G.Narayanamma Institute of Technology and Science (For Women)
(Autonomous)
Department of Electrical & Electronics Engineering
Power Electronics and Electric Drives
Advanced Electric Drives Laboratory

Experiment-1

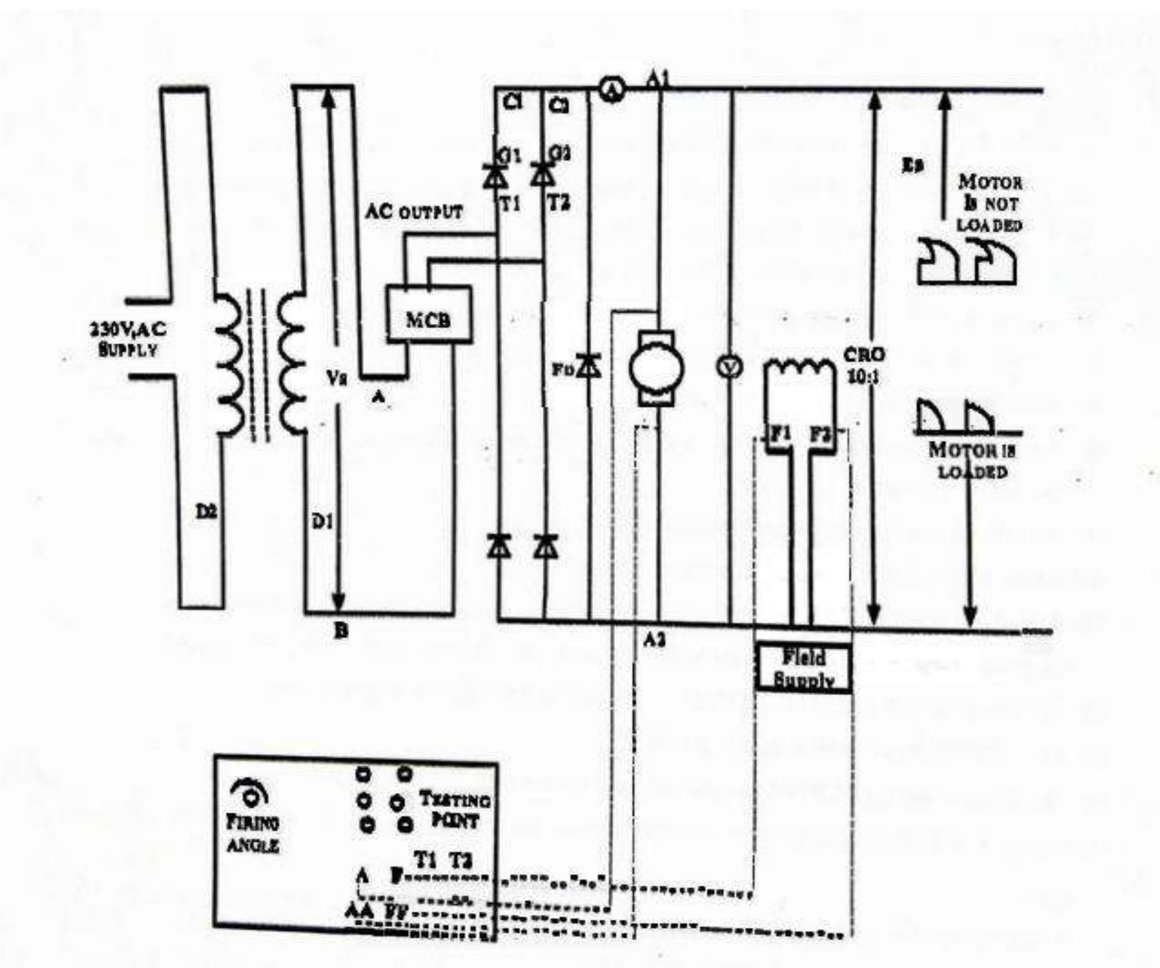
Thyristorised Drive for 1 HP DC Motor with closed loop control

Aim: To control the speed of the DC motor using Thyristorised converter unit.

