EXPT NO: 1
DATE: 14/03/2022

SINGLE PHASE AC VOLTAGE CONTROLLER

AIM:

To vary the AC load voltage using single phase AC voltage controller.

APPARATUS REQUIRED:

S.No	Apparatus	Specifications	Quantity
1.	SCR	H2P4M	2
2.	Rheostat	185Ω /1.5 A	1
3.	Transformer	230V/24V	1
4.	Ammeter	(0-100mA) MI	1
5.	Voltmeter	(0-30V) MI	1

PROCEDURE:

1. Make the connections as shown in circuit diagram.
2. Give 230V AC supply to the main circuit.
3. Note down the ammeter and voltmeter reading
4. Observe the waveform of load voltage in CRO and calculate the value of firing angle in degrees.
5. Change the value of 'α' by changing the resistance R in UJT triggering circuit and for each value of 'α', repeat steps 3 and 4
6. Draw the graph for output voltage

THEORY :

* AC voltage controllers are semi-conductor based circuits which convert fixed alternating voltage directly to variable alternating voltage without a change in frequency.

* Applications of AC voltage controllers include transformer tap changing, lighting control, speed control of single phase and three phase drives and starting of induction motors.

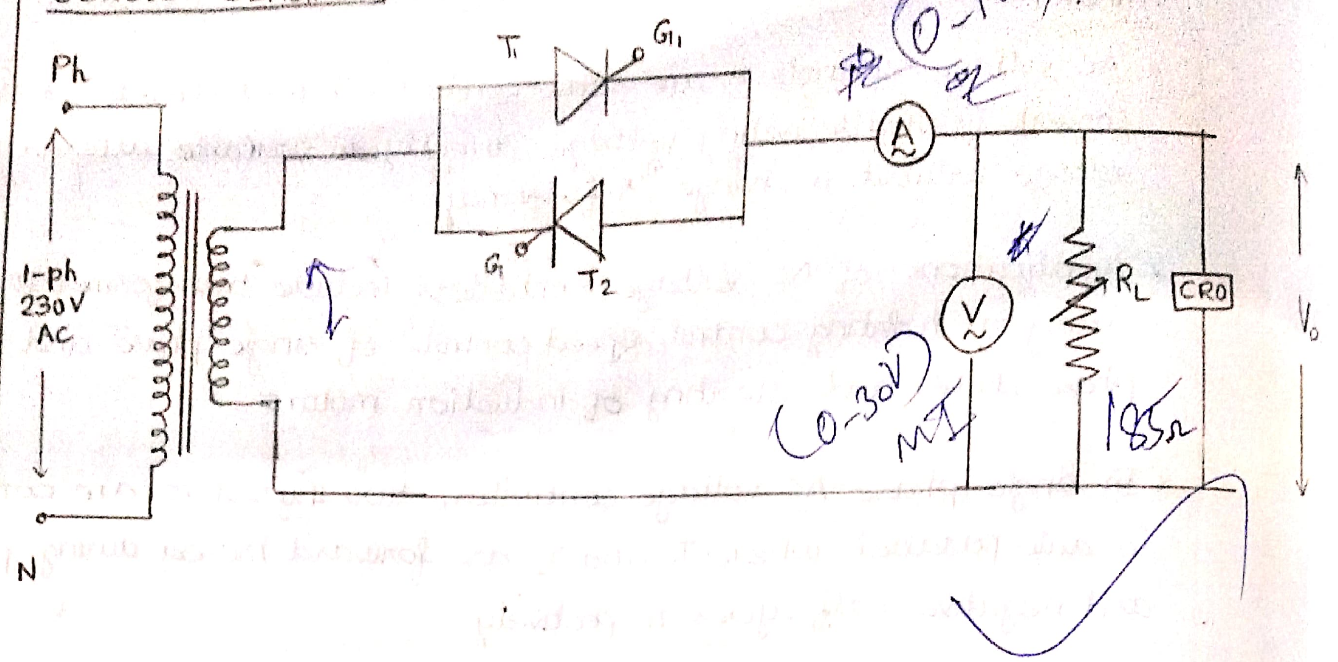
* In single phase AC voltage controller, two thyristors are connected in anti-parallel where T_1 and T_2 are forward biased during positive and negative half cycles respectively.

* During positive half cycle, T_1 is triggered at a firing angle 'α'. Hence it starts conducting and source voltage is applied to load from α to π.

* During negative half cycle, T_2 is triggered at a firing angle $(\pi+\alpha)$ hence it starts conducting and source voltage is applied to load from $(\pi+\alpha)$ to 2π.

* Thus the fixed ac voltage can be controlled and varied for different firing angles.

CIRCUIT DIAGRAM



SPECIFICATIONS OF 2P4M SCR

* Repetitive peak off-state voltage (V_{DRM}) = 400V
* Repetitive peak reverse voltage (V_{RRM}) = 400V
* Maximum gate current ($I_{g max}$) = 0.2 mA
* Maximum anode current = 2 A

CIRCUIT DESIGN:

$$V_o\ rms = \frac{V_m}{\sqrt{2\pi}} \sqrt{(\pi-\alpha) + \frac{\sin 2\alpha}{2}}$$

When $\alpha = 0$, $V_o\ rms = \frac{V_m}{\sqrt{2}}$

V_m max = 400V $\Rightarrow$ let us take some V_m below 400 V

Available AC voltmeter is (0-30V) MI $\Rightarrow$ choose V_{rms} = 24 V

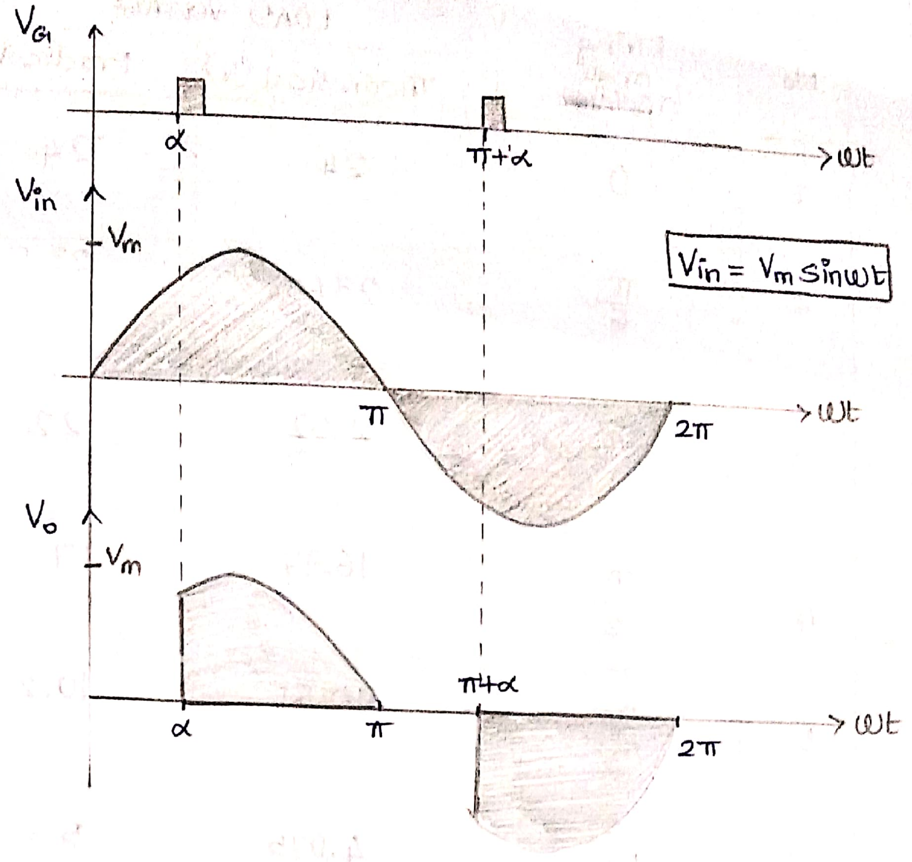
$V_o\ rms = \frac{V_m}{\sqrt{2}} \Rightarrow 100 = \frac{V_m}{\sqrt{2}} \Rightarrow V_m = 100 \times \sqrt{2} = 141.4V$

Maximum anode current = 2 A $\Rightarrow$ let us take 0.8 A $\Rightarrow$ (0-1) MI

$R_L = \frac{V_o\ rms}{I_L} = \frac{100}{0.8} = 125\,\Omega$

Hence we choose R_L rheostat = 185Ω / 1.5A

DERIVATION OF $V_o(rms)$



W.K.T

$$V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi}[v(t)]^2 d(\omega t)}$$

Since V_o^2 waveform will look exactly same after every π period, we can consider base $= \pi$ and waveform from 0 to π

$$V_{o\,rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} V_m^2 \sin^2\omega t \, d(\omega t)}$$

$$= \sqrt{\frac{V_m^2}{\pi}\int_0^{\pi} \sin^2\omega t \, d(\omega t)}$$

$$\sin^2 x = \frac{1-\cos 2x}{2}$$

$$= \sqrt{\frac{V_m^2}{2\pi}\int_\alpha^{\pi} (1-\cos 2\omega t)\, d(\omega t)}$$

$$= \frac{V_m}{\sqrt{2\pi}}\sqrt{\left[\omega t - \frac{\sin 2\omega t}{2}\right]_\alpha^{\pi}}$$

TABULATION:

S. No	Firing angle (radians)	LOAD VOLTAGE Theoretical (V)	Practical (V)	Load current (mA)
1.	0	24	24	~~129.7~~ 155
2.	$\frac{\pi}{6}$	23.65	23.5	127 152
3.	$\frac{\pi}{3}$	21.52	22	145
4.	$\frac{\pi}{2}$	16.97	17	115
5.	$\frac{2\pi}{3}$	10.61	10.2	60
6.	$\frac{5\pi}{6}$	4.075	5.3	5
7	π	0	0	0

THEORETICAL CALCULATION:

(i) $\alpha = 0°$

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

$$= \frac{24 \times \sqrt{2}}{\sqrt{2}\sqrt{\pi}} \sqrt{(\pi - 0) + \frac{\sin 2(0)}{2}}$$

$$= 24V$$

(ii) $\alpha = 30°$ ($\frac{\pi}{6}$ radians)

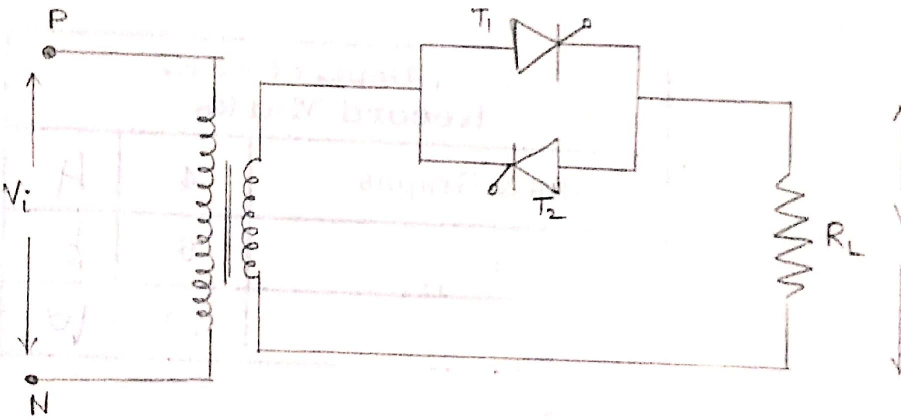
$$V_{o\,rms} = \frac{24\sqrt{2}}{\sqrt{2\pi}} \sqrt{\left(\pi - \frac{\pi}{6}\right) + \frac{\sin\left(\frac{2\pi}{6}\right)}{2}} = 23.65\,V$$

$$V_{o\,rms} = \left(\frac{V_m}{\sqrt{2\pi}}\right)\sqrt{\left(\pi - \frac{\sin 2\pi}{2}\right) - \left(\alpha - \frac{\sin 2\alpha}{2}\right)}$$

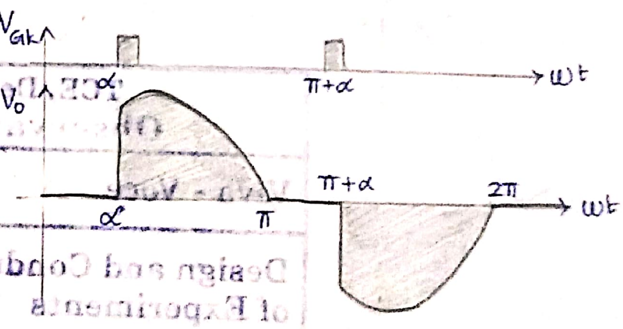
$$\boxed{V_{o\,rms} = \frac{V_m}{\sqrt{2\pi}}\sqrt{(\pi-\alpha) + \frac{\sin 2\alpha}{2}}}$$

INFERENCE:

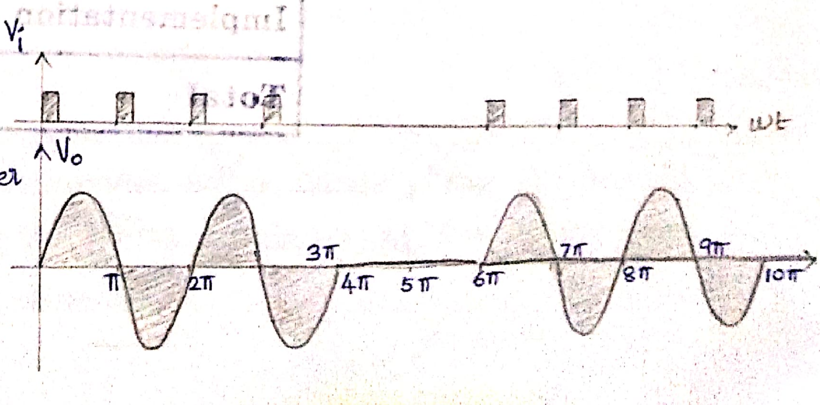
* AC voltage controllers give Variable AC supply from constant AC suppl
* AC Voltage can be controlled by 2 methods:
    1. Phase Control
    2. Integral Cycle Control (on-off control)



* Output of Phase controlled ~~AC voltage~~ controller



* Output of integral cycle AC voltage controller

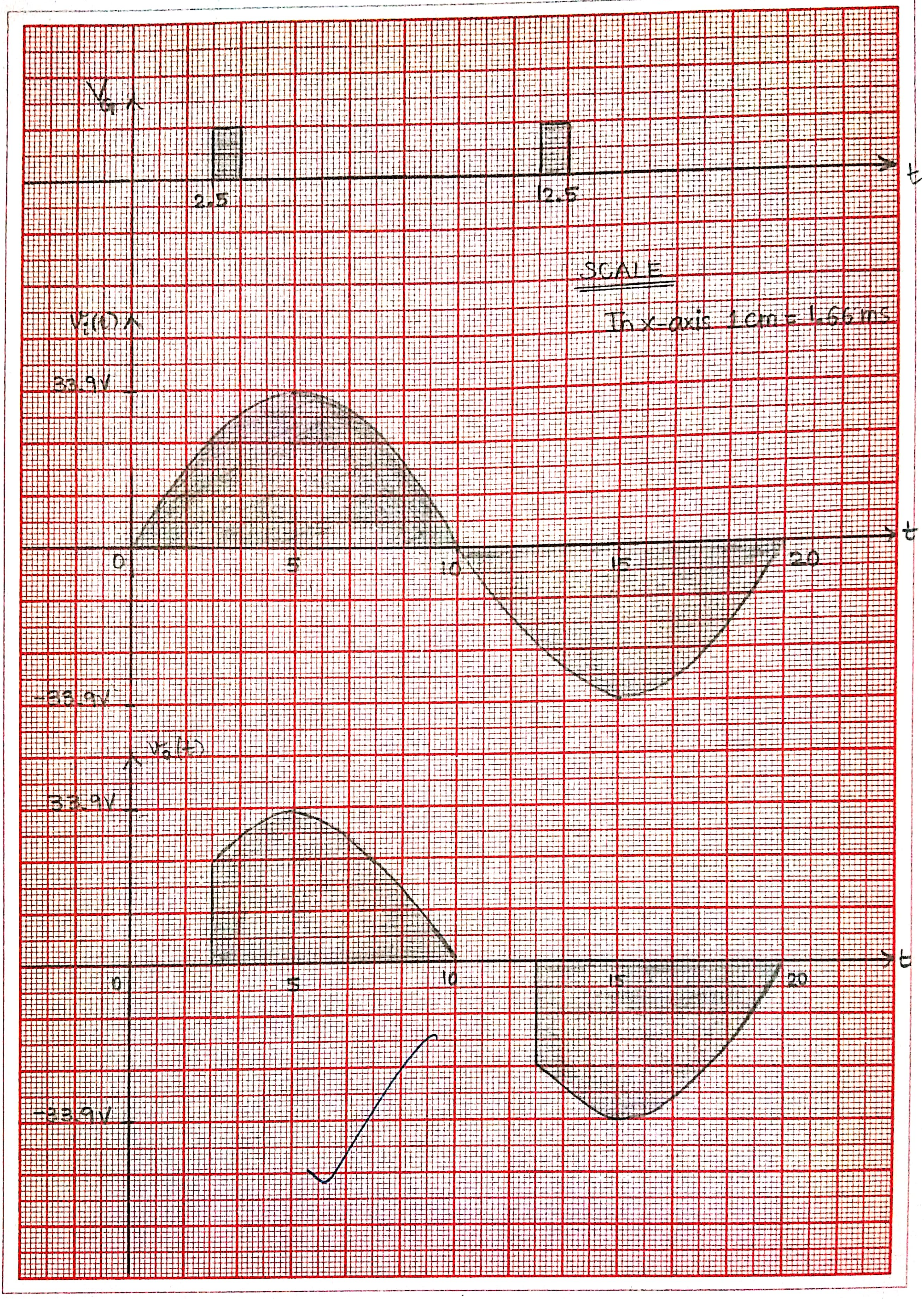


No. of on cycles $(N) = 2$

No. of off cycles $(M) = 1$

$\Rightarrow N + M = 3$

OUTPUT OF AC VOLTAGE CONTROLLER (FIRING ANGLE = $\frac{\pi}{4}$)



TABULATION:

Sl. No	Firing Angle (α) in degrees	Peak Voltage (v)
1.	0°	31
2.	30°	31
3.	60°	31
4.	90°	31
5.	120°	28
6.	180°	0

TCE, Dept. of EEE. Record Marks		
...ults & Graphs	4	4
...ance	6	6
	10	10

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TCE, Dept. of EEE. Observation Marks		
Viva - Voce	5	4
Design and Conduct of Experiments	10	10
Observation / Coding / Implementation	5	5
Total	20	19

* RMS value of Integral Cycle controlled AC Voltage controller's output is given by

$$V_{o\,rms} = \sqrt{\frac{N}{N+m} \int_0^{2\pi} V_m^2 \sin^2\omega t \, d(\omega t)}$$

where,

N = no. of on cycles
M = no. of off cycles.

* Total Harmonic Distortion in output voltage $= \frac{\sqrt{\sum_{k=2}^{\infty} V_{k\,rms}^2}}{V_{1rms}} \times 100\%$

* Distortion Factor $= \sqrt{\frac{1}{1+THD^2}}$

* W.K.T pf = Displacement power factor x Distortion Factor
= $\cos(\phi_v - \phi_i)$ x Distortion Factor

* Ideally, for a pure sinusoidal output voltage, THD = 0 and distortion factor = 1

* When the harmonic content in output voltage increases, distortion factor decreases and thus power factor also decreases.

* If the input to the motor has harmonics, the motor is subjected to overheating due to increased iron and copper loss at harmonic frequencies

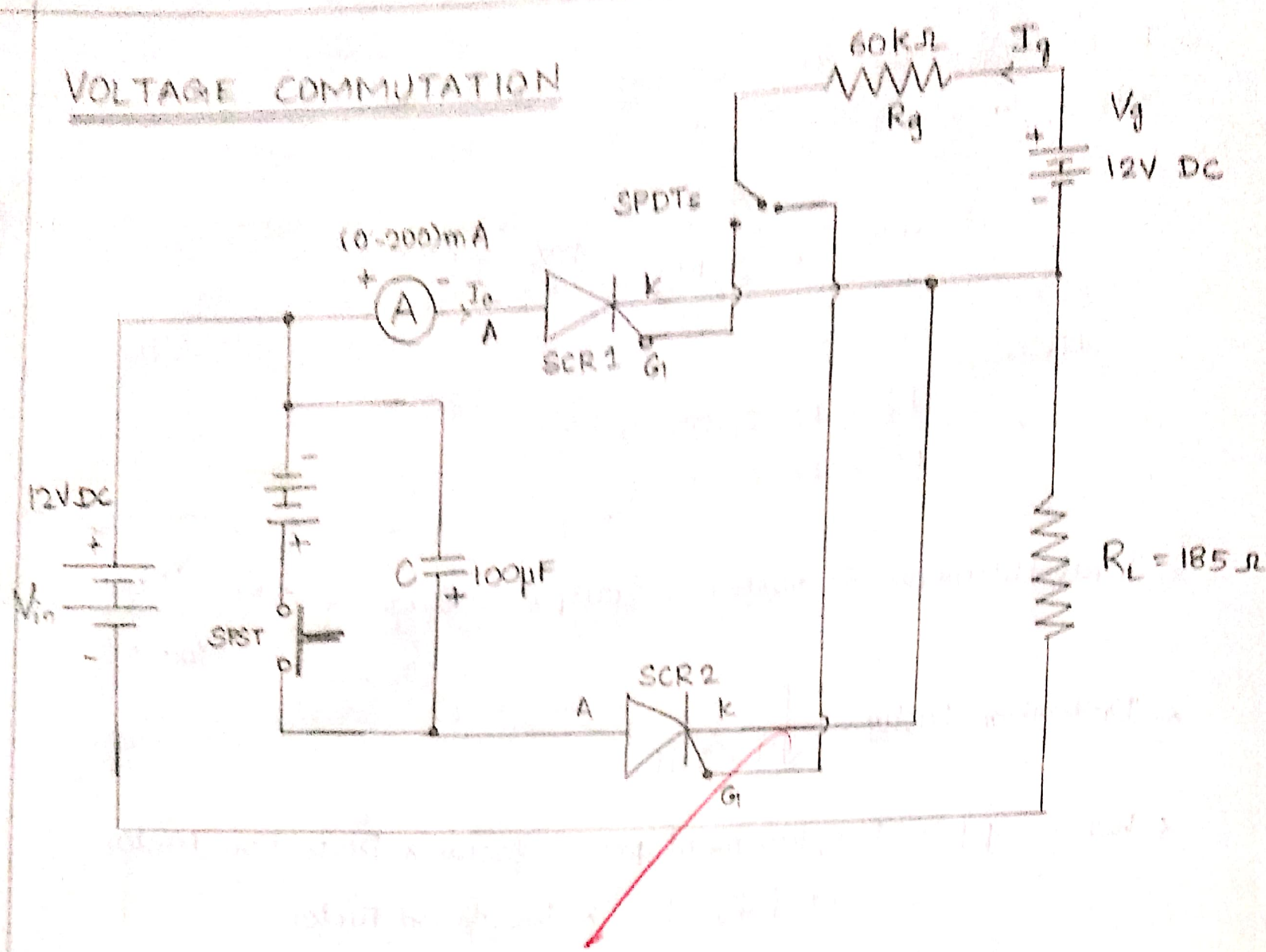
* In power cables or transmission lines, due to harmonics, the value of RMS current increases, skin effect increases and proximity effect also increases.

