of the Single Phase Half Wave Controlled Rectifier With Resistive, Inductive Load and Freewheeling Diode for α = 90° .

(2 marks)

D. Single Phase Full Wave Controlled Bridge Rectifier

1. Fill the measured output voltage (Vo) in Table 2 for each setting of α.

2. Sketch the waveform of input voltage (Vi) and output voltage (Vo) of the Single Full Wave Controlled Bridge Rectifier for the firing angle, α = 0°, 90 and 180 deg. (3 marks)

H. DISCUSSION

1. Calculate the average output voltage (Vo) and output current (Io) for firing angle at α =0° and 90° and 180⁰ in Procedure A. By using table, compare your answer with the result.

(6 marks)

2. Explain the effect of inductive load to the rectifier output voltage.

(3 marks)

4. Calculate the average output voltage (Vo) and output current (Io) for firing angle at 0° and 90° and 180° in Procedure D. By using table, compare your answer with the result.

(6 marks)

I. CONCLUSION

Summarize your experiment by relating to the objective of this experiment.

(5 marks)

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(Course Lecturer)	*(Course Coordinator/ Head of Programme)*	*(Head of Programme/ Head of Department)*
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Date: 2/8/2024		Date: 2/8/2024

POLITEKNIK MALAYSIA
KUCHING SARAWAK

DET40073 – POWER ELECTRONICS

PRACTICAL WORK2 & SINGLE PHASE CONTROLLED RECTIFIER

CLO 2	**Construct converters circuits and make observation on displayed waveforms using appropriate methods and equipment.**	**PLO 5**	**DP1: Cannot be resolved without extensive practical knowledge as reflected in DK5 and DK6 supported by theoretical knowledge defined in DK3 and DK4** **DP2: Involve several issues, but with few of these exerting conflicting constraints** **DP3: Can be solved in standardized ways**
CLO 3	**Demonstrate the ability to practice leadership skills to complete assigned power electronics tasks.**	**PLO 9**	**DK DP NA (Not Related)**

RESULT

A. Single Phase Half Wave Controlled Rectifier With Resistive Load

1. Fill the measured output voltage (Vo) in Table 1 for each setting of α.

(1 marks)

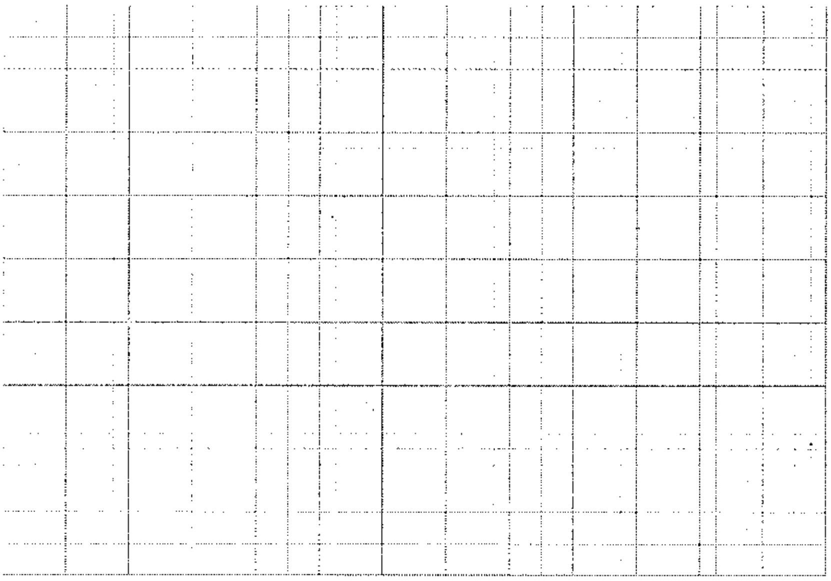
α° (degree)	0	30	60	90	120	150	180
V_o (V)							