Apparatus required:

1. Single phase half-controlled power circuit -230V/5A
2. Thyristorised drive for DC motor with close loop control firing unit.
3. Single phase isolation transformer-1KVA
4. DC shunt motor -1HP/220 with mechanical loading arrangement.

Circuit diagram:



Procedure:

1. Connect the circuit as per circuit diagram.
2. Take the readings of load current and load voltage running RPM in open loop.
3. Take the readings of load current and load voltage running RPM in closed loop.
4. Connect DC motor field and armature terminals to respective point in the power circuit and speed sensor to feed back terminals in control circuit.
5. Connect the trigger pulses T1-T2 to power circuit from control circuit.
6. Connect the isolation transformer secondary to the power circuit.
7. Switch on the field supply of the motor.
8. Keeping PID switches at on position , keep all the knobs at minimum position now switch on the firing circuit.
9. Switch on the firing controller mains supply switch.
10. Keep the CL/OL switch in OL.
11. Switch on the MCB in the power circuit of single phase isolation transformer with tappings may be used to set the voltage slowly or to avoid sudden surge of current.
12. Set the rpm to suitable value through the knobs SET RPM (say 800 rpm).
13. Keep the CL/OL switch in CL position.
14. Note down the RUN RPM for closed loop by varying P, I and D gain.
15. Using P,I,D knobs adjust the running rpm to set rpm by varying P gain , I timings , D gain.
16. Load the motor up to 2A load. Note down the speed for different loads observe the current and voltage waveforms using CRO.
17. Release the load slowly. Bring the set rpm knob to minimum position slowly and all the knobs at minimum position. Reduce autotransformer voltage to zero.
18. Switch off the power circuit by MCB, switch off the firing circuit , switch off field supply and remove connections.

Tabular column:

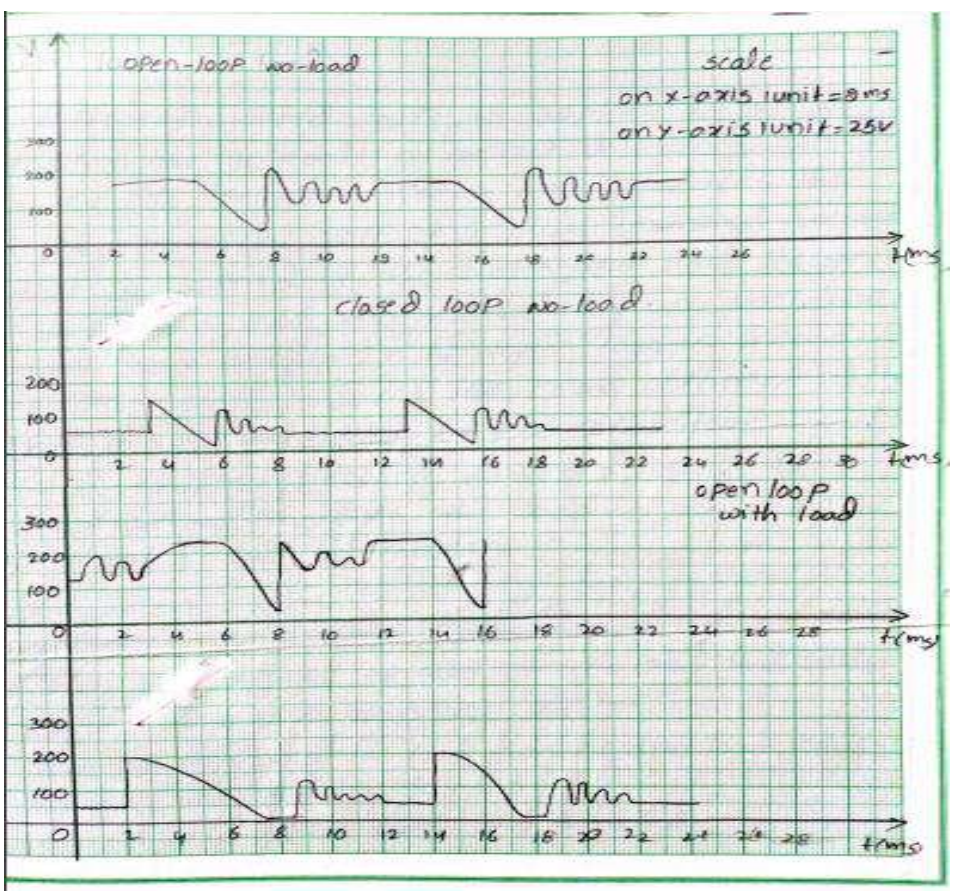
Open loop: Set rpm=1003rpm P=50%; I=25%; D=50%