Hence the transmission power losses also increases and excessive overheating of transmission lines will deteriorate the lines.

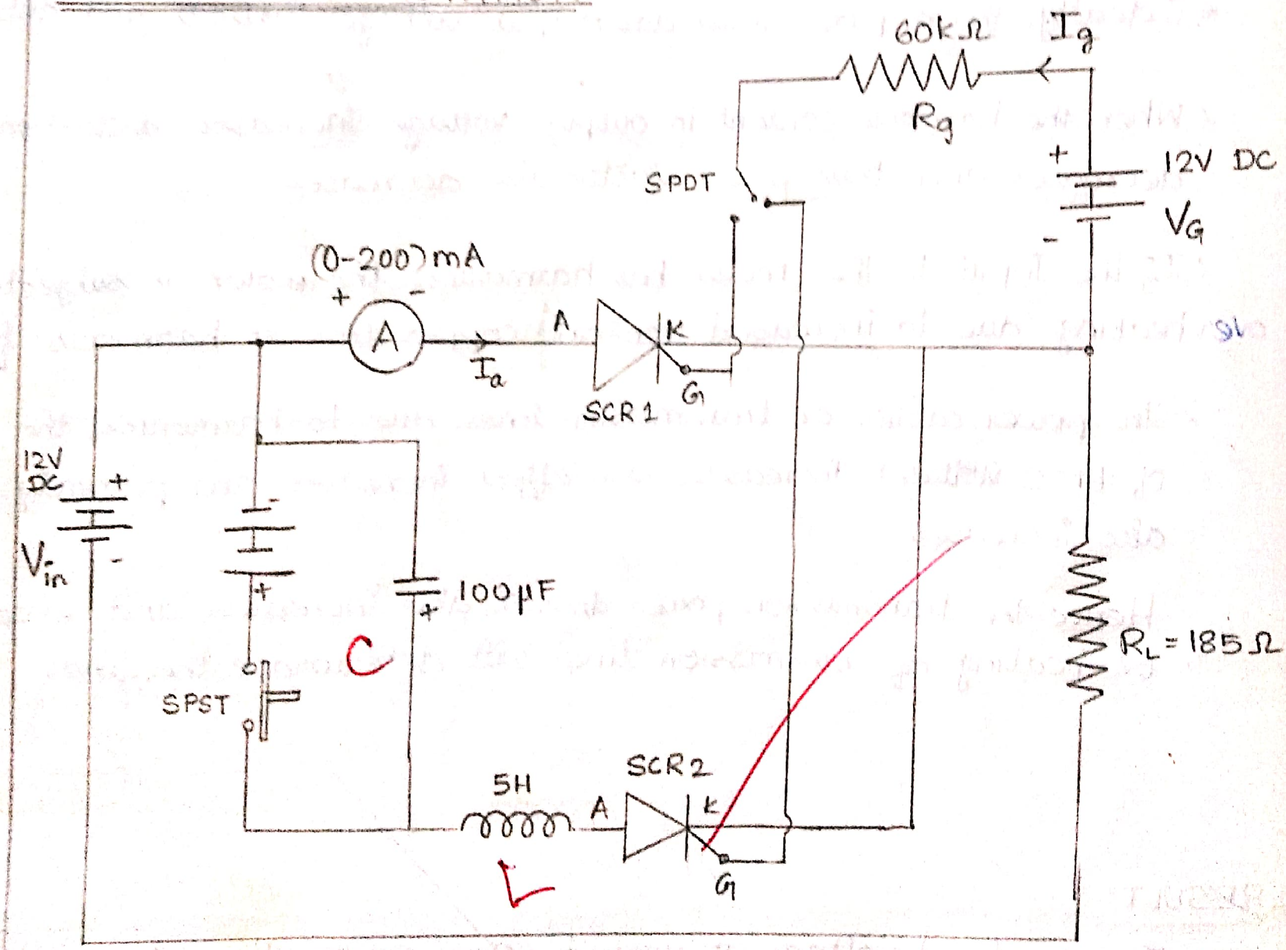
RESULT:

* The AC load voltage is varied using single phase AC voltage controller by adjusting the firing angle (α) of the SCRs and the output waveforms are observed.

VOLTAGE COMMUTATION



CURRENT COMMUTATION



EXPT NO: 2
DATE: 22/3/22

COMMUTATION OF SCR

AIM:

To turnoff or commutate the conducting SCR by voltage commutation, current commutation.

APPARATUS REQUIRED:

S.No	NAME	SPECIFICATION	QUANTITY
1.	SCR	H2P4M	2
2.	SPST switch	–	1
3.	Inductor	5H	1
4.	Resistor	1kΩ, 60kΩ	1 each
5.	Capacitor	100μF	1
6.	MC Ammeter	(0-500)mA	1

SPECIFICATIONS OF SCR H2P4M:

* Peak Inverse voltage = 400V
* Maximum forward current = 2A
* Gate Triggering current = 0.2 mA
* Holding current = 1 mA

CIRCUIT DESIGN:

Capacitance Calculation

$$I_p = V\sqrt{\frac{C}{L}} \Rightarrow C = \frac{I_p^2 \times L}{V^2}$$

where I_p - Peak Resonance Current (A)
V - Supply voltage to SCR
C - Capacitance
L - Inductance

Let $I_p = 60mA$, $L = 5H$; $V = 12V$

Then $C = (60 \times 10^{-3})^2 \times \frac{5}{12^2} = 125\mu F \simeq 100\mu F$

Resistance (R_L) calculation

Assume Load current $I_L = 200\,mA$

Assume $V_{i\,max} = 12V$

Load Resistance $= \frac{V_{i\,max}}{I_L} = \frac{12}{0.2} = 60\Omega$

1.5

So, R_L is chosen as $185\Omega / 0.2A$

Triggering Circuit

$V_g = 12V$; $I_g = 0.2\,mA$

$$R_g = \frac{V_g}{I_g} = \frac{12}{0.2 \times 10^{-3}} = 60k\Omega$$

PROCEDURE:

1. Circuit connections are given as shown in the diagram
2. SPSTs Switch is closed for 10s to charge the capacitor 'C'
3. SCR-1 is triggered by closing the SPDT switch. Now the load current flows.
4. Meter readings are noted.
5. Now after sometime SCR2 is closed to turn off SCR 1
6. The current is made to zero due to commutation.

INFERENCE:

* Commutation is the process of turning off a conducting SCR.

Commutation
- Natural Commutation
- Forced commutation
  - Voltage commutation
  - Current commutatio

Natural Commutation:

* It occurs in AC circuits.
* When the supply voltage is in the negative half cycle, the negative voltage appearing across the SCR ~~becom~~ turns it off.
* As there are no special Commutation circuits needed, this commutation method is called natural commutation.

Forced Commutation:-

* Natural commutation is not possible in DC circuits.
* So, a seperate commutation circuit is used to turn off the conducting SCR.

OBSERVATION:

Voltage Commutation :

S. No	Current through SCR1 before triggering SCR2 (mA)	Current through SCR1 after triggering SCR2 (mA)
1.	30	0

Current Commutation:

S. No.	Current through SCR1 before triggering SCR2 (mA)	Current through SCR1 after triggering SCR2 (mA)
1	30	0

TCE, Dept. of EEE. Record Marks		
Results & Graphs	4	4
Inference	6	5
Total	10	9

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29/3/22

1. Voltage Commutation

In this commutation, the conducting SCR is turned off by applying reverse bias to the SCR (When cathode voltage is greater than anode voltage)

2. Current Commutation

In this commutation, the anode current of SCR is reduced below the holding current value and thus, the SCR turns off.

* The minimum anode current value below which the anode current must fall to turn off the SCR is called the holding current (I

TCE, Dept. of EEE. Observation Marks		
Viva - Voce	5	4
Design and Conduct of Experiments	10	10
Observation / Coding / Implementation	5	5
Total	20	19

RESULT:

The conducting SCR was turnedoff (commutated) by

1. Voltage commutation

2. Current commutation

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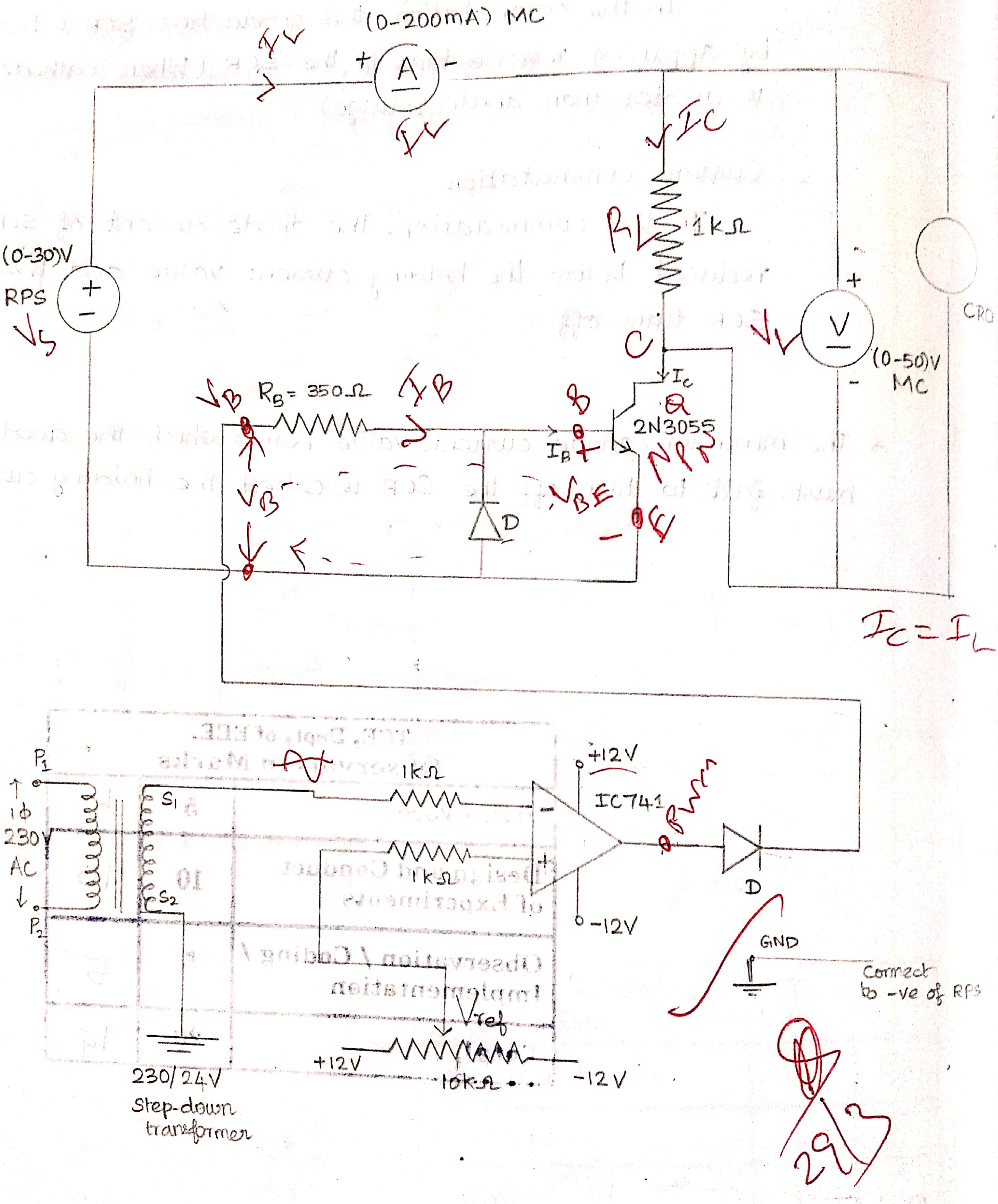
24/3/22

CIRCUIT DIAGRAM



EXPT NO: 3
DATE: 29/03/2022

DC CHOPPER

AIM:

To design and study the operation of step-down DC chopper.

APPARATUS REQUIRED:

S.No	APPARATUS	SPECIFICATION	QUANTITY
1.	Power BJT	2N3035	1
2.	Op-Amp	IC741	1
3.	Diode	1N4001	1
4.	Resistor	1kΩ, 10kΩ	1 each
5.	Rheostat	115 Ω/1.5A	1
6.	Potentiometer	5kΩ	1
7.	Transformer	230V/24V	1

Pw

Transistor 2N3035 Specifications

* Max Collector Current = 5A
* Max. base current = 1 A
* Max collector base Voltage = 100V
* Max. collector emitter voltage = 100V
* $H_{fe} = 20 - 70$ $= \frac{I_C}{I_B}$

Power Transistor

FORMULA USED:

$$\boxed{V_L = D\,V_s}$$

where

V_L - load voltage (V)

D - Duty Cycle $= \frac{T_{ON}}{T_{ON} + T_{OFF}}$

V_s - Supply voltage

CIRCUIT DESIGN:

Let $I_c = I_L = 30mA$ 30mA

Max. supply Voltage, $V_s = 30V$ DC

Load Resistance $R_L = \frac{V_L}{I_L} = \frac{30}{30mA} = 1k\Omega$

We have chosen R_L as $1\,k\Omega$

Let $H_{fe} = 30$

$$\Rightarrow I_b = \frac{I_c}{H_{fe}} = \frac{30mA}{30} = 1mA$$

By kirchoff's voltage law,

$V_{BE} = 0.7V$ (To turn on &
$V_B = V_{BE} + I_B R_B$

$$R_b = \frac{V_b - V_{BE}}{I_b}$$

$V_b = +V_{sat} = +12V$

$$= \frac{12 - 0.7}{1 \times 10^{-3}} = 11.3k\Omega \simeq 10k\Omega$$ (Since $10k\Omega$ is available in lab)

Hence R_b is chosen as $10k\Omega$

Design:

Load resistance $= 1k\Omega$ (Assuming $V_s = 30V$ & $I_c = I_L = 30mA$)

Base resistance $= 10k\Omega$ (Assuming $H_{fe} = 30$ and $V_b = V_{sat} = 12V$)

PROCEDURE:

* Make the connections as shown in the circuit diagram.
* Give the output of control unit to the base of the power transistor in the main circuit.
* Note down the ammeter and voltmeter readings.
* Observe the waveform of the load voltages in CRO and calculate ON time and OFF time.
* Vary the ON time of load voltage in steps by adjusting the potentiometer in control unit.
* Draw the following graph: Time Vs Load voltages for a particular duty cycle.

THEORY:

* DC Chopper is a static circuit that converts fixed DC input voltage to a variable DC voltage directly. The power semiconductor devices used for a chopper circuit can be force commutated thyristor, power BJT, power MOSFET, GTO or IGBT.

* These devices can be generally considered as switches.
* When the switch is off, no current can flow and when the switch is on, current flows.
* In a similar way, it connects source to load and disconnects the load from source at a faster speed.
* By adjusting the duty cycle, dc voltage can be varied.

DC Chopper

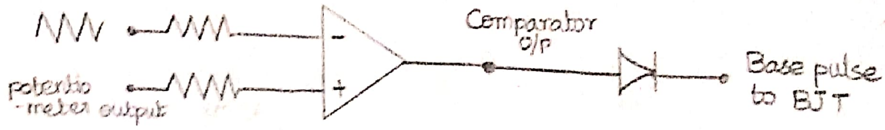
Input voltage = 30 V DC (constant)

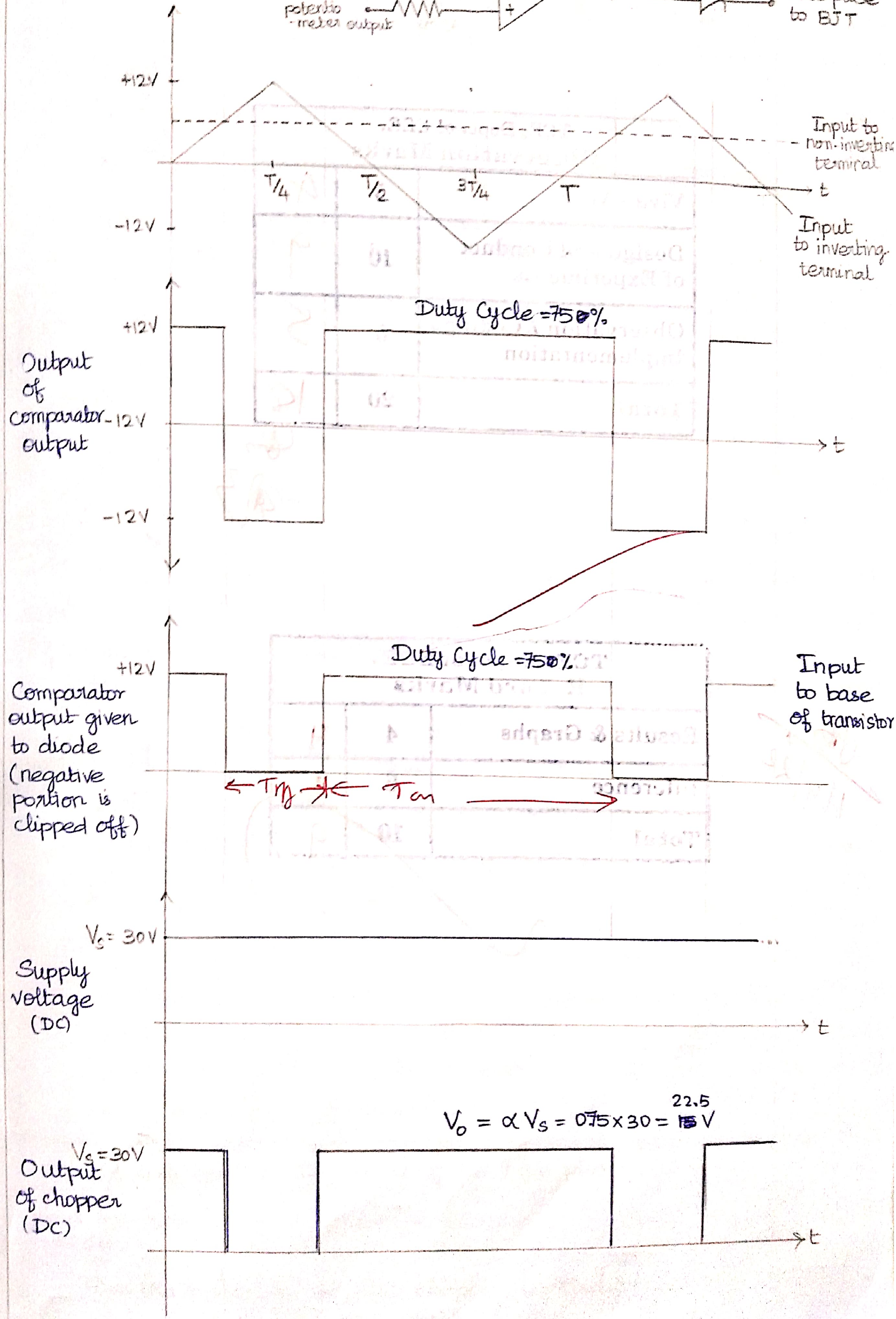
Output voltage = (0-30V) DC (Variable)

TABULATION (Time Period = 0.5 ms)