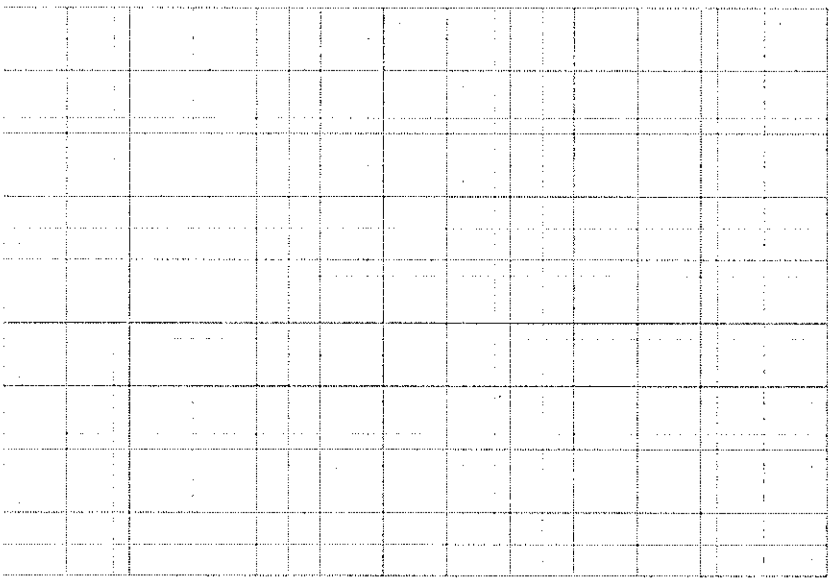
2. Sketch the waveform of input voltage (Vi) and output voltage (Vo) of the Single phase Half Wave Controlled Rectifier With Resistive Load when the firing angle, α is 0°,90⁰ and 180⁰.

(2 marks)

B. Single Phase Half Wave Controlled Rectifier With Resistive and Inductive Load

3. Sketch the waveform of input voltage (Vi), output voltage (Vo) and of the Single Phase Half Wave Controlled Rectifier With Resistive and Inductive Load for $\alpha=0^0$ **,90 0 and 180^0 deg.**





C. Single Phase Half Wave Controlled Rectifier With Resistive, Inductive Load and Freewheeling Diode

1. Sketch the waveform of input voltage (Vi) and output voltage (Vo) of the Single Phase Half Wave Controlled Rectifier With Resistive, Inductive Load and Freewheeling Diode for $\alpha = 90°$.

(2 marks)

D. Single Phase Full Wave Controlled Bridge Rectifier

1. Fill the measured output voltage (Vo) in Table 2 for each setting of α.

α° (degree)	0	30	60	90	120	150	180
V_o (V)							

4. Sketch the waveform of input voltage (Vi) and output voltage (Vo) of the Single Full Wave Controlled Bridge Rectifier for the firing angle, α = 0°, 90 and 180 deg. (3 marks)

B. DISCUSSION

1. Calculate the average output voltage (Vo) and output current (Io) for firing angle at α =0° and 90° and 180^0 in Procedure A. By using table, compare your answer with the result.

   (6 marks)

2. Explain the effect of inductive load to the rectifier output voltage.

(3 marks)

4. Calculate the average output voltage (Vo) and output current (Io) for firing angle at 0° and 90° and 180° in Procedure D. By using table, compare your answer with the result.

(6 marks)

C. CONCLUSION

(5 marks)

RUBRIC FOR PRACTICAL WORK (80%)

COURSE CODE : DET40073
COURSE NAME : POWER ELECTRONICS
STUDENT NAME :
REGISTRATION NO. :
PRACTICAL TITLE : SINGLE PHASE CONTROLLED RECTIFIER