S.No	Load current	Load voltage	Run RPM
1	0.22	265	1765
2	0.56	237	1567
3	1	211	1372

Set RPM=1000rpm P=50%;I=25%; D=50%

S.No	Load current	Load voltage	Run RPM
1	0.18	150	990
2	0.6	151	988
3	1.01	19	996

Modal graph:



Precautions:

1. Connections should be tight.
2. Make sure that load current cannot increase more than rated current.

After the completion of experiment release the load slowly and switch off the power supply and then field supply

Result:

Faculty signature:

Date:

Experiment 2

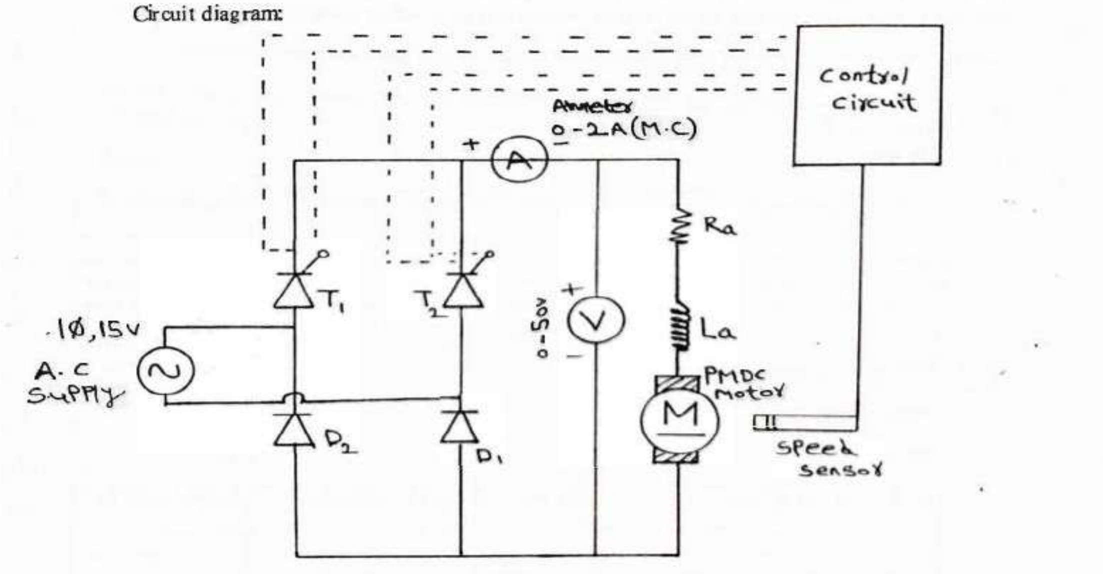
Thyristorised Drive for PMDC Motor with Speed measurement and closed loop control

Aim: To analyze speed control of PMDC motor using open and closed loop control of half controlled thyristor drive.