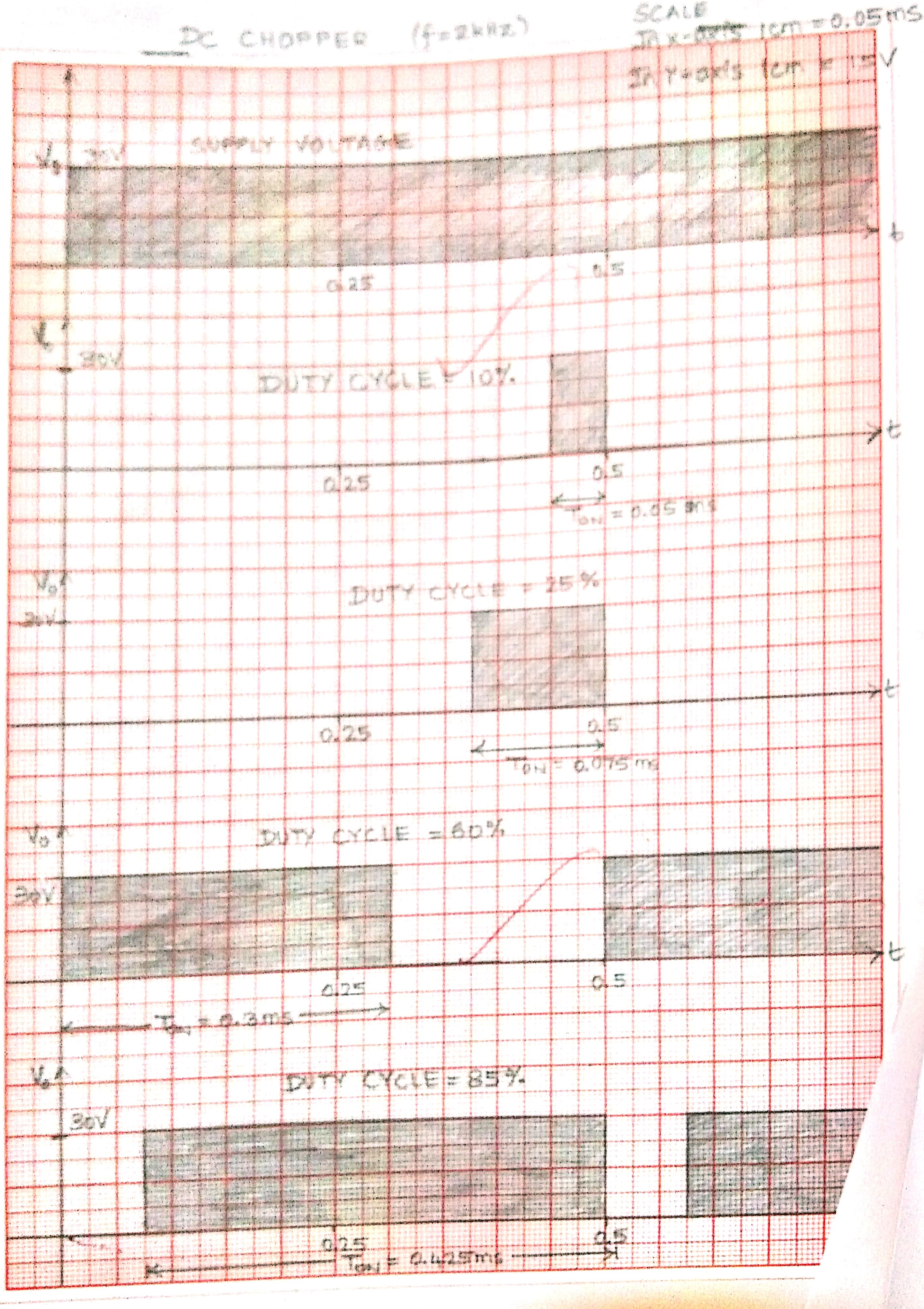
Sl. No	Supply voltage V_s (V)	Theoretical Load voltage (V_L)	Load Voltage Actual V_L (V)	Load current (mA)	On time T_{ON} (ms)	OFF time T_{OFF} (ms)	Duty cycle (%)
1	30	4.68	4.4	4.5	0.078	0.422	15.6
2.	30	7.05	7.6	7	0.1175	0.3825	23.5
3.	30	11.22	11.2	12	0.187	0.313	37.4
4.	30	14.1	14	15	0.235	0.265	47
5.	30	17.7	17.6	19	0.295	0.205	59
6.	30	21.45	21.6	22	0.3575	0.1425	71.5
8.	30	24.21	24.6	26	0.4035	0.5965	80.7
9.	30	26.76	26.8	29	0.446	0.054	89.2
10.	30	29.52	30	31	0.492	0.008	98.4

Model waveform





DC CHOPPER (f=2kHz)



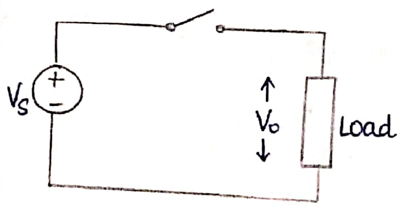
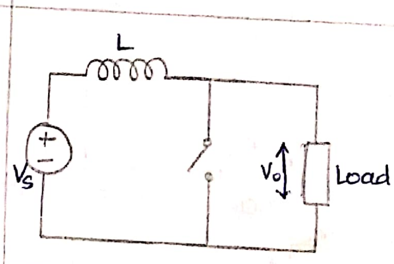
INFERENCE:

* Choppers are used in power electronics applications where very high efficiency (more than 90%) is required.

* Since in choppers, the load voltage is entirely zero for sometime, power consumption (V×I) is equal to zero. Hence power consumption is reduced to a larger extent.

* There are 2 major classification of choppers ⇒ step up and step-down

Comparison between step-up and step-down chopper:

	STEP DOWN CHOPPER	STEP UP CHOPPER
Circuit diagram		
When switch is "ON"	When switch is "ON", $V_o = V_s$	The closed switch short circuits the load and inductor starts charging
When switch is "OFF"	$\boxed{V_o = 0V}$	Inductor discharges. RPS and inductor together in series supplies to load $\boxed{V_o > V_s}$
Expression for output voltage	$V_o = D V_s$	$V_o = \frac{V_s}{(1-D)}$
Applications	Motor speed control	Battery charging / voltage boosters

* Output of DC chopper is independent on PWM signal's frequency. It only depends on the duty cycle of the base pulse.

RESULT:

Thus the operation of DC chopper is studied.

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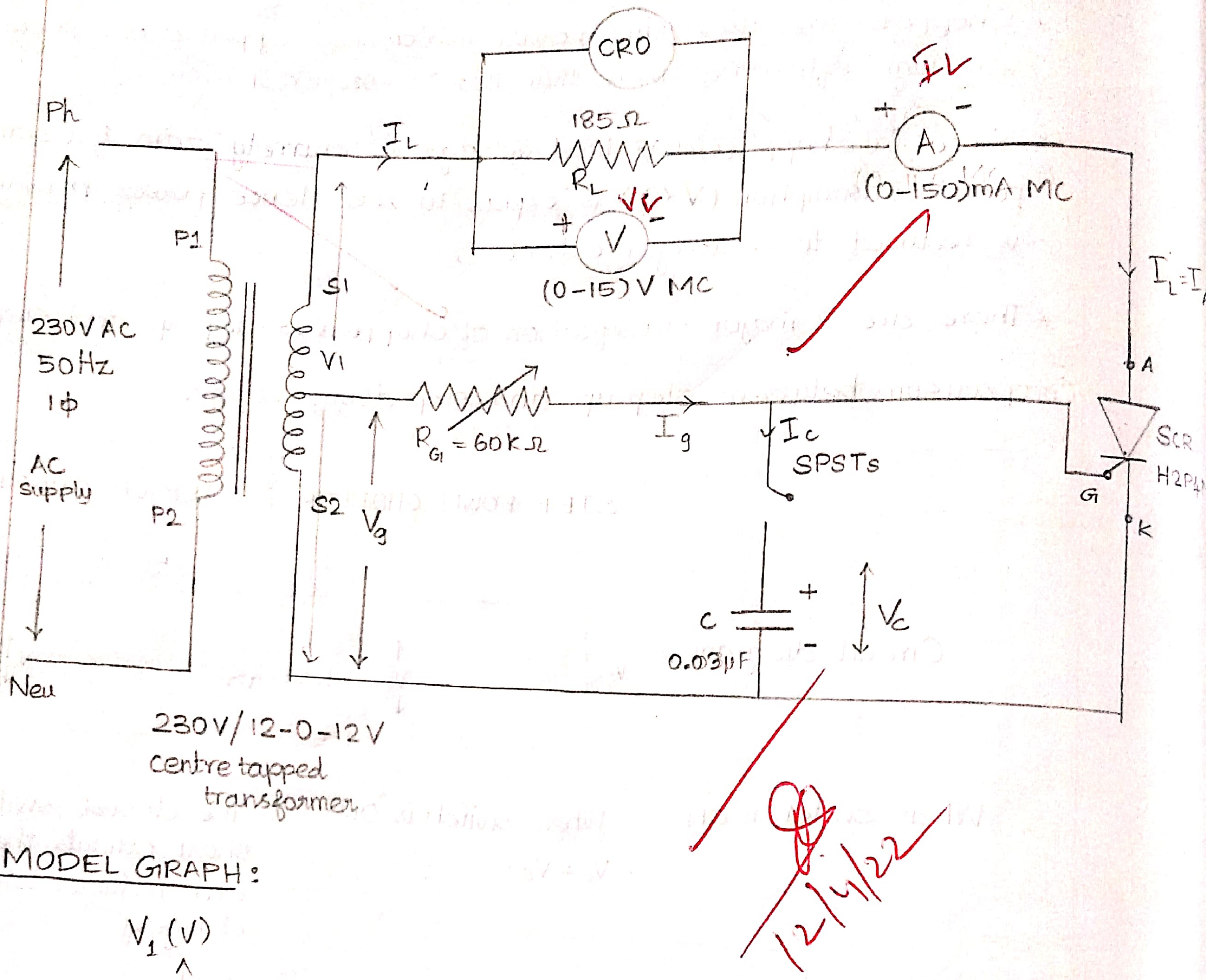
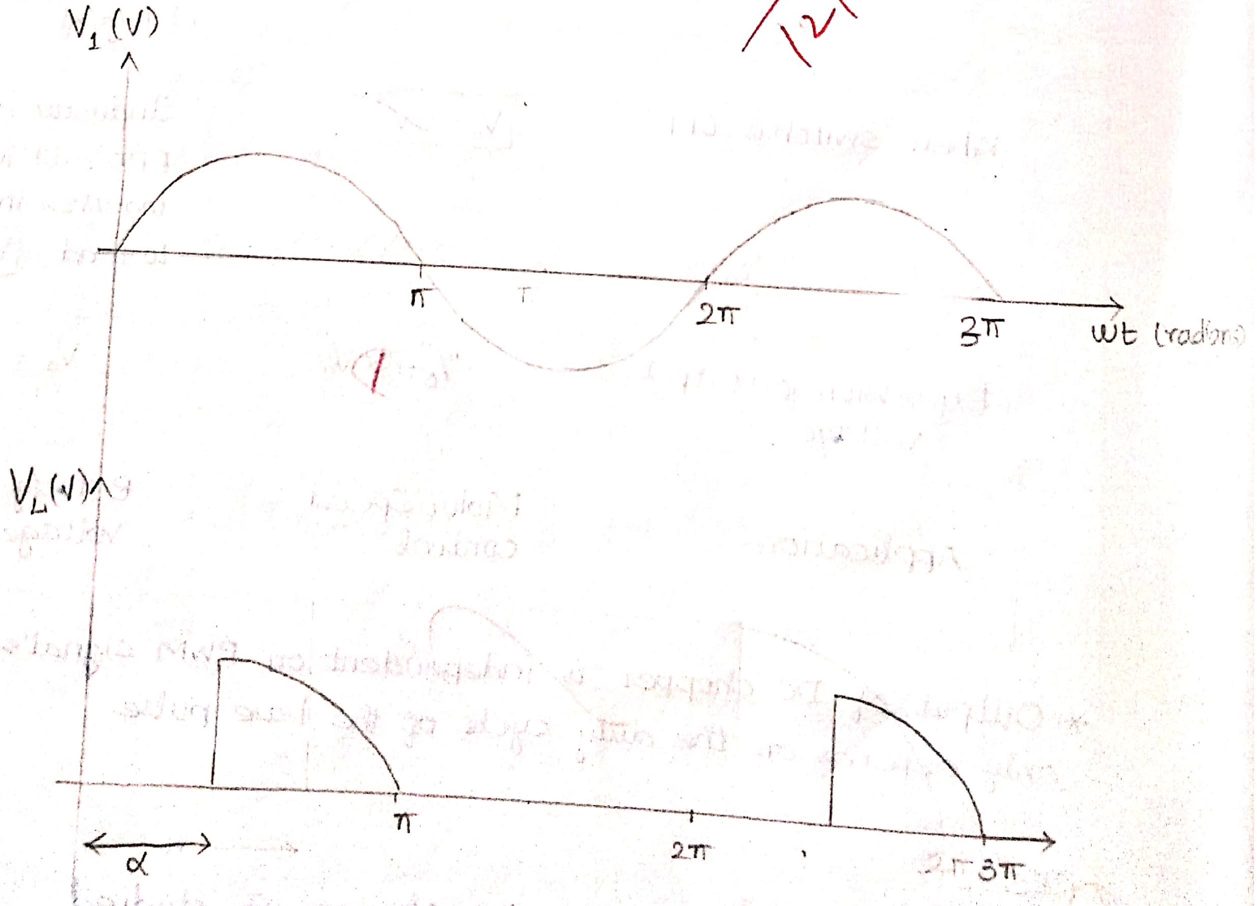
CIRCUIT DIAGRAM



MODEL GRAPH:



α = Firing angle

EXPT NO: 4
DATE: 12-04-2022

SCR TRIGGERING CIRCUITS

AIM:

To trigger the SCR using 'R' and 'RC' triggering methods.

APPARATUS REQUIRED:

S. No	APPARATUS	SPECIFICATION	QUANTITY
1.	SCR	H2P4M	1
2.	Ammeter	(0-150)mA MC	1
3.	Voltmeter	(0-15)V MC	1
4.	Resistor	33kΩ, 10kΩ, 2.2kΩ	1 each
5.	Decade Resistance Box	100 MΩ	1
6.	Capacitor	0.03 μF	1
7.	Centre Tapped Transformer	230V/12-0-12V	1

Specifications of SCR H2P4M:

Peak Inverse Voltage = 400V

Maximum forward current = 2A

Maximum gate triggering current = 0.2 mA

Holding current = 1 mA

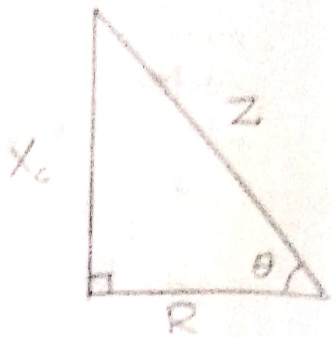
CIRCUIT DESIGN:

The output of the centre tapped transformer = 12 V

⇒ So MC voltmeter of range (0-15)V is chosen

Let $I_g = 0.2$ mA (Gate current of SCR)

$$\Rightarrow R_g = \frac{V_g}{I_g} = \frac{12}{0.2\times10^{-3}} = 60\,k\Omega$$



$$\theta = \tan^{-1}\left(\frac{X_c}{R_g}\right)$$

$$\Rightarrow X_c = R_g \tan\theta \quad \text{and} \quad X_c = \frac{1}{2\pi f C}$$

Let $\theta = 60^\circ$ ~~and~~

$$\frac{1}{2\pi\times50\times C} = 60\times10^{3}\times\tan60^\circ$$

$$\Rightarrow C = \frac{1}{2\pi\times50\times60\times10^{3}\times\tan60^\circ} = 0.03\,\mu F$$

For Half-wave controlled rectifier

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

Let $\alpha = 0^\circ$ and $V_{rms} = 24V$

$$V_{L(avg)} = \frac{V_m(1+1)}{2\pi} = \frac{\sqrt{2}\times V_{rms}}{\pi} = \frac{\sqrt{2}\times24}{\pi}$$

$$\boxed{V_{L(avg)} = 10.8\,V}$$

Let $I_L = 100$ mA

$$R_L = \frac{V_{L(avg)}}{I_L} = \frac{10.8}{100\times10^{-3}} = 108\,\Omega$$

Hence R_L is chosen as 185 Ω / 1.5 A

PROCEDURE:

Initial conditions:

* CRO should be isolated
* Ensure all components are in good conditions.

1. Circuit connections are given as shown in the circuit diagram.
2. The SPST switch is in open conditions for 'R' triggering.
3. By varying the R_g (decade resistance box) the firing angle is varied.
4. The firing angle is varied from 0° to 90°
5. Ammeter, voltmeter and CRO readings (4 to 5 readings) are observed.
6. 1st channel of CRO is connected across the output to observe the output waveform.
7. 2nd channel of the CRO is connected across the input to observe the input waveform.
8. Graph are plotted between
   * Input voltage Vs Time
   * Output voltage Vs Time
9. The same procedure is followed by closing the SPSTs.

OBSERVATIONS:

Sl. No	Firing Angle α (degrees)		Without Capacitor (R Triggering)		With Capacitor (RC Triggering)	
	R Triggering	RC Triggering	Load voltage (V)	Load current (mA)	Load voltage (V)	Load current (mA)
1.	0°	6°	8.5	46	8.5	46
2.	12°	24°	8.4	44	8.2	43
3.	24°	36°	8.1	43	7.7	41
4.	36°	42°	7.5	41	7.2	38
5.	48°	52°	6.6	39	6.7	32
6.	60°	66°	6.2	32	61	30
7.	66°	78°	6	31	5.4	28

Sl. No	Gate Resistance R_G (kΩ)	Firing Angle (α) [degree]	
		R Triggering	RC Triggering (C = 0.1 μF)
1.	60	0°	6°
2.	160	12°	24°
3.	260	24°	36°
4.	360	36°	42°
5.	460	48°	52°
6.	560	60°	66°
7.	610	66°	78°

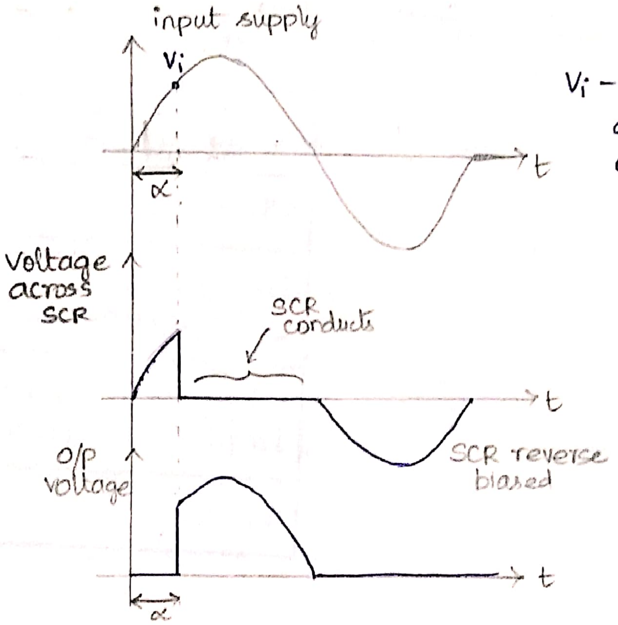
INFERENCE :

* To make an SCR conduct, two conditions must be satisfied.
  - (i) The SCR must be forward biased (Anode voltage > Cathode voltage)
  - (ii) Gate pulse must be applied.

* For H2P4M SCR, minimum 0.2mA should flow in gate circuit to make the SCR conduct.

* By varying the gate resistance, we can vary the angle at which minimum gate current flows and thus making the SCR to conduct.

* In sinusoidal supply, the voltage value rises from 0 to peak value.
  - ⇒ When gate resistance is low, lesser instantaneous voltage will turn on the SCR



V_i – instantaneous voltage at which SCR starts conducting

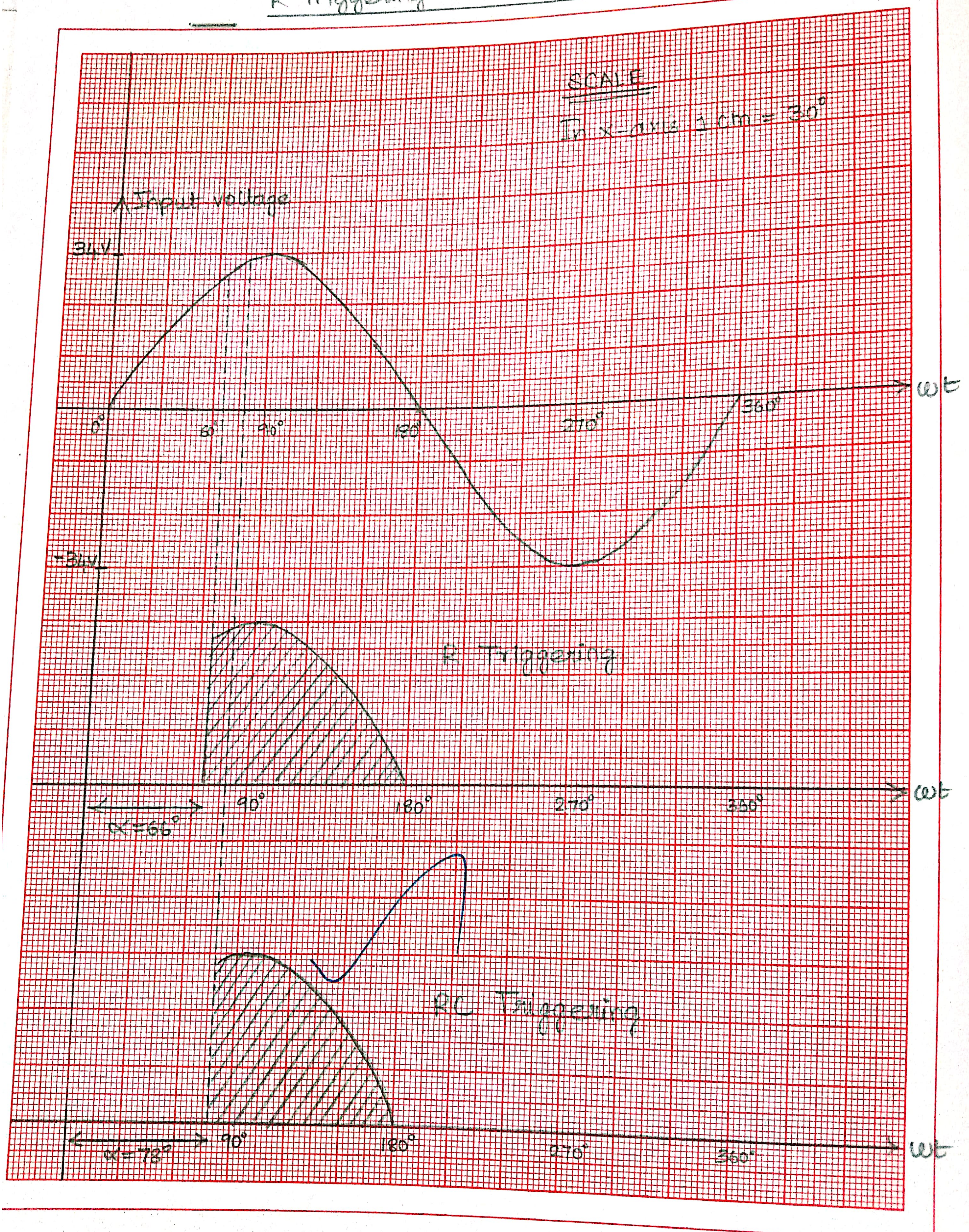
$$\Rightarrow \quad \frac{V_i}{R_G} = 0.2\,mA$$

  - ⇒ When gate voltage is larger, larger instantaneous voltage will be required to turn on the SCR.