CLO2: Construct converters circuits and make observation on displayed waveforms using appropriate methods and equipments. (P4,PLO5)			**PLO 5:** Apply appropriate techniques, resources, and modern engineering and IT tools to well-defined engineering problems, with an awareness of the limitations			**DK DP NA (Not Related)**	
Criteria	**SCORE**					**CRITERIA WEIGHTAGE**	**MARKS**
	5	**4**	**3**	**2**	**1**		
Apply safety rules	**Display full attention to safety rules in fieldwork.**					**2**	
	The experiment is carried out with full attention to relevant safety procedures.	The experiment is carried out with some attention to relevant safety procedures	The experiment is carried out with some attention to relevant safety procedures.	The experiment is carried out with some attention to relevant safety procedures. Seldom need assistance.	Safety procedures were ignored. Always needs assistance.		
Identify Equipment	**Organizes proper equipment based on the type of fieldwork**					**3**	
	Always identifies equipment without any assistance.	Identifies 90% of the equipment.	Identifies equipment with some assistance.	Identifies equipment with full assistance.	Attempt to identify equipment most of the time. Always needs assistance.		
Follow the procedure.	**Construct the experiment by following the standard procedures based on the type of fieldwork.**					**3**	
	Demonstrate excellent knowledge of lab procedures, thoroughly follow each procedure independently	Demonstrate sound knowledge of lab procedures with minimal help	Demonstrate good knowledge of lab procedures with moderate help	Requires help from lecturer with some steps in procedures	Often requires help from the lecturer to even complete basic procedures		
Construct the circuit/equipment correctly.	**Construct and Organizes proper equipment based on the type of circuit.**					**4**	
	Successfully construct all circuits independently	Able to construct all circuits correctly with minimal supervision	Able to construct all circuits correctly with moderate supervision	Able to construct all circuits correctly with major supervision	Unable to construct circuits correctly, require constant supervision		
Displays the result/waveform.	**Display the ability to gather data**					**4**	
	Results/Waveforms are clearly displayed with proper justification and analysis.	Results/Waveforms are displayed with lack justification and analysis.	Results/Waveforms are displayed with wrong justification and analysis.	Results/Waveforms are displayed with no justification and analysis.	Results/Waveforms is incorrect with wrong justification and analysis.		
						TOTAL MARK (/80)	

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Date: 2/8/2024	Date:	Date: 2/8/2024

RUBRIC FOR PRACTICAL WORK REPORT (20%)

COURSE CODE : DET40073

COURSE NAME : POWER ELECTRONICS

STUDENT NAME : ______

REGISTRATION NO. : ______

PRACTICAL TITLE : SINGLE PHASE CONTROLLED RECTIFIER

CLO2: Construct converters circuits and make observation on displayed waveforms using appropriate methods and equipments. (P4,PLO5)	**PLO 5:** Apply appropriate techniques, resources, and modern engineering and IT tools to well-defined engineering problems, with an awareness of the limitations				DK DP NA (Not Related)	
Criteria	**SCORE**				**CRITERIA WEIGHTAGE**	**MARKS**
	5	**4**	**3**	**2**	**1**		
DISCUSSION							
CONCLUSION	**Summarizes the main findings and their implications to the specified objectives, providing clear and concise insights.**					1	
	Exceptionally clear, concise, and strongly summarizes findings. Excellent connection, the conclusion aligns seamlessly with the introduction and hypotheses.	The conclusion is very clear and succinct. Strongly connects the conclusion with the introduction.	The conclusion is clear and summarizes key findings. Adequate connection to introduction.	The conclusion is vague or incomplete. Weak connection to the introduction land acks relevance.	The conclusion is unclear or missing. No connection between the conclusion and the introduction.		
					TOTAL MARK (/20)		

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Date: 2/8/2024	Date:	Date: 2/8/2024

iCGPA: RUBRIC FOR ATTRIBUTE TEAMWORK (10%)

COURSE CODE : DET40073
COURSE NAME : POWER ELECTRONICS
STUDENT NAME : ____________________
REGISTRATION NO. : ____________________
PRACTICAL TITLE : SINGLE PHASE CONTROLLED RECTIFIER

CLO3: Demonstrate the ability to practice leadership skills to complete assigned power electronics tasks. (A3, PLO9)			PLO 9: Function effectively as an individual, and as a member in diverse technical teams.		DK6: Not Related		
Criteria	SCORE					CRITERIA WEIGHTAGE	MARKS
	5	4	3	2	1		
	Group Tasks (Practical)						
Leadership - Knowledge and skills in leadership	Very clear evidence of knowledge and understanding demonstrated in practice	Able to demonstrate knowledge and understanding in practice well	Able to demonstrate knowledge and understanding in practice and require minor improvements	Able to demonstrate knowledge and understanding in practice but require improvements	No clear evidence of knowledge and understanding demonstrated in practice	1	
	Group Tasks (Practical)						
Leadership - Effective leadership	High ability to lead effectively self and/or others towards goal achievement.	Able to lead effectively self and/or others towards goal achievement	Able to lead self and/or others towards goal achievement with some effect and require minor improvements	Able to lead self and/or others towards goal achievement but with limited effect and require further improvements	No clear evidence of ability to lead self and/or others	1	
TOTAL MARK (/10)							

PREPARED BY:	CHECKED BY:	APPROVED BY:
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