* So, by increasing the gate resistance, firing angle can be increased.

Disadvantage of R Triggering:-
* Firing angle of the SCR can be in the range of 0° to 90° only.
* Reason:- Beyond 90°, the value of instantaneous voltage reduces. So, even though resistance is increased, we cannot get firing angle more than 90°.

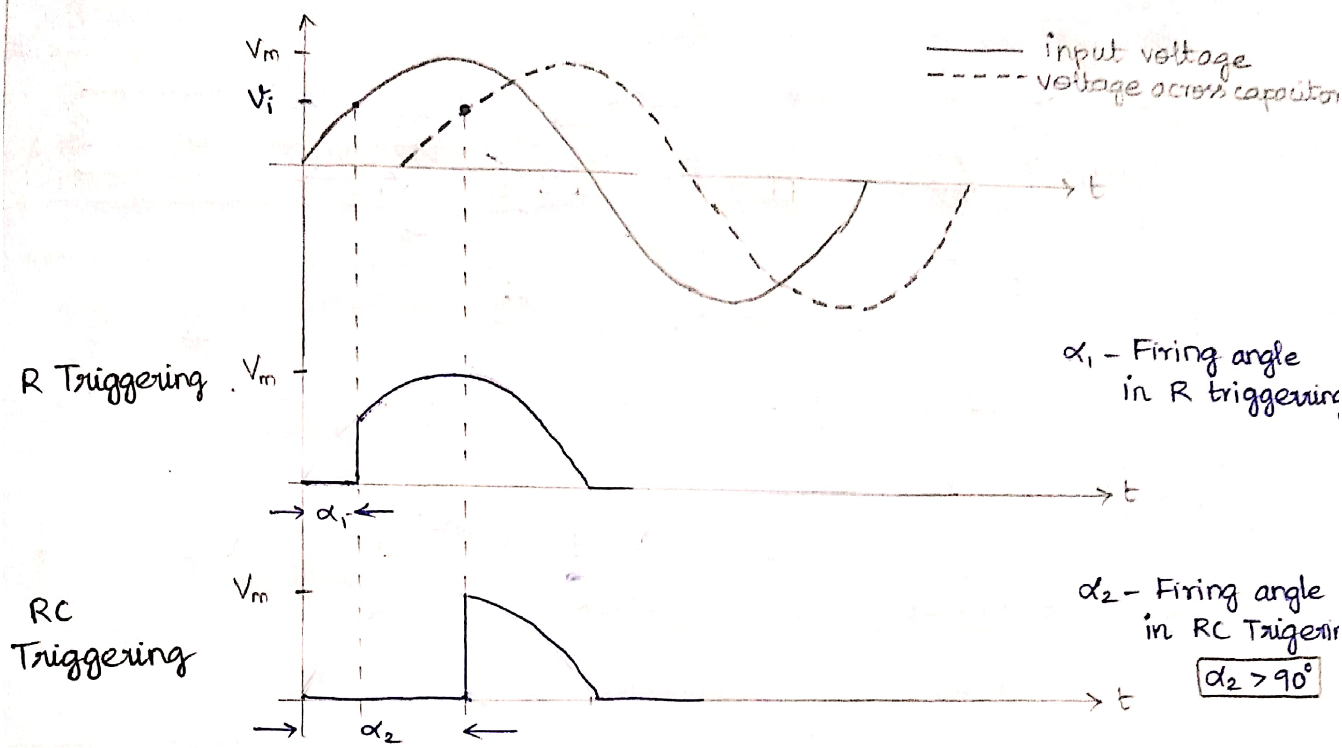
R Triggering and RC Triggering



RC Triggering:-

* The capacitor voltages lags the gate resistance voltage by an angle ϕ where $\phi = \tan^{-1}\left(\frac{X_c}{R_g}\right)$

X_c - Capacitance reactance $\Rightarrow X_c = \frac{1}{2\pi f C}$



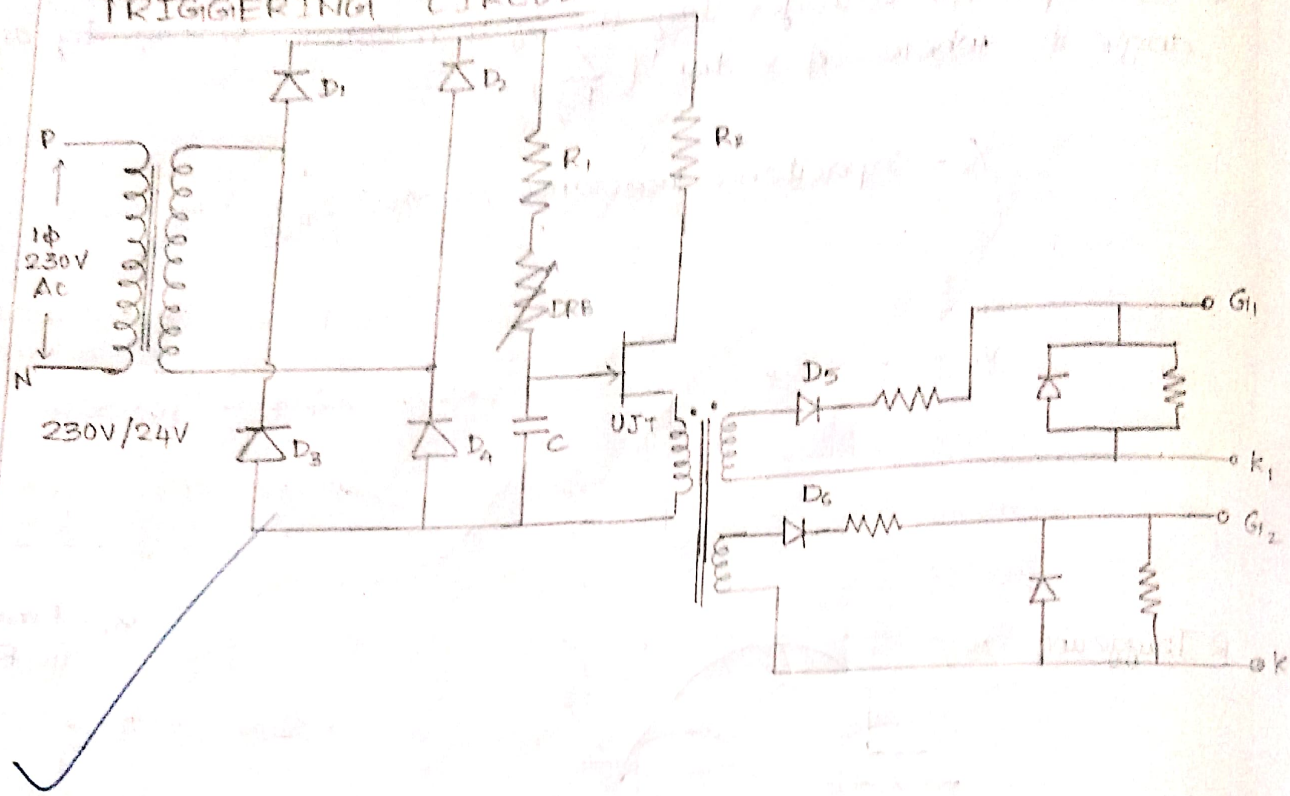
* Hence by adjusting the value of capacitance, we can increase the firing angle

RESULT:

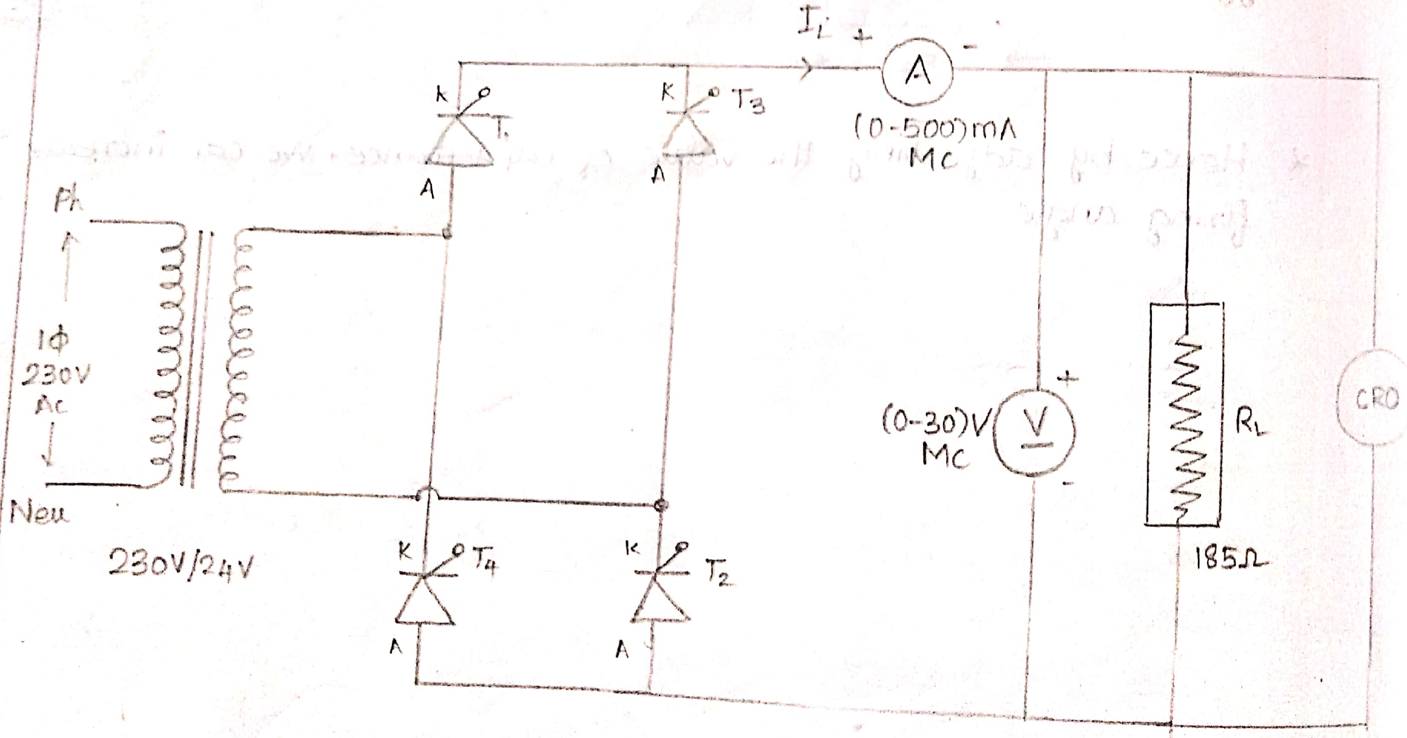
* The SCR in the half wave controlled rectifier circuit is triggered by R and RC triggering.

* R triggering and RC triggering concepts are understood.

TRIGGERING CIRCUIT:



SINGLE PHASE FULL CONVERTER



EXPT NO: 5
DATE: 21-04-22

SINGLE PHASE SEMI AND FULL CONVERTER WITH 'R' AND 'RL' LOAD

AIM:

To vary the DC load voltage across load using single-phase full converter and semi-converter by changing the firing angles.

APPARATUS REQUIRED:

S.No.	APPARATUS	SPECIFICATION	QUANTITY
1.	Diode	1N4007	2
2.	Decade Resistance Box	0-10 MΩ	1
3.	UJT	H2N2646	1
4.	SCR	H2P4M	4

PROCEDURE:

(i) Make the connections as per the circuit diagram

(ii) Give 230V AC to main circuit and triggering circuits

(iii) Note down the ammeter and voltmeter readings.

(iv) Observe the waveforms of load voltage in CRO and calculate 'α'

(v) Vary the firing angle 'α' in steps of 0° to 180° by adjusting resistan 'R' in UJT Triggering circuit. and for each α, do steps (iii) and (iv)

(vi) Draw the graph (load voltage Vs ωt)

EXPT NO: 5
DATE: 21-04-22

SINGLE PHASE SEMI AND FULL CONVERTER WITH 'R' AND 'RL' LOAD

AIM:

To vary the Dc load voltage across load using single-phase full converter and semi-converter by changing the firing angles.

APPARATUS REQUIRED:

S.No.	APPARATUS	SPECIFICATION	QUANTITY
1.	Diode	1N4007	2
2.	Decade Resistance Box	0-10 MΩ	1
3.	UJT	H2N2646	1
4.	SCR	H2P4M	4

PROCEDURE:

(i) Make the connections as per the circuit diagram

(ii) Give 230V AC to main circuit and triggering circuits

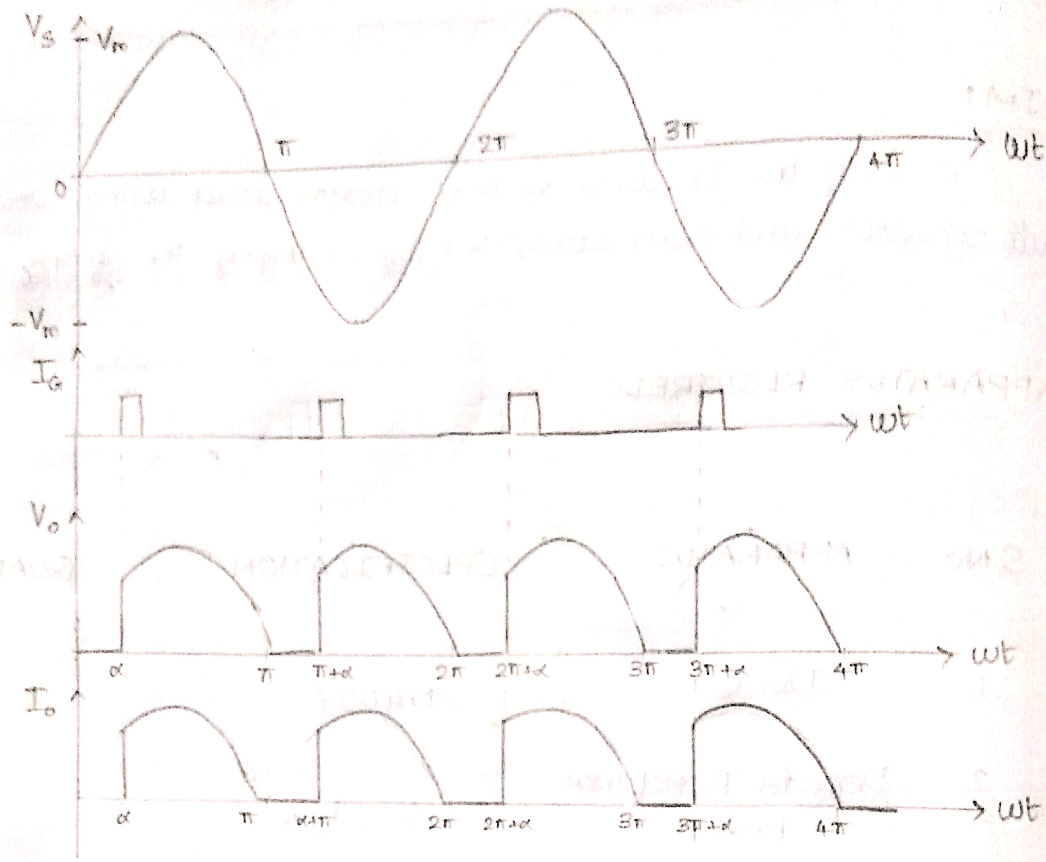
(iii) Note down the ammeter and voltmeter readings.

(iv) Observe the waveforms of load voltage in CRO and calculate 'α'

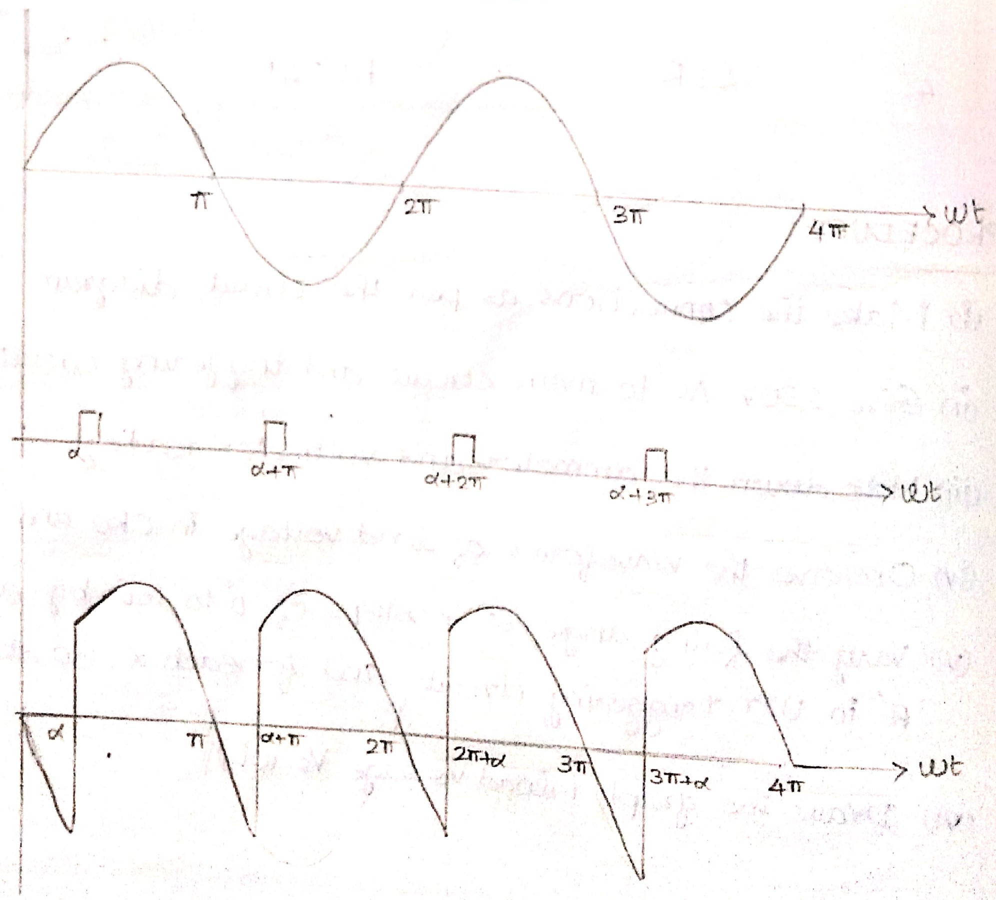
(v) Vary the firing angle 'α' in steps of 0° to 180° by adjusting resistance 'R' in UJT Triggering circuit. and for each α, do steps (iii) and (iv)

(vi) Draw the graph (load voltage Vs wt)

SINGLE PHASE FULL CONVERTER – R LOAD



SINGLE PHASE FULL CONVERTER – RL LOAD:



DESIGN:

Let load current be, $200mA \le I_L \le 500 mA$

(i) Let $I_L = 500mA$, $R_{L(min)} = \frac{V_{in\ peak}}{I_{L(max)}} = \frac{24\sqrt{2}}{500\times10^{-3}} = 67.88\,\Omega$

(ii) $I_L(min) = 200mA$, $\Rightarrow R_L(max) = \frac{V_{in\ peak}}{I_L(min)} = \frac{24\sqrt{2}}{200\times10^{-3}} = 169.7\,\Omega$

Hence R_L is chosen as $185\,\Omega / 1.5A$

Since $I_L(max) = 500mA$, Ammeter is chosen as (0-500) mA MC

SPECIFICATIONS OF H2P4M:

* PIV = 400 V
* Max. forward current = 2 A
* Max. gate triggering current = 0.2 A
* Holding current = 1 mA

DERIVATION OF AVERAGE VOLTAGE:

1ϕ Full converter – R load:-

$$V_{o\,avg} = \frac{1}{2\pi}\int_0^{2\pi} V_o(t).d(\omega t) = \frac{1}{\pi}\int_0^{\pi} V_o(t).d(\omega t)$$

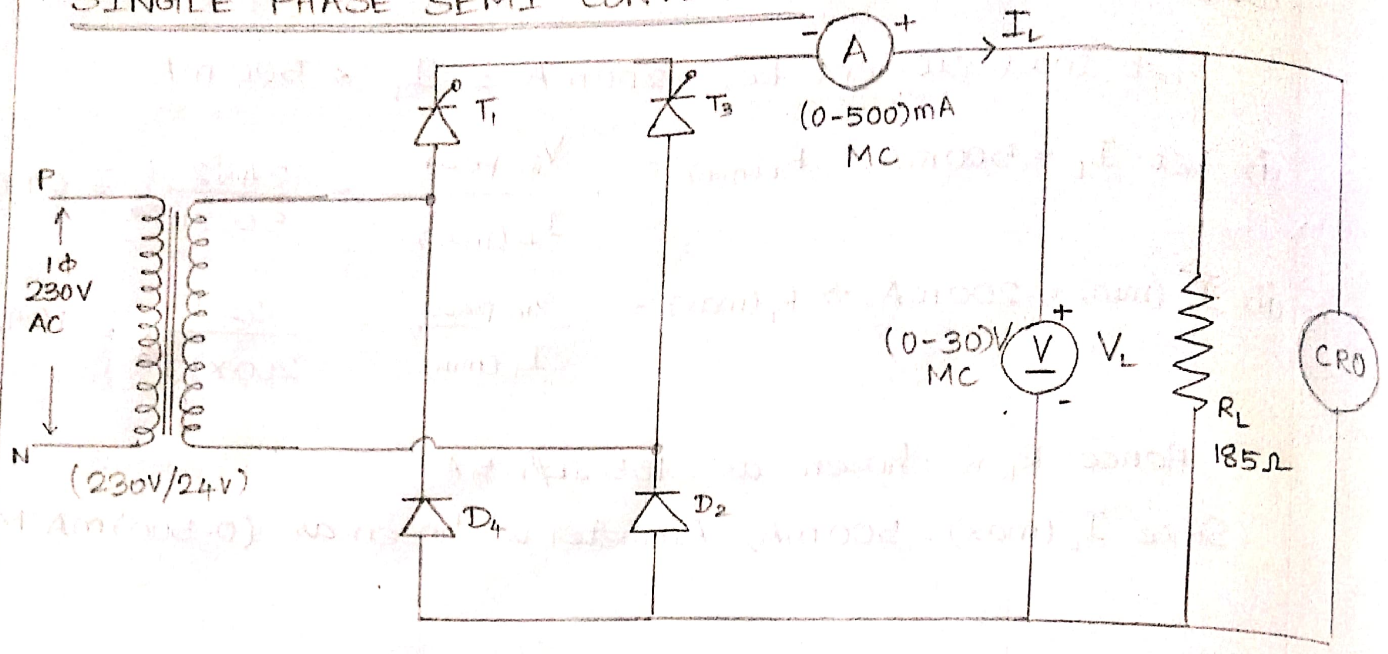
$$= \frac{1}{\pi}\int_\alpha^{\pi} V_m \sin \omega t . d(\omega t)$$

$$= \frac{V_m}{\pi}\left[-\frac{\cos\omega t}{1}\right]_\alpha^{\pi} = -\frac{V_m}{\pi}\left[\cos(\pi) - \cos(\alpha)\right]$$

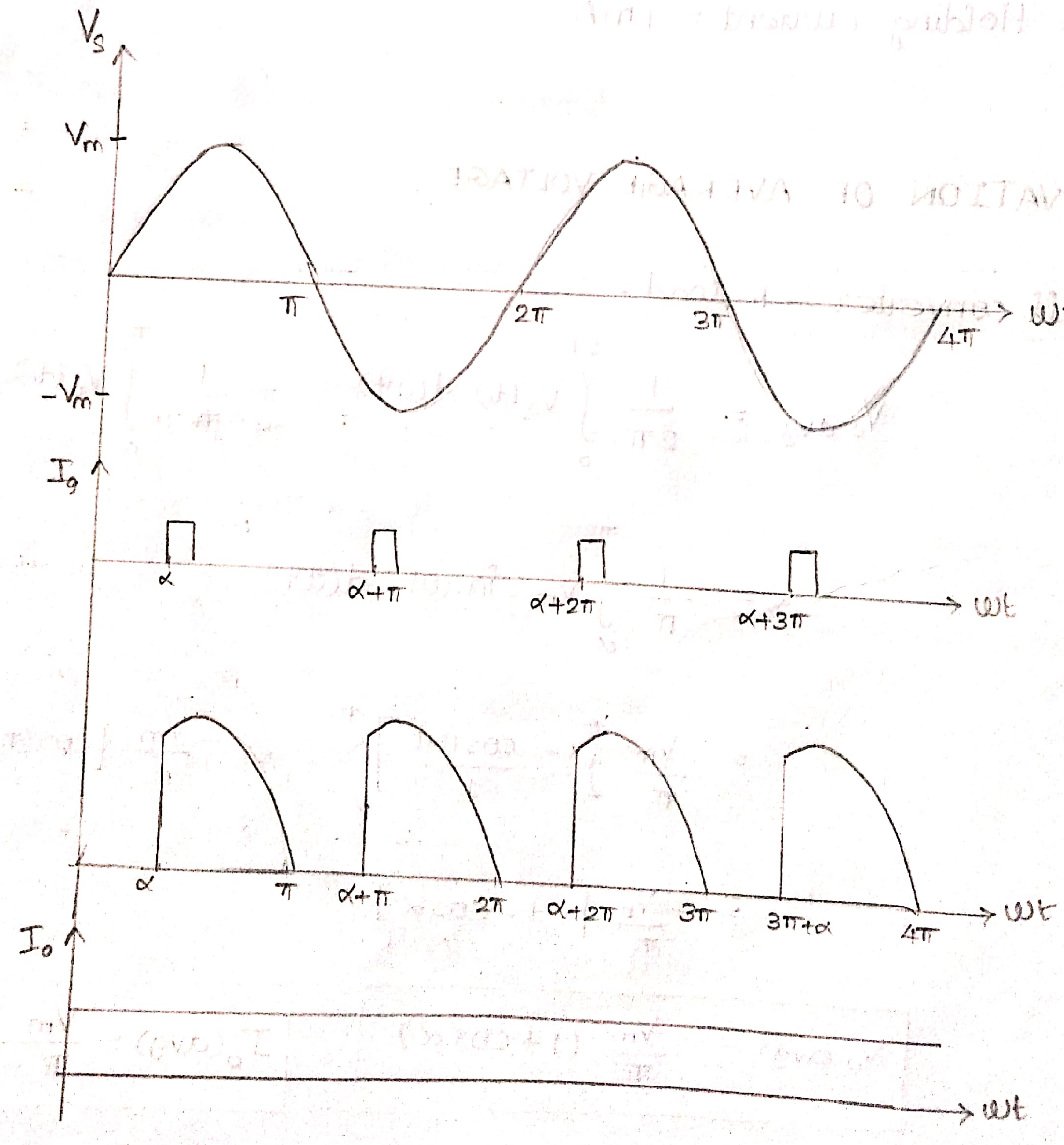
$$= -\frac{V_m}{\pi}\left[-1-\cos\alpha\right]$$

$$\boxed{V_o(avg) = \frac{V_m}{\pi}(1+\cos\alpha)} \qquad \boxed{I_o(avg) = \frac{V_m}{\pi}(1+\cos\alpha).\frac{1}{R}}$$

SINGLE PHASE SEMI CONVERTOR



SINGLE PHASE SEMI CONVERTER – R LOAD and RL LOAD

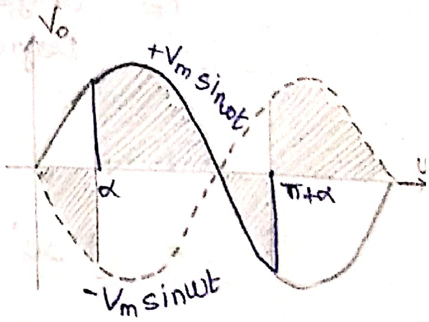


1ϕ Full Converter with RL load

$$V_{o\,avg} = \frac{1}{\pi}\left[\int_0^{\alpha} -V_m \sin\omega t \, d(\omega t) + \int_{\alpha}^{\pi} V_m \sin\omega t \, d(\omega t)\right]$$

* Since the voltage waveform from 0° to π rad and π rad to 2π rad are symmetrical.

* So let us use a base of π for easy calculation



(or)

$$V_{o\,avg} = \frac{1}{\pi}\left[\int_{\alpha}^{\pi+\alpha} V_m \sin\omega t \, d(\omega t)\right]$$

$$= \frac{V_m}{\pi}\left[\int_{\alpha}^{\pi+\alpha} \sin\omega t \, d(\omega t)\right] = \frac{V_m}{\pi}\left[-\frac{\cos\omega t}{1}\right]_{\alpha}^{\pi+\alpha}$$

$$= -\frac{V_m}{\pi}\left[\cos(\pi+\alpha) - \cos(\alpha)\right] = -\frac{V_m}{\pi}\left[-\cos\alpha - \cos\alpha\right]$$

$$\boxed{V_{o\,avg} = \frac{2V_m}{\pi}\cos\alpha}$$

Note:- When $\alpha = \frac{\pi}{2}$, $V_o = 0V$

$$\boxed{I_{o\,avg} = \frac{2V_m}{\pi R}\cos\alpha}$$

TABULATION:-

SINGLE PHASE FULL CONVERTOR:

Sl. No	Firing angle (α) Degree	R LOAD			RL Load		
		Load Voltage (V)		Load current (mA)	Load Voltage (V)		Load current (mA)
		Theoretical	Experimental		Theoretical	Experimental	
1.	0°	21.6	23	21	21.6	23	21
2.	30°	20.16	22	19	18.71	21	17
3.	60°	16.2	17.5	15	10.8	16.5	14
4.	90°	10.8	12	11	0	10.5	9
5.	120°	5.40	5.5	6	-10.8	5	4
6.	150°	1.44	1.5	2	-18.7	1.5	1
7.	180°	0	0	0	-21.6	0	0

SINGLE PHASE SEMI CONVERTER:

Sl. No	Firing angle (α) [Degree]	R Load			RL load		
		Load Voltage (V)		Load current (mA)	Load voltage (V)		Load current (mA)
		Theoretical	Experimental		Theoretical	Experimental	
1.	0°	21.6	23	20	21.6	23	20
2.	30°	20.16	22	18	20.16	21	18
3.	60°	16.2	18	15	16.2	17	15
4.	90°	10.8	12	11	10.8	11.5	10
5.	120°	5.40	6	5	5.40	5	5
6.	150°	1.44	2	2	1.44	1.5	1.5
7.	180°	0	0	0	0	0	0

1ϕ Semi-converter – R Load and RL load

$$V_o\,(avg) = \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin \omega t \, . \, d(\omega t)$$

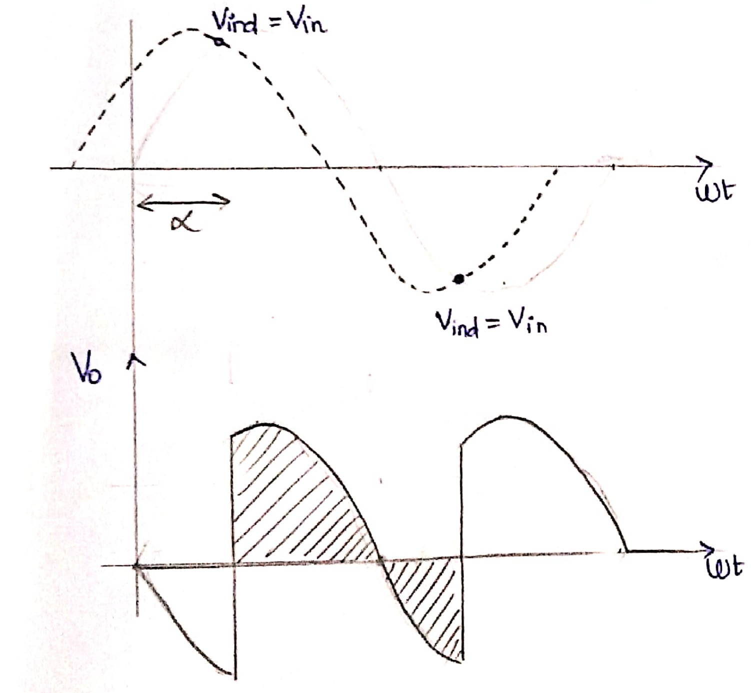
$$= \frac{V_m}{\pi}\left[-\cos \omega t\right]_{\alpha}^{\pi} = \frac{V_m}{\pi}\left[-\cos\pi + \cos\alpha\right]$$

$$\boxed{V_o\,(avg) = \frac{V_m}{\pi}(1+\cos\alpha)}$$

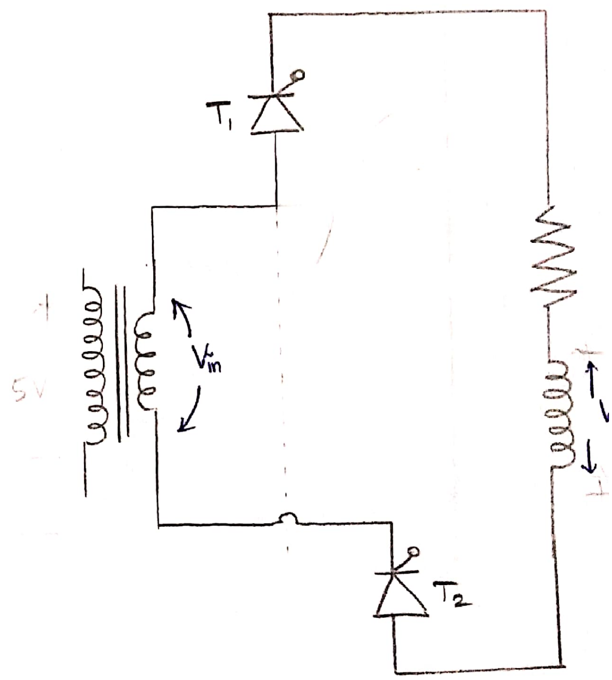
$$\boxed{I_o\,(avg) = \frac{V_m}{\pi R}(1+\cos\alpha)}$$

INFERENCE:

1ϕ - Full converter – RL load



Positive half cycle



Let us consider positive half cycle,

⇒ SCRs T_1 and T_2 are triggered when $\omega t = \alpha$

⇒ Now the circuit is closed and load is supplied. The inductor starts charging and a voltage is built up in the inductor.

⇒ The output voltage follows input voltage from $\omega t = \alpha$ to $\omega t = \pi$

* When $\omega t = \pi$, input voltage becomes zero and the inductor starts discharging

* When inductor discharges, voltage polarity reverses and current polarity remains same

  ⇒ Voltage polarity reverses ⇒ This is why we get negative spikes in output voltage

  ⇒ Current polarity remains same ⇒ Load current > Holding current and SCR still conducts.

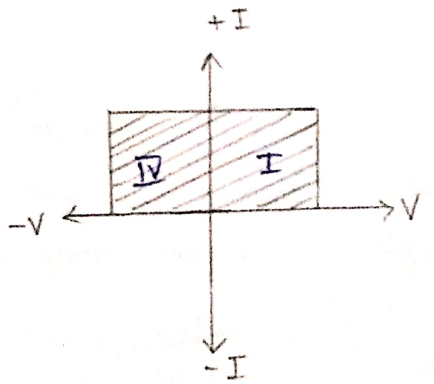
* Inductor voltage leads input voltage, when $V_{inductor} = V_{in}$, the load current becomes zero and SCR turns off.

* The angle at which SCR turns off is called extinction angle (β)

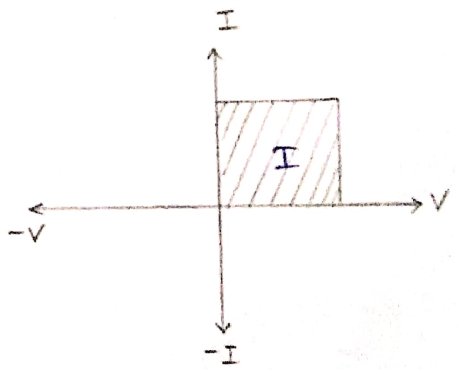
1ϕ Semi Converter – RL load

* When $\omega t = \pi$, input voltage becomes zero and inductor voltage reverses polarity.
* Hence a net negative voltage appears which reverse biases the diode and hence opens the circuit.
* Hence, in 1ϕ semi-converter, RL load, the output waveform is similar to 1ϕ semi-converter R load.

Quadrants of ~~r~~operation:-



1ϕ - Full converter RL load



1ϕ full converter → R load

1ϕ semi-converter → R load, RL load

* When $\omega t = \pi$, input voltage becomes zero and the inductor starts discharging

* When inductor discharges, voltage polarity reverses and current polarity remains same

  ⇒ Voltage polarity reverses ⇒ This is why we get negative spikes in output voltage

  ⇒ Current polarity remains same ⇒ load current > Holding current and SCR still conducts

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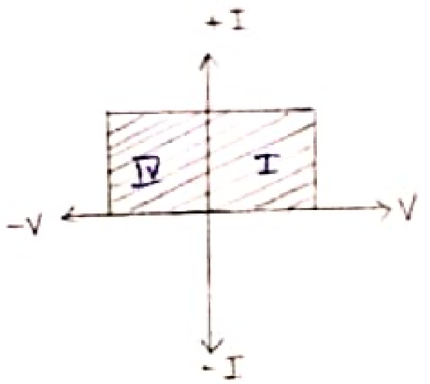
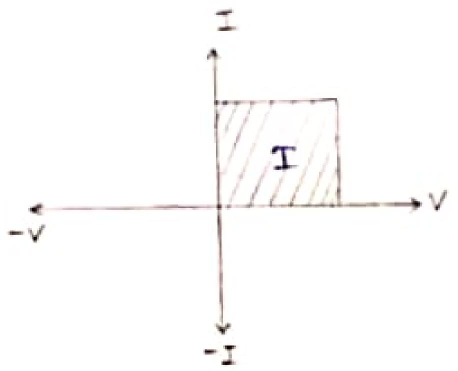
Quadrants of operation:-



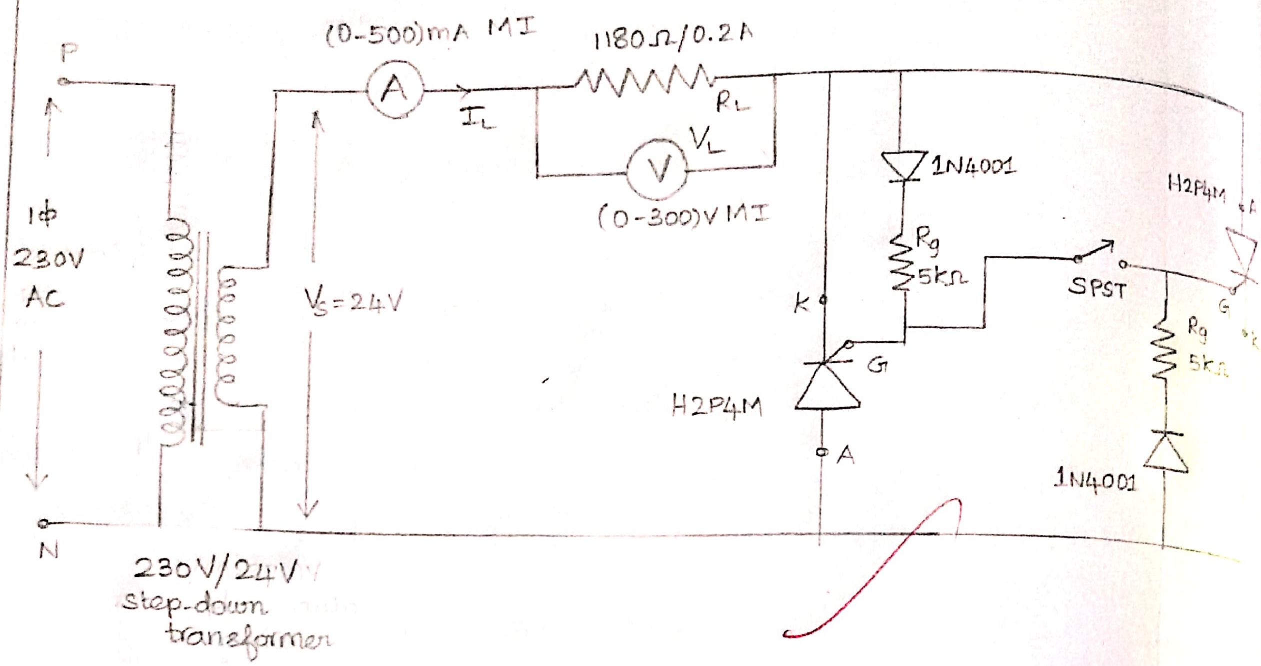
1ϕ - Full converter RL load



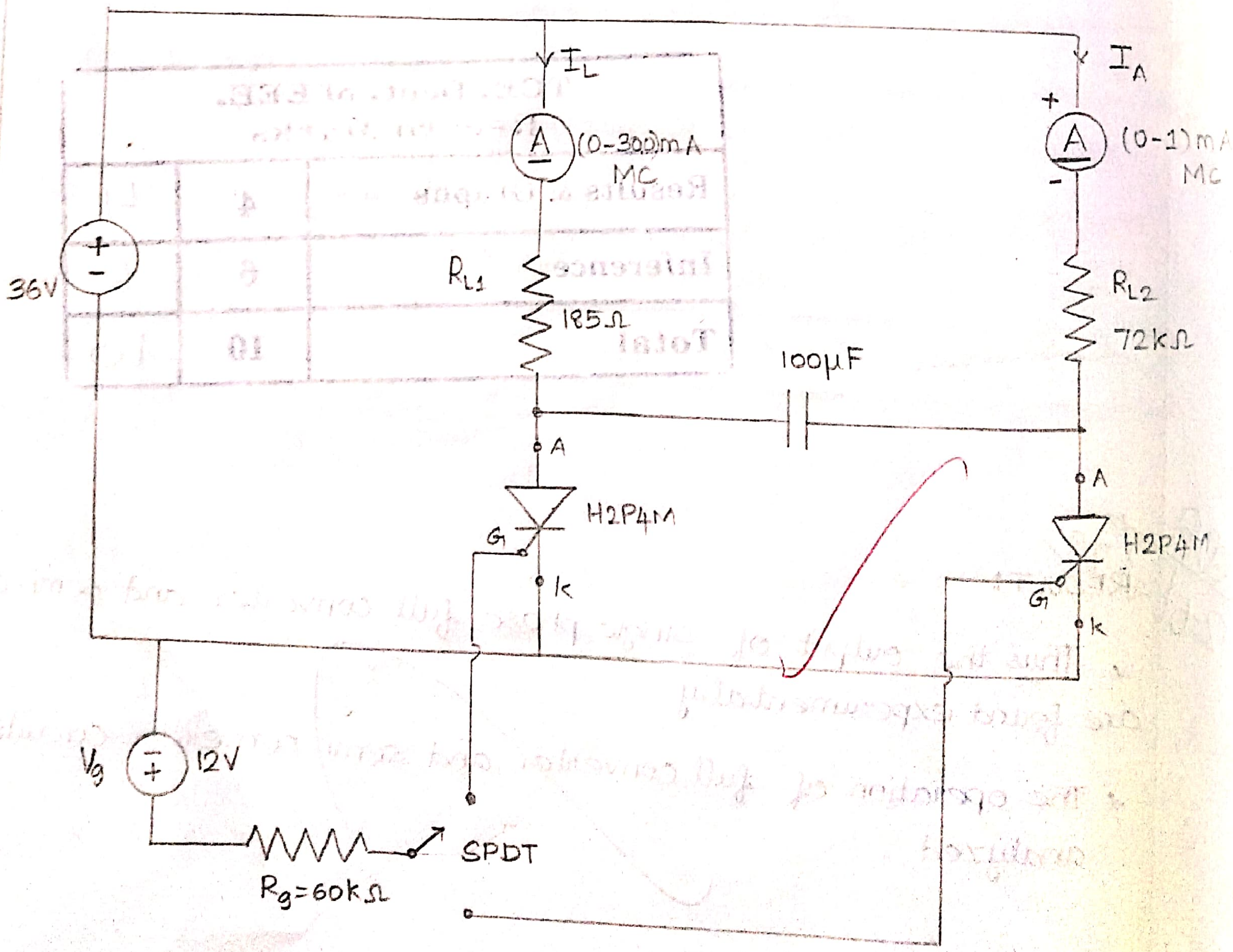
1ϕ full converter → R load

1ϕ semi-converter → R load, RL load

STATIC AC CIRCUIT BREAKER



STATIC DC CIRCUIT BREAKER



EXPT NO: 6
DATE: 28/04/2022

STATIC DC AND AC CIRCUIT BREAKER

AIM:

To study the operation of static AC and DC static circuit breaker.

APPARATUS REQUIRED:

S.No	APPARATUS	SPECIFICATION	QUANTITY
1.	Variac	j4 (230/0-270)V	1
2.	SCR	H2P4M	1
3.	Diode	1N4001	1
4.	Resistor	5kΩ, 185Ω, 60kΩ	1 each
5.	Rheostat	3600Ω/0.2A 1180Ω/0.6A	1 each
6.	Capacitor	100 μF	1
7.	Ammeter	MI (0-500)mA MC (0-300) mA MC (0-1 mA)	1 each
8.	MC Voltmeter	(0-250)V MC	1

Specifications of SCR:

* SCR Type: H2P4M
* Peak Inverse voltage: 400 V
* Max forward current: 2A
* Gate Triggering current: 0.2 mA
* Holding current: 1 mA

CIRCUIT DESIGN:

Triggering Circuit

$V_g = 12V$; $I_g = 0.2\,mA$

$$R_g = \frac{V_g}{I_g} = \frac{12}{0.2 \times 10^{-3}} = 60\,k\Omega$$

AC Circuit Breaker

Assume load current $I_L = 200\,mA$

Assume $V_{max} = \cancel{100V}\ 24V$

$$\text{Load resistance } R_L = \frac{V_{max}}{I_L} = \frac{\overset{24}{\cancel{100}} \times 1.414}{0.2} = \overset{169.7\,\Omega}{\cancel{707.1\,\Omega}} \simeq 1.85\,\Omega$$

So R_L is chosen as $\overset{185\,\Omega}{\cancel{\ \ \Omega}} / \overset{1.5A}{\cancel{\ \ A}}$

$$R_g = \frac{V_g}{I_g} = \frac{1}{0.2 \times 10^{-3}} = 5\,k\Omega$$

To have $\alpha \simeq 0°$, We choose $V_g = 1V$

DC Circuit Breaker

Assume load current $I_L = 0.2\,A$

$$R_{L_1} = \frac{V}{I_L} = \frac{36}{0.2} = 180\,\Omega$$

$$R_{L_2} = \frac{V}{I_L}$$

Let $I = 0.5\,mA$ ($I_A <$ holding current)

$$R_{L_2} = \frac{36}{0.5 \times 10^{-3}} = 72\,k\Omega$$

9

28/11/22

PROCEDURE :

For AC circuit breaker

1. Circuit connections are given as shown in circuit diagram
2. The gate switch is in closed condition.
3. The readings of the voltmeter and ammeter are measured.
4. Now the gate switch is opened and the voltmeter and ammeter readings are measured.
5. When the gate is opened, both SCR are off and meter readings are zero.

For DC circuit breaker

1. Circuit connections are given as shown in circuit diagram.
2. The SPDT switch is closed to SCR1
3. The readings of the ammeters are measured.
4. Now the SPDT switch is closed to SCR2 and ammeter readings are measured.
5. When the SPDT is closed to SCR2 both SCRs are off and meter readings are zero.

OBSERVATION:

AC Circuit Breaker

Switch Position	Load Voltage V_L (V)	Load current I_L (mA)
Opened	0	0
Closed	24	120

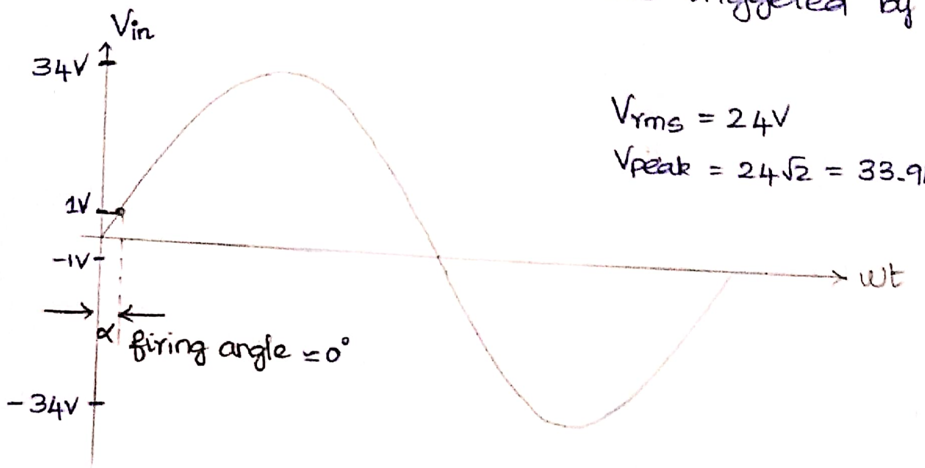
DC Circuit Breaker

Switch Position	Load Current I_L (mA)	Auxiliary current I_A (mA)
SCR1 Triggered	32	0
SCR2 Triggered	0	0.425

INFERENCE:

* Static circuit breaker – circuit breaker with no moving parts.
* The SCR conducts only if the two conditions are satisfied.
  (i) The SCR should be forward biased.
  (ii) Gate pulse must be given to the SCR.

* In AC circuit breaker, the SCR's are triggered by R triggering.



$V_{rms} = 24V$

$V_{peak} = 24\sqrt{2} = 33.94\,V$

* The resistance is chosen by assuming $V_g = 1V$ so that the firing angle is nearer to 0°. So $V_{in} \simeq V_{out}$

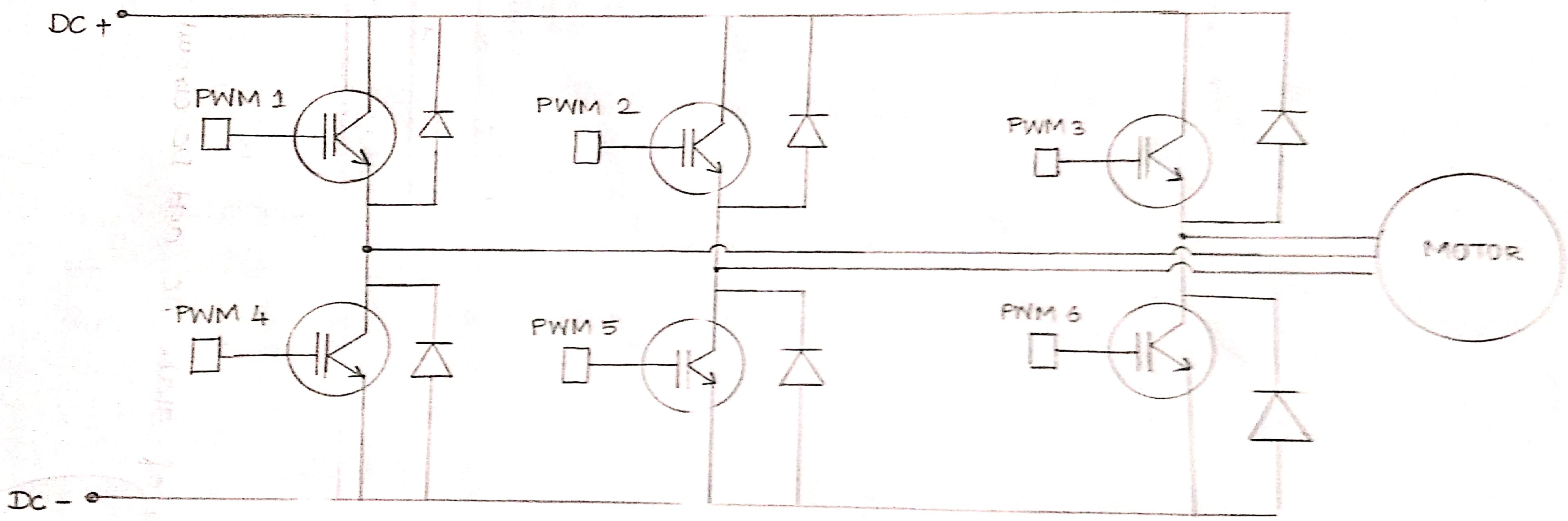
* When the SPST switch is open in the AC circuit breaker, the gate triggering for both SCRs will be restricted. Hence the circuit will be opened.

DC Circuit Breaker

* SCR2 is an auxillary device used to turn off SCR1
* SCR1 is turned off by voltage commutation technique. When SCR2 conducts, the charged capacitor reverse biases the SCR1 and thus SCR1 turns off.

* Now SCR1 is off and SCR2 is on. To automatically turn off SCR2 after it turns off SCR1, a high resistance is chosen such that the current flowing through SCR2 is below SCR's holding current
* So as soon as capacitor discharges, SCR2 also turns off.

FUNCTIONAL DIAGRAM 3-HALF BRIDGE CIRCUIT



PT NO: 7
TE: 06-05-22

CONTROL OF THREE PHASE INDUCTION MOTOR USING MATLAB AND ARM Cortex M4 CONTROLLER

AIM:

To control the speed of three phase induction motor using IGBT / SIC MOSFET based power module with MATLAB Cortex M4.

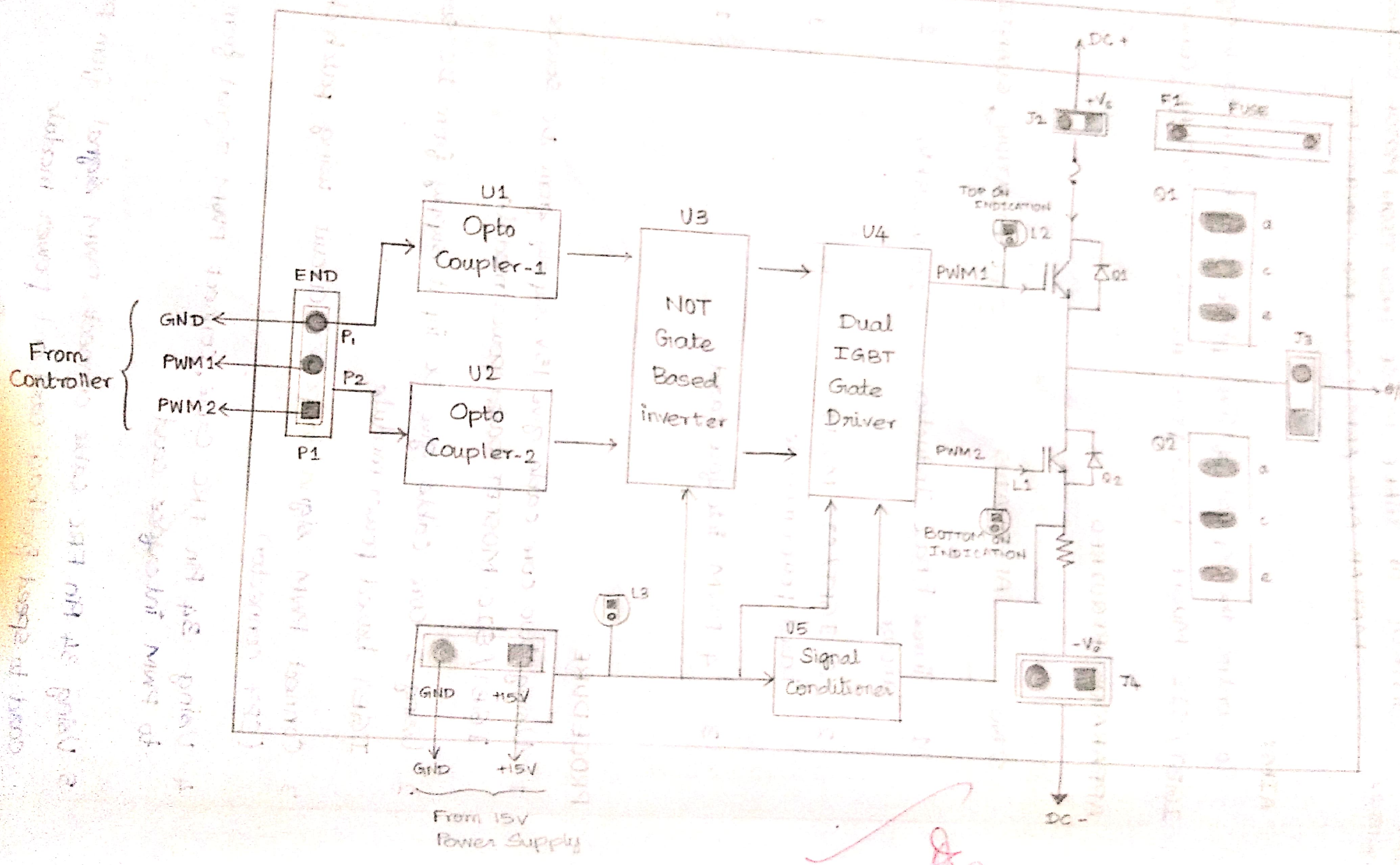
APPARATUS REQUIRED:

S.No	APPARATUS	SPECIFICATION	QUANTITY
1.	Three Phase Induction motor	200V, 0.5kW	1
2.	3 IGBT / SIC MOSFET based power module		1
3.	4 PWM interface card		1

PROCEDURE:

1. Using two core cable give 15V supply from DC source to IGBT / SIC MOSFET based power module.
2. Using 2 Core Cable give DC input supply from DC source to IGBT based power module.
3. Connect PWM signal to power circuit using patch chord (SP7 connector)
4. Using 34 Pin FRC Cable, connect PWM signal from controller to PWM interface card.
5. Using 34 Pin FRC cable, connect PWM signal from PWM interface card to speed feedback card and power module.

BLOCK DIAGRAM OF GATE DRIVE CIRCUIT FOR DUAL IGBT MODULE



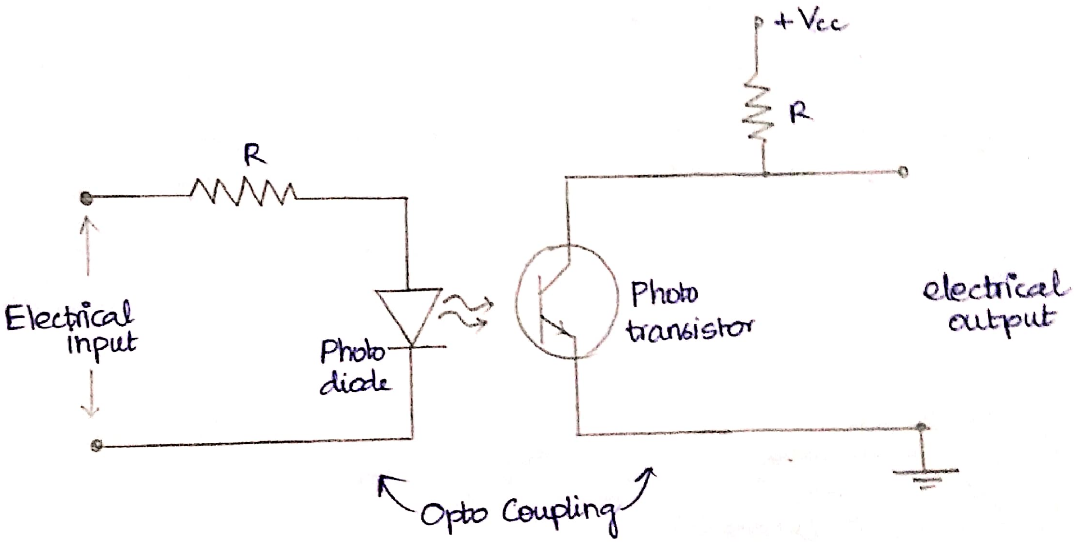
6. Three phase inverter output is given to three phase AC motor.

7. Motor speed feedback from motor which is given to controller through feedback card.

8. Connect power chord to DC voltage source module and controller board

INFERENCE:

* The PWM signal is fed to the opto coupler to remove electrical noise and to provide electrical isolation



* When +5V is given as input, transistor conducts and O/P = 0V
When 0V is given as input, transistor is off and O/P = V_{cc} = 5V

* Hence, an inverter (NOT gate) is required to get the input signal.

* The speed control of induction motor is done at the cost of ~~decrease in efficiency~~ and ~~low~~ moderate electrical power factor.

6. Three phase inverter output is given to three phase AC motor.

7. Motor speed feedback from motor which is given to controller through feedback card.

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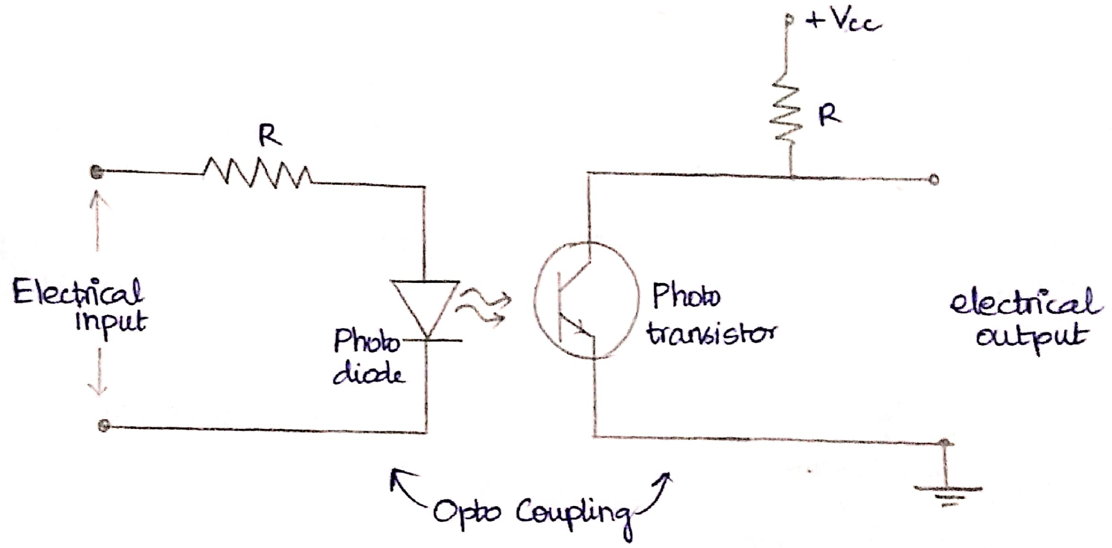


* When +5V is given as input, transistor conducts and O/P = 0V
When 0V is given as input, transistor is off and O/P = V_{cc} = 5V

* Hence, an inverter (NOT gate) is required to get the input signal.

* The speed control of induction motor is done at the cost of ~~decrease in efficiency~~ and ~~low~~ moderate electrical power factor.

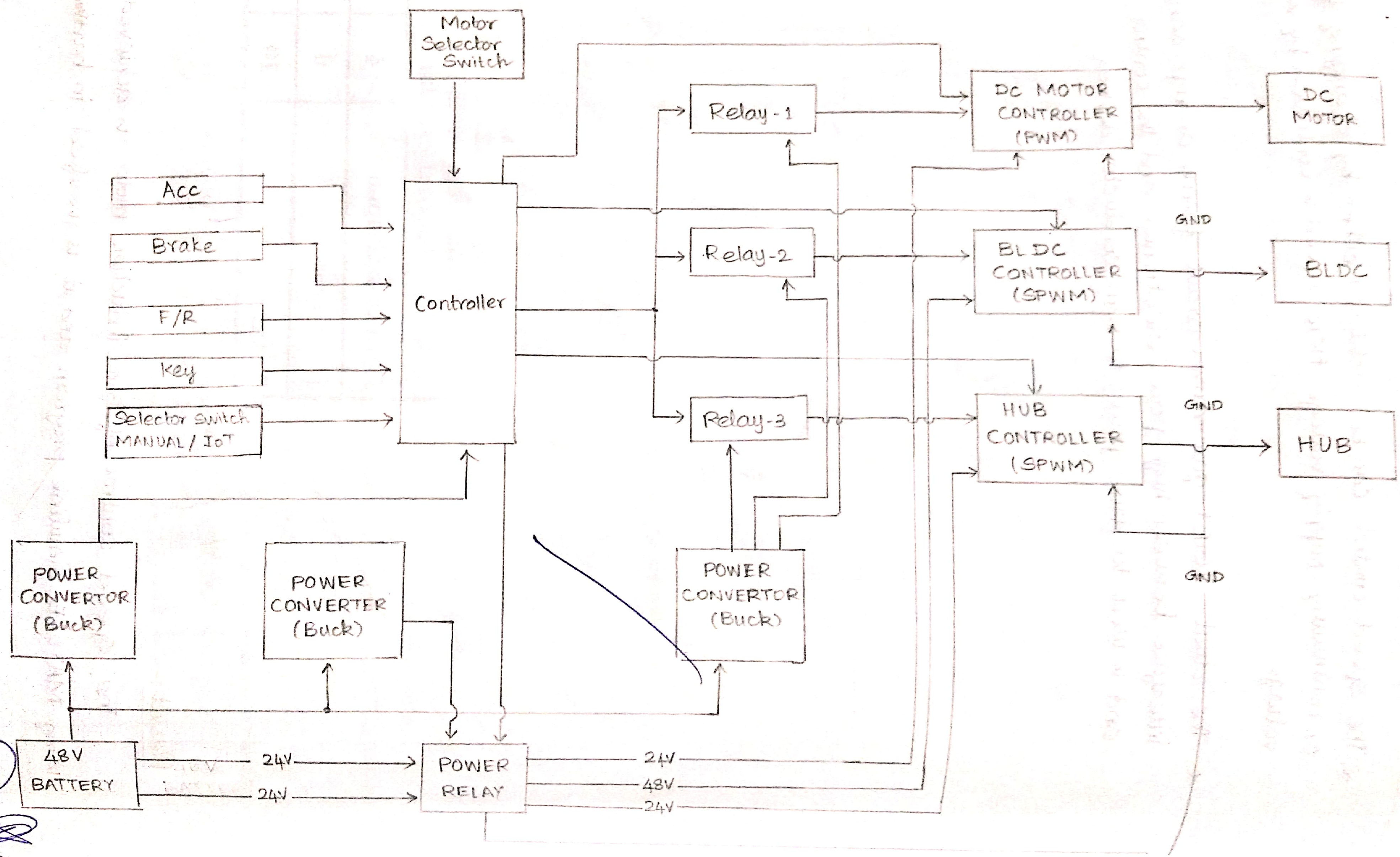
* The speed control can be achieved either by changing frequency, or controlling supply voltage. Here speed is controlled by supply voltage.

* The dual IGBT gate driver circuit forms an important interface between high power electronics and the control circuit and is used to drive power to semi-conductor devices.

TCE, Dept. of EEE. Record Marks		
Results & Graphs	4	
Inference	6	
Total	10	

Result :-

The speed control of 3-ϕ induction motor is achieved using MATLAB simulink program and it is verified in hardware setup.


Motor Selector Switch
Acc
Brake
F/R
Key
Selector Switch MANUAL / IoT
Controller
Relay-1
Relay-2
Relay-3
DC MOTOR CONTROLLER (PWM)
BLDC CONTROLLER (SPWM)
HUB CONTROLLER (SPWM)
DC MOTOR
BLDC
HUB
GND
GND
GND
POWER CONVERTOR (Buck)
POWER CONVERTER (Buck)
POWER CONVERTOR (Buck)
48V BATTERY
24V
24V
POWER RELAY
24V
48V
24V

EXP. NO: 8
DATE: 27/05/22

CONTROL OF IOT BASED ELECTRIC VEHICLE

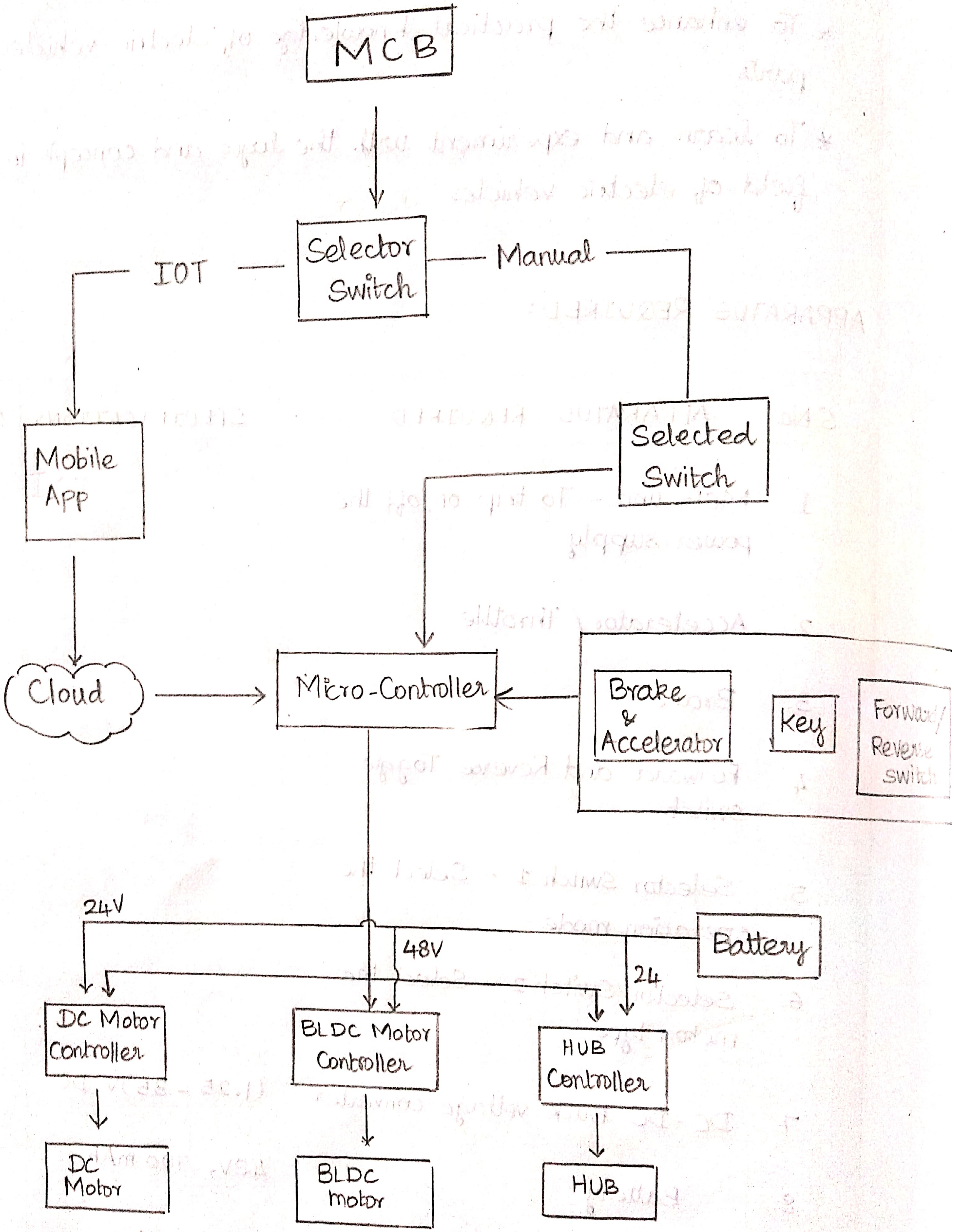
AIM:

* To enhance the practical knowledge of electric vehicles and their parts.
* To learn and experiment with the logic and concepts in the field of electric vehicles.

APPARATUS REQUIRED:

S.No.	APPARATUS REQUIRED	SPECIFICATIONS	Quantity
1.	MCB unit - To trip on/off the power supply		1
2.	Accelerator / Throttle		1
3.	Brake		1
4.	Forward and Reverse Toggle switch		1
5.	Selector Switch 1 - Select the operation mode		1
6.	Selector Switch 2 - Select the motor type		1
7.	DC-DC Buck voltage converter	(1.25 - 35)V DC	1
8.	Battery	48V, 700 mAh	1
9.	Charger	48 V, 10 A	1
10.	Relay	5V, 30 A	1
11.	SPWM Controller - To control the BLDC and Hub motor functionality		1

Flow Diagram



S.No	APPARATUS	SPECIFICATIONS	Quantity
12.	PWM Controller - To control the DC motor functionality		1
13.	BLDC motor	48V, 750W	1
14.	DC Motor	24V, 250 W	1
15.	HUB Motor	24V, 250W	1

PARTS OF THE ELECTRIC VEHICLE:

1. MCB Unit

* DC MCB is designed for Direct Current (DC) control circuit applications, used for overcurrent protection within appliances or electrical equipment.
* It provides optimization products for EVs.

2. Accelerator

* The accelerator pedal sends a signal to the controller which adjusts the vehicle's speed by changing the frequency of the PWM from the converter to motor.
* The motor connects and turns the wheels through a cog.

3. Brake

* When the brakes are pressed or the car is decelerating, the motor becomes an alternator and produces power, which is sent back to the battery.
* Electric vehicles (EV) run primarily off the charge they stored and plugged into the outlet, but regenerative braking is used to help top up the battery.

4. Forward / Reverse

* The direction in which it rotates determines if the car will move forward or backward.

* Reversing the direction in which the motor is rotating can be done by just giving an electrical input via the driver selector. switch or knob

5. key

* key which acts as a motor kill and activated by controlling the PWM and SPWM controller

6. Selector Switch

* In our design, there are 2 selector switches
* One is to select the respected motor by rotating the selector switch.

* Another one is to select the functional model of the system as manual / IoT.

7. Power Converter

* The Buck converter is used in SMPS circuits where the DC output voltage needs to be lower than the DC input voltage.

* The DC input can be derived from rectified AC or from DC power supply.

* It is useful where electrical isolation is not needed between the switching circuit and the output.

8. Micro-controller

* The predecessor of EBP32, the ESP8266 has a built-in processor.

* However, due to multi-tasking involved in Wifi stack updation, most of the applications use a seperate microcontroller for data processing, interfacing sensors and digital input-output.

* With ESP32 you may not want to use an additional micro controller.

* ESP32 has Xtensa Dual Core 32-bit LX6 microprocessors, which can rup upto 600 DMIPS.

* The ESP32 will run on breakout boards and modules from 160 MHz upto 240 MHz.

* That is a very good speed for anything that requires a micro-controller with connectivity options.

* The two cores are named Protocol CPU (Pro_CPU) and Application CPU (APP_CPU).

9. Battery

* Four Amaron 12V batteries which are connected in series to give 48V 28Ah.

* Batteries are directly connected to BLDC motor and HUB motor.

10. Charger

* Lead acid batteries are charged in a method called "constant current constant voltage" (CCCV).

* After full charge, auto cut-off is provided.

11. Relay

* A relay is an electrically operated switch.
* It has set of input terminals and a set of operating contact terminals.

12. Controller

* Motor Control Unit (MCU) is an electronic module that interfaces between the batteries and motor to control the electric vehicle's speed and acceleration based on throttle input.
* Controller transforms the battery's direct current into alternating current and regulates energy flow from the battery.
* The controller also reverses the motor rotation during regen which in turn charges the battery.

13. Motors

* Electric vehicles have motors instead of internal combustion engine
* The vehicles use a large traction battery pack to power the electric motor and must be plugged into a charging equipment.

(i) Wheel HUB Motor (24W 250W)

⇒ Electric motor incorporated into the hub of wheel and drives it directly.

(ii) DC Motor (24W 250W)

⇒ Take electrical power through direct current and convert it to mechanical rotation.

(iii) Brushless DC Motor

⇒ Electric motor powered by a direct current voltage and commutated electronically instead of using brushes as in conventional motors.

WORKING PROCEDURE:

* Select the Mode by using the mode selection switch (IoT/manual)
* Turn on the main power supply by using the tripper switch
* If Manual mode is selected,
  - ⇒ Select the motor type which you want to run
  - ⇒ Toggle the switch which is very next to the accelerator set up for the forward and reverse operations which we need
  - ⇒ Turn the key ON which is next to forward/reverse switch
  - ⇒ If you selected the BLDC motor, turn on the S-PWM controller's key which is next to the BLDC motor.
  - ⇒ Once all set, if you select BLDC or DC motor, you can connect the selected motor alone with the wheel by using the chain bracket if required.
  - ⇒ Then we can perform functions like acceleration and brake
  - ⇒ If needed, we can switch between forward and reverse mode at any point
* When IoT mode is selected,
  - ⇒ Install the mobile app sent to you
  - ⇒ Open the mobile app, sign up or sign in by entering required credentials.
  - ⇒ Turn on mobile "WiFi" and scan for the WiFi under the name "iotev", connect to the Wi-Fi by using password "quantanicsiotev"
  - ⇒ Once the Wi-Fi is connected, go to the web page and type "192.168.4.1" in the address bar.
  - ⇒ Wi-Fi configuration page opens. Select the Wi-Fi config button and enter the Wi-Fi credential over there and click "Save"
  - ⇒ Then the mobile app asks you to turn on the motor. Once you turn it on, it goes to the controlling page.

INFERENCE:

* From this experiment, I came to know that when accelerated, acc and pedal sends signal to the controller.

* When brake is applied, the vehicle starts to decelerate.

* There are three keys ⇒ key on/off, BLDC motor keys
  two modes of motor operation ⇒ forward/reverse
  two modes of control ⇒ manual mode / IoT mode

* In IoT mode, an app is installed and is connected to EV through mobile Wi-Fi.

* The speed control of any motor can be done smoothly by adjusting the options provided in the app.

TCE, Dept. of [illegible]
Record Marks

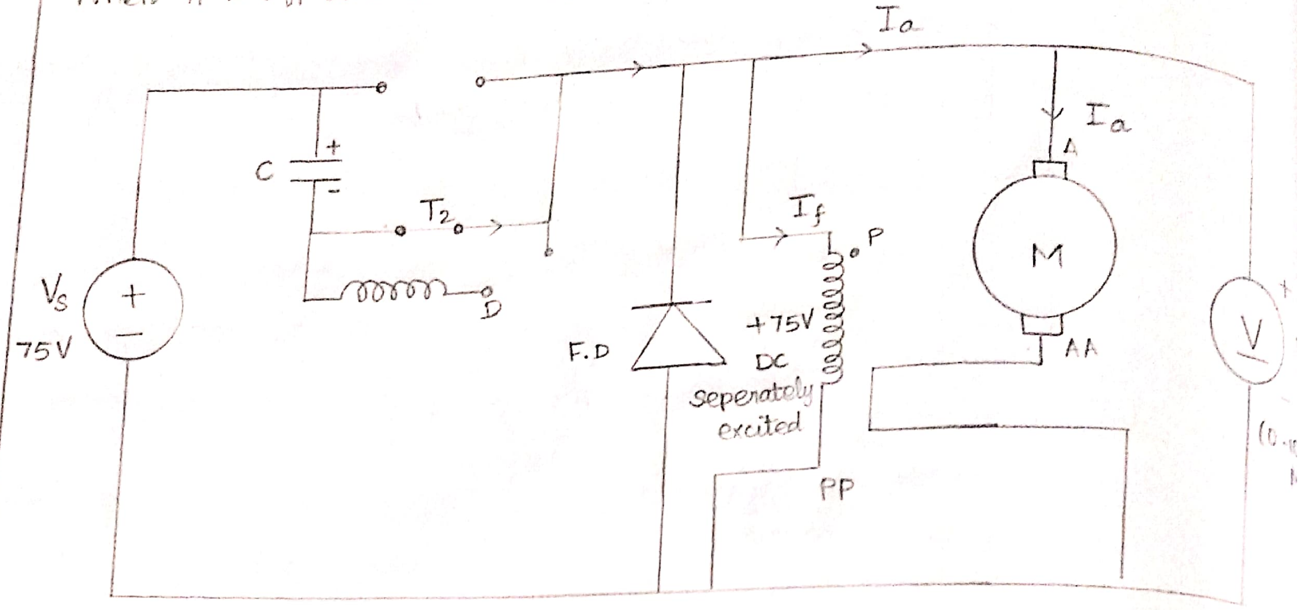
Results & Graphs	4	4
Inference	6	5
Total	10	9

2/6/22

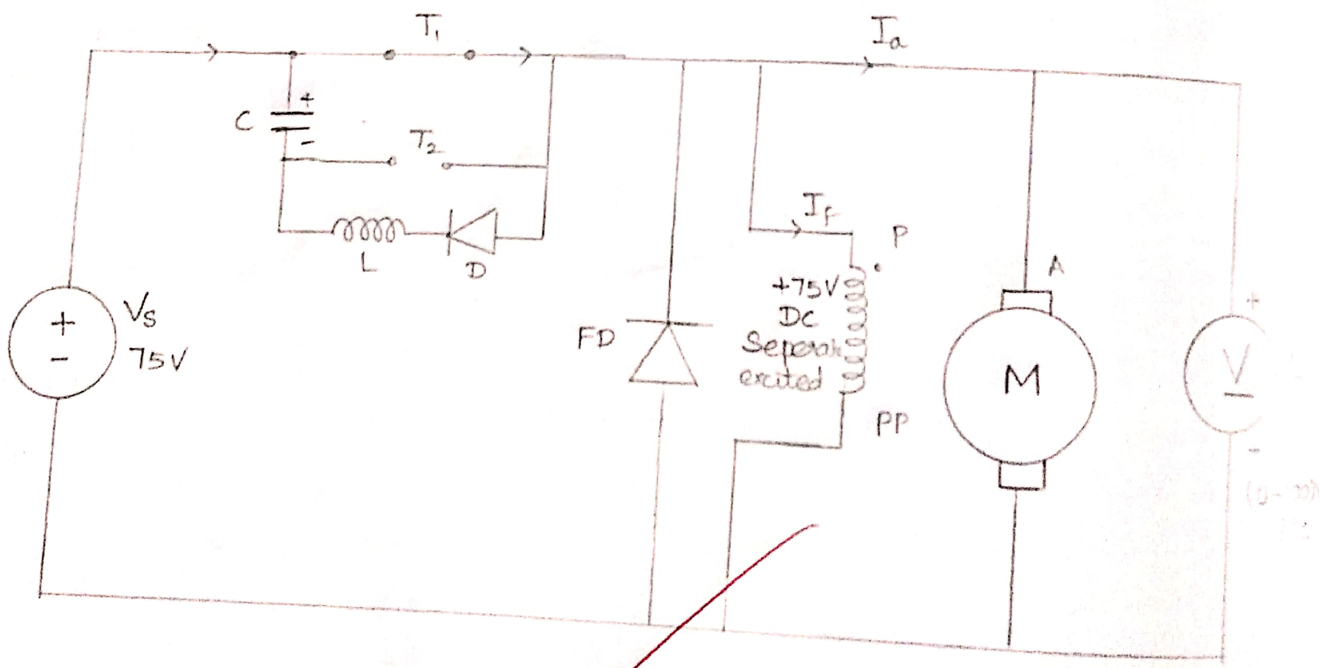
RESULT:

* Hence the speed control of given EV, control of EV movement (forward/reverse) is done manually and via IoT mobile app.

When T_1 is off and T_2 is triggered



When T_1 is triggered



EXP. NO: 9
DATE: 31/5/22

VOLTAGE COMMUTATED CHOPPER FED DC DRIVE

AIM:

To drive the motor (dc motor) using voltage commutated chopper and study its characteristics.

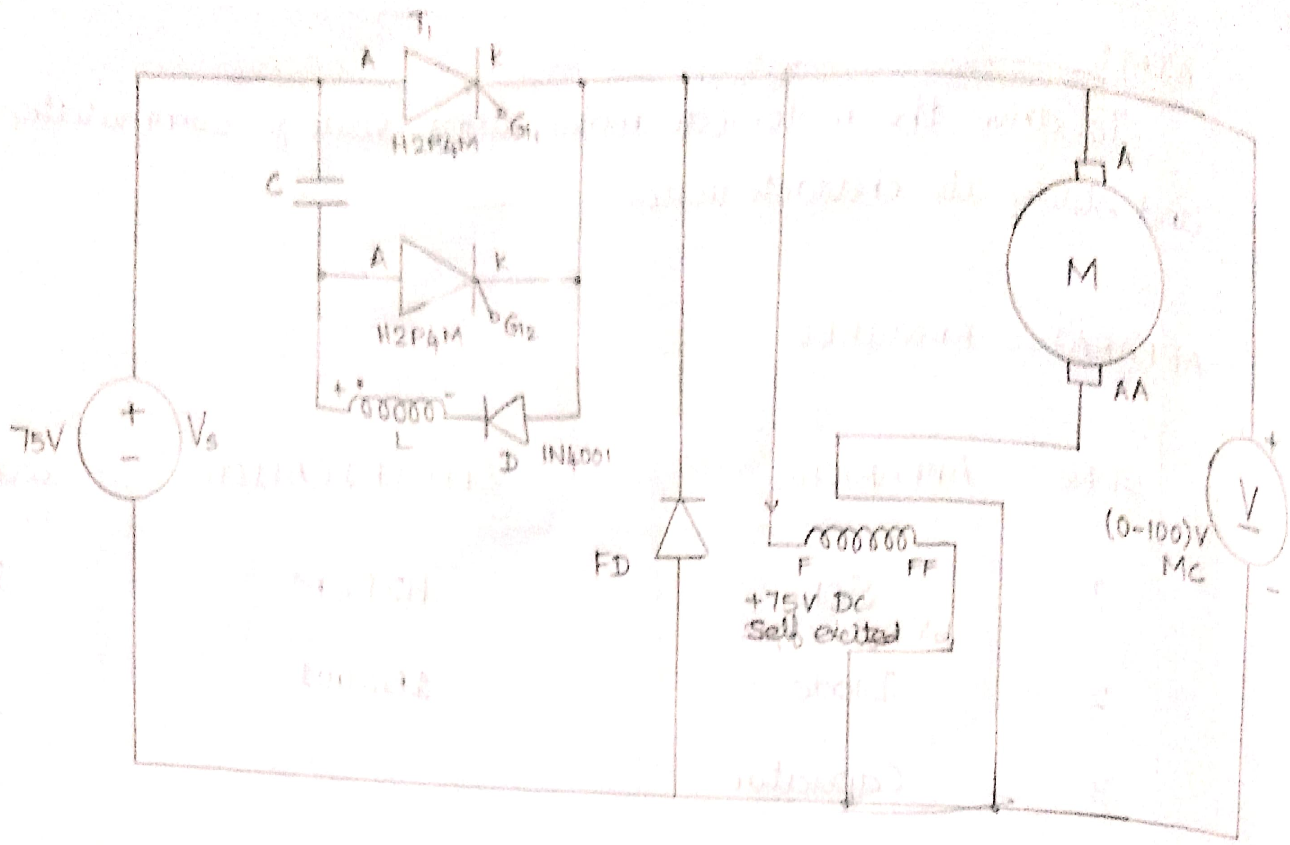
APPARATUS REQUIRED:

Sl. No	APPARATUS	SPECIFICATION	QUANTITY
1.	SCR	H2P4M	2
2.	Diode	1N4001	2
3.	Capacitor	-	1
4.	Inductor	-	1
5.	Dc Chopper firing circuit	-	1
6.	DC Motor	Voltage = 220 V Power = 0.6 W current = 2.9 A Speed = 1500 rpm	1
7.	DC Voltmeter	(0-100) V	1
8.	Tachometer	-	1

PROCEDURE:

1. The circuit connections are made as shown in the circuit.
2. By varying the duty cycle of the chopper, corresponding load voltage and speed are noted.
3. The graph is plotted between load voltage and speed.

CIRCUIT DIAGRAM:



Motor Name Plate Details

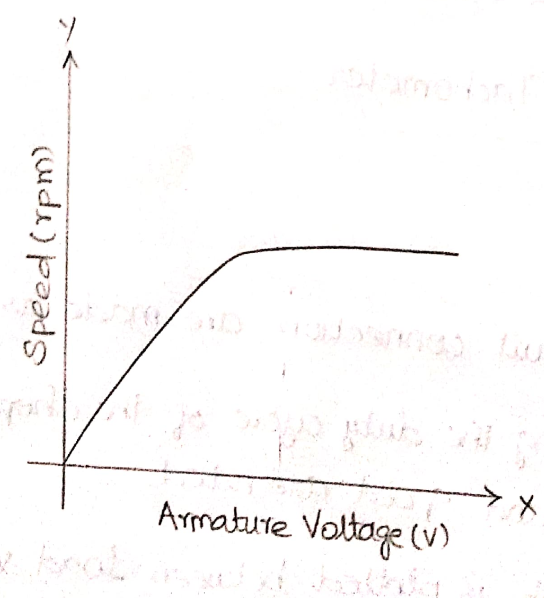
Rated voltage = 220V

Rated power = 0.6W

Rated current = 2.9A

Rated speed = 1200 rpm

MODEL GRAPH:



frequency may constant

duty cycle → 10%, 20%, 30%, 40

THEORY (DC Chopper Fed DC Drive)

* Chopper, also known as DC-DC converter, is used to get variable DC from fixed DC voltage

* Self-commutated devices such as MOSFET, power transistor, IGBT, GTO are prefered over SCRs because they can be commutated by low power control signal

* T_1 is operated periodically with period T and remains on for a duration T_{ON}. Present day choppers operate at a frequency which is high enough to ensure continuous conduction waveform of motor terminal voltage V_a and armature current I_a for continuous conduction are shown in figure

$$I_a R_a + L \frac{dI_a}{dt} + E = V \qquad 0 \leq E \leq T_{ON}$$

* In this interval, armature current increases from I_{a_1} to I_{a_2} once the motor is connected to the source during this interval. It is called duty interval

* Duty cycle $= \dfrac{T_{ON}}{T_{ON} + T_{OFF}}$

T_{on} = on time of T_1

T_{off} = off time of T_1

$$V_L = DV_s = \text{Duty cycle} \times \text{Supply voltage}$$

$$F = \frac{1}{T} = \frac{1}{\text{Time period}}$$

INFERENCE:

* T_1 thyristor is the main switch that is used to make/break the circuit.

* Since thyristors are not self-commutated devices, we need to have seperate circuit for commutation.

* The commutation circuit has an auxillary SCR T_2, a capacitor and inductor, a diode.

* Initially T_2 is triggered and the capacitor is charged.

* Now, T_1 is triggered which turns off T_2 and supply power to load. Th is the normal operating condition of the circuit.

* When T_1 needs to be commutated, T_2 is triggered and the capacito voltage appears across T_1 and it gets turned off due to reverse voltage.

* The flywheel diode acts as a short circuit path for negative voltage thus allowing only positive voltage to the motor.

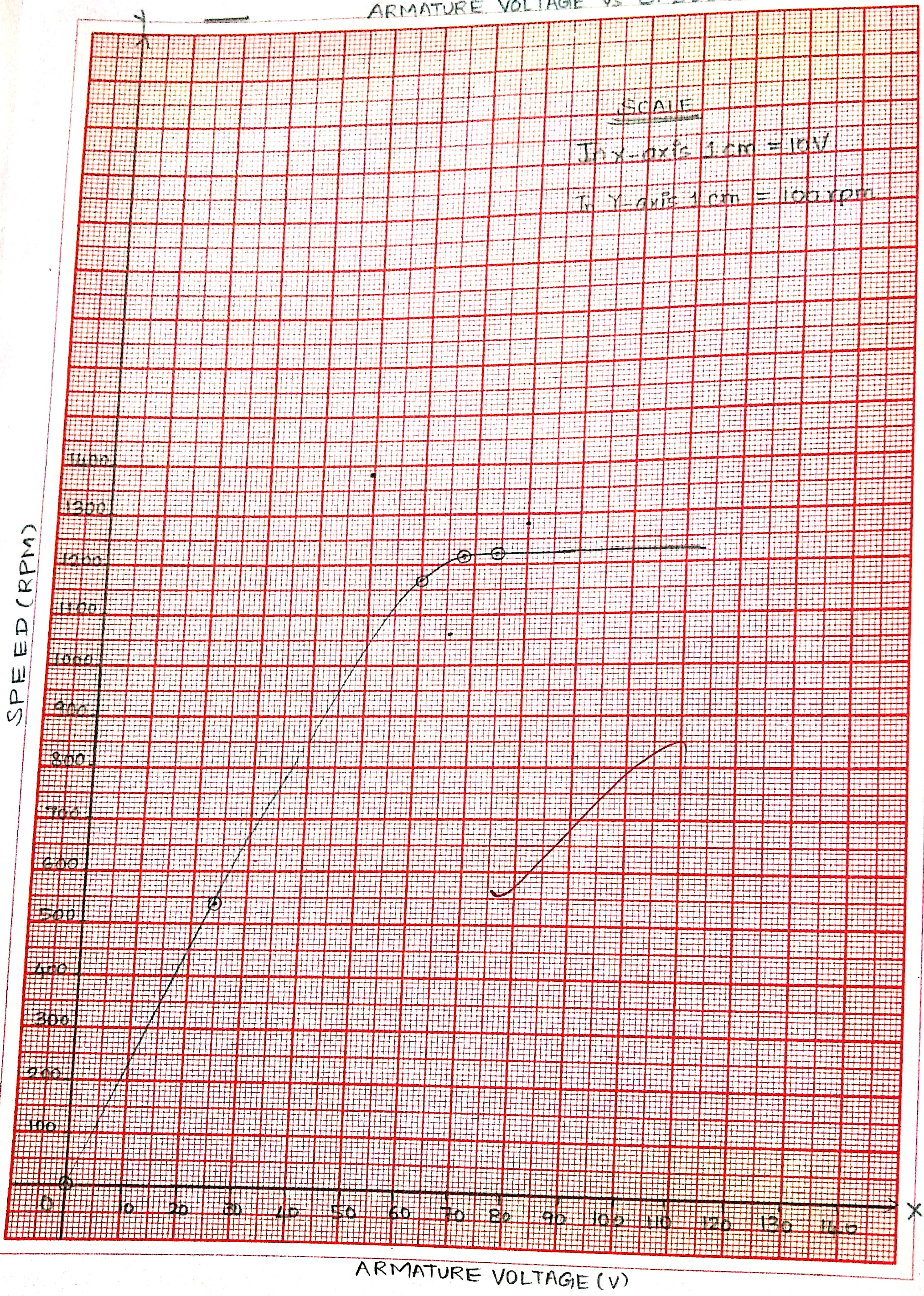
* The motor has shunt field winding meaning both motor and field winding are connected to the same supply in parallel.

TABULATION:

S.No	Speed (rpm)	Armature Voltage (V)	Duty Cycle (%)
1.	1284	80	90
2.	1224	74	80
3.	1222	68	60
4.	1066	66	50
5.	1170	60	30
6.	545	24	20
7.	0	6	10

VOLTAGE COMMUTATED CHOPPER FED DC DRIVE

ARMATURE VOLTAGE Vs SPEED



	6	5
Total	10	9

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RESULT:

* The DC Motor is driven using a voltage commutated chopper at different duty cycles and its characteristics (spe armature voltage) are studied.

* Voltage across armature Vs Speed (rpm) is plotted.

Exp.No: 10
DATE: 31/05/22

SINGLE PHASE HALF CONTROLLED RECTIFIER FED DC MOTOR

AIM:

To design a single phase half controlled rectifier to regulate the speed of a DC motor.

APPARATUS REQUIRED:

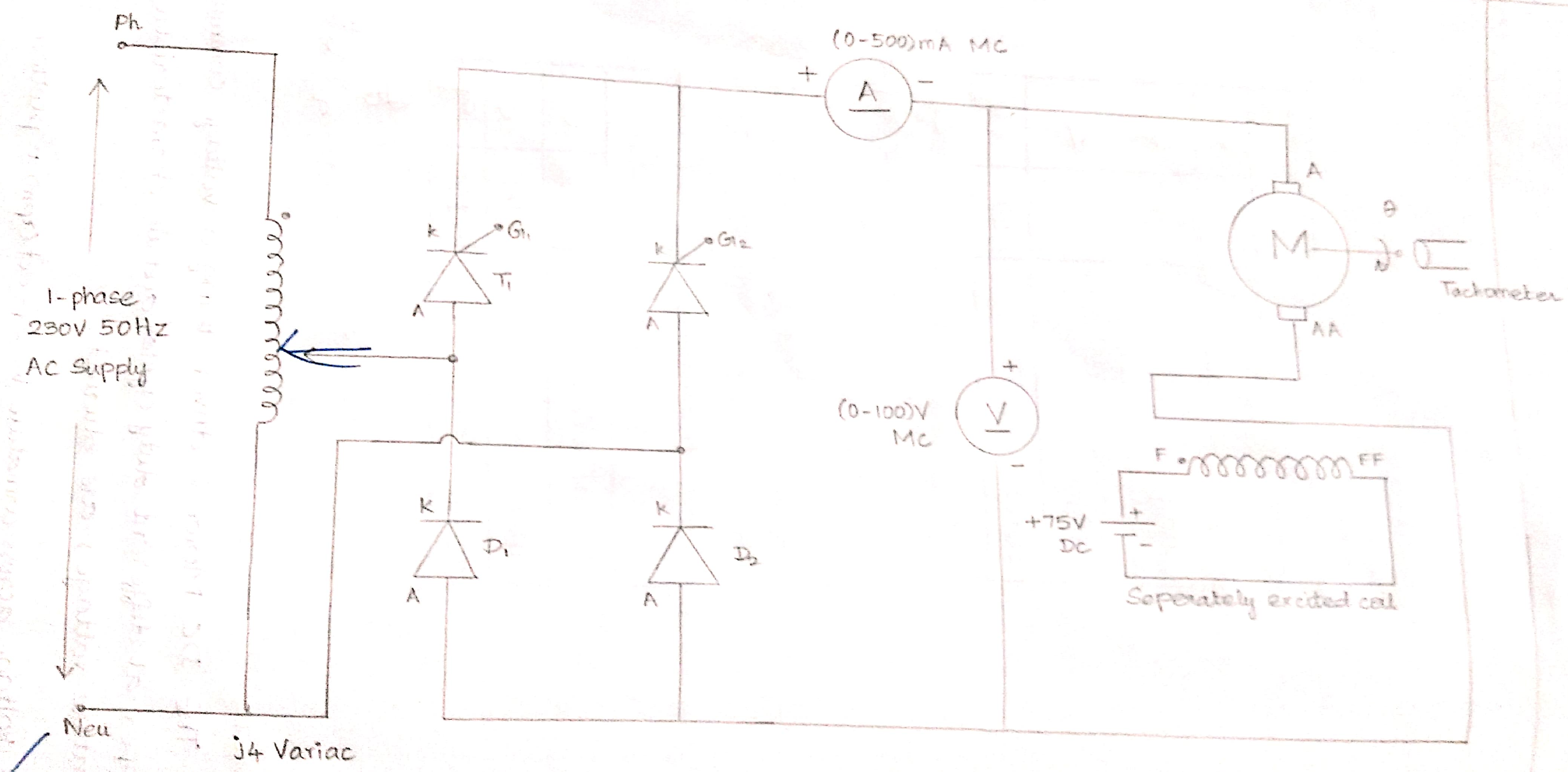
S.No	APPARATUS	Specification	Quantity
1	1φ Variac	230V/(0-270)V	1
2.	Power SCR	-	2
3.	Power Diode	-	2
4.	MC Ammeter	(0-500 mA)	1
5.	MC voltmeter	(0-100) V	1
6.	DC Motor	230V, 0.37 kW 2.3 A, 1500 rpm	1
7.	CRO	-	1
8.	Tachometer	-	1

SPECIFICATION:

SCR H2P4M

* PIV = 400 V
* Maximum forward current = 2 A
* Holding current = 1 mA
* Gate Triggering current = 0.2 mA

CIRCUIT DIAGRAM:



Name Plate Details of DC Motor

Voltage : 230V , Power = 0.37 kW , Current = 2.3A

TABULATION:

S. No	Armature Voltage (V)	Speed (rpm)	Firing Angle (α)
1.	75	954.8	0°
2.	70	875.9	50°
3.	67	908.7	60°
4.	55	728.8	80°
5.	38	492.2	100°
6.	17.5	199.7	120°
7.	10	90.4	130°
8.	5	20.7	142°

Diode 1N4001

* RMS inverse voltage = 50V
* Forward current = 1A

Motor

* Rated power = 0.37 kW
* Rated Voltage = 230V
* Rated current = 2.3 A

PROCEDURE:

1. The circuit connections are made as shown in the figure
2. The supply voltage is given to the circuit through the variac
3. By varying the firing angle, the corresponding load voltage, load current and speed are noted down
4. The graph is plotted between firing angle and speed, firing angle and load voltage

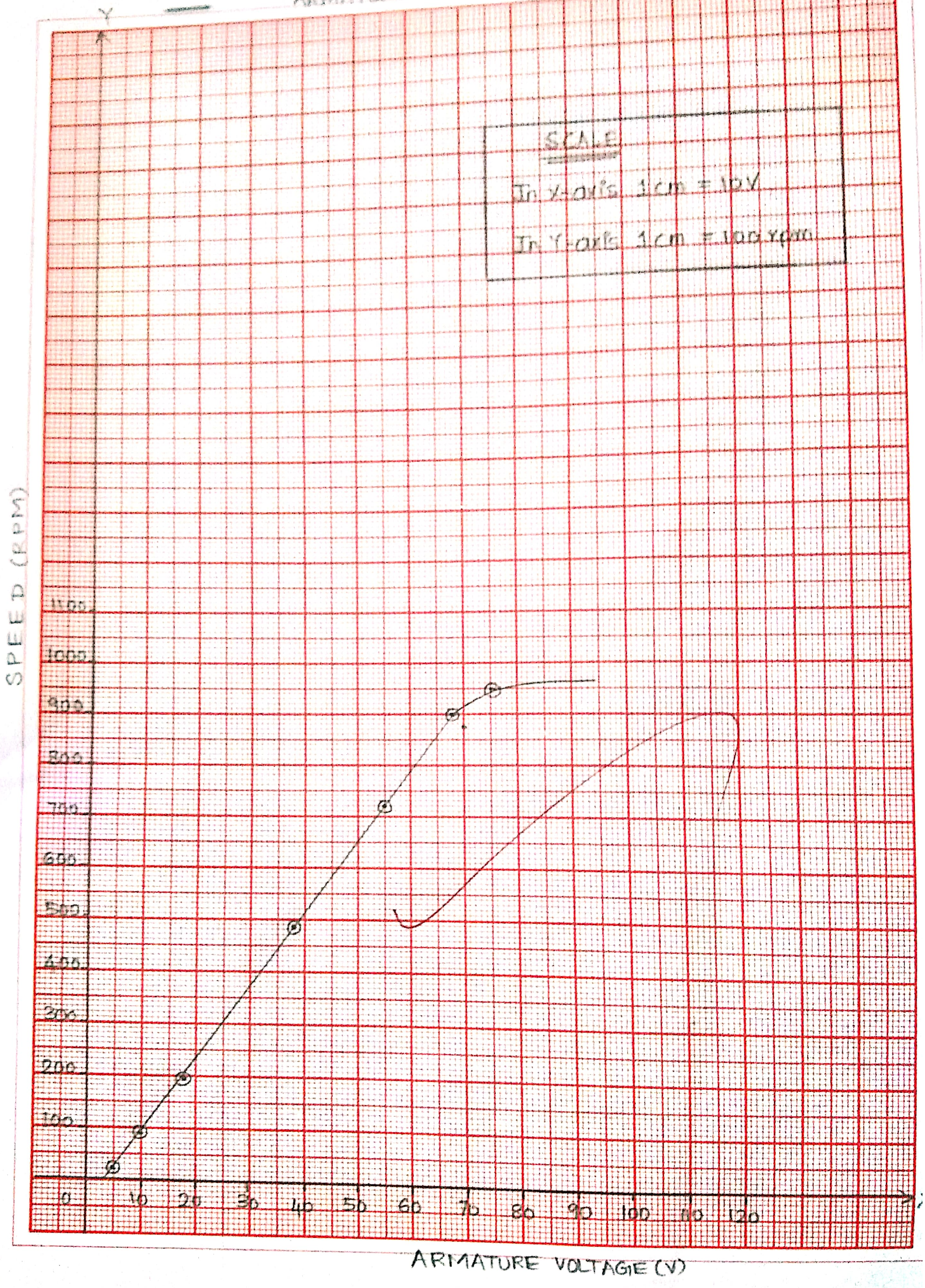
THEORY:

* In a seperately excited DC motor, T_1 receives gate pulse from α to π and T_2 from $\pi+\alpha$ to 2π.
* The AC to DC converter using thyristors is often referred to as controlled rectifier
* When input voltage is positive and when T_1 is triggered, the load current flows through SCR T_1, load resistance and diode D_1
* T_1 is turned off when input voltage becomes negative.
* During the next half cycle, T_2 and D_2 conducts.
* Output voltage is controlled by varying the firing angle of SCRs T_1 and T_2

The output voltage, $V_o = \frac{V_m}{\pi}(1+\cos\alpha)$

HALF CONTROLLED RECTIFIER FED DC MOTOR

ARMATURE VOLTAGE VS SPEED



INFERENCE:

* In this experiment, single phase AC supply is rectified using a semi-controlled rectifier and it is fed to the DC motor.
* Since, it is a semi-controlled rectifier, it has diodes, which blocks negative voltage thus supplying only positive voltage to the motor.
* The field of the motor is seperately excited by a seperate DC supply.
* When the firing angle (α) is increased, the output voltage is decreased and thus the speed of motor is also reduced.
* The motor is operated at no load condition and the input to the rectifier circuit is kept constant.

Dept. of EEE. Record Marks		
Results & Graphs	4	4
Inference	6	5
Total	10	9

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RESULT:

* The single phase half controlled rectifier is designed for the control and speed regulation of the DC motor.
* The motor operation for various firing angles are observed.
* Armature voltage vs Speed (rpm) is plotted.