Apparatus required:

1. Half controlled power unit
2. Control unit
3. PMDC motor
4. Loading arrangement.

Circuit diagram:



Theory:

PMDC motor is controlled by PID controller and thyristor based controlled rectifier power circuit. The PID circuit is to study the characteristics of the feedback control system. The output of the controller then adjusts the value of each variable(gain) in the control system until it is equal to predetermined value called a set point. The system controller must maintain each variable as close as possible to its set point value and it must compensate as quickly and accurately as possible for any change in the variable caused by the motor.

Speed Sensor:

A metallic toothed rotor mounted on shaft whose speed is to be measured. When the rotor rotates the reluctance of the air gap between pickup and the toothed rotor changes gives rise to an induced emf in the pickup coil whenever a metallic part is brought near to it. The emf is amplified by the transistor circuit. The output of the proximity switch goes high whenever a metallic brought bear to it, and the output goes low. If the metallic part is taken away as indicated by the LED. This output is in the form of pulses. These pulses are connected to frequency to voltage converter to read the corresponding RPM. The sensor must be properly adjusted to preferably 1-3mm space must be maintained from screw tooth to the sensor.

Tabular column:

1. Open loop operation
   Input voltage= 12V (PMDC Motor=12V; current=2.6A; speed=1200rpm)
   Set speed= 1200rpm

S.No	Load in gms	Output voltage (V)	Current (A)	Speed in RPM
1	0 (No Load)	12	0.4	1412
2	50gm	11.5	0.45	1358
3	100gm	11	0.5	1315
4	150gm	11	0.55	1285

2. Closed loop operation:
   Input voltage=12VDC
   Set speed=1200rpm P=85%, I=85%

S.No	Load in gms	Output voltage (V)	Current (A)	Speed in RPM
1	0 (No load)	10	0.4	1215
2	50	10	0.45	1203
3	100	10	0.5	1193
4	150	10	0.53	1182

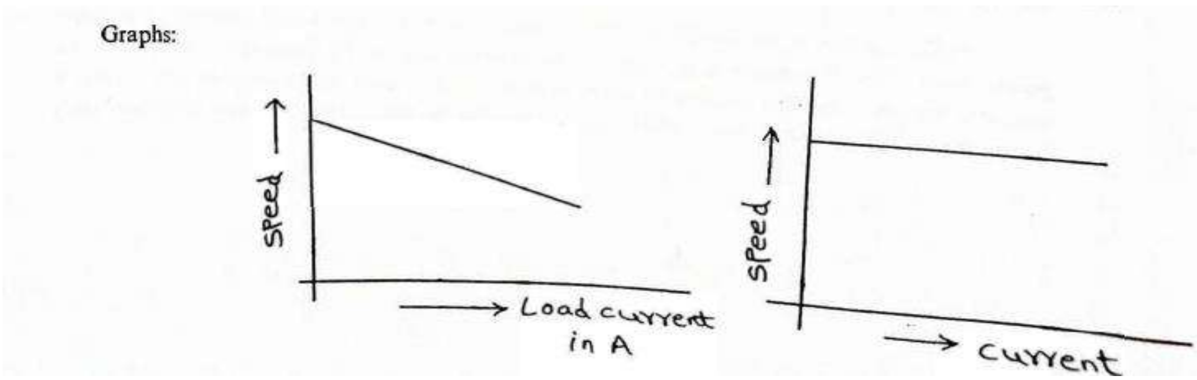
Procedure:

1. To make the connections as per circuit diagram.
2. Keep the PID controller switches in OFF position and set the rated speed using set speed knob.
3. Apply the load gradually and note down the readings of voltmeter, current and actual speed.

4. In closed loop operation, close PID controller switches one by one and observe the actual speed.
5. Keep the PID controller switches 75% margin and vary the load, note down the readings of voltmeter, current and actual speed.

Graphs:

Draw the graph between output current Vs speed of open loop and closed loop operation.



Result:

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Experiment 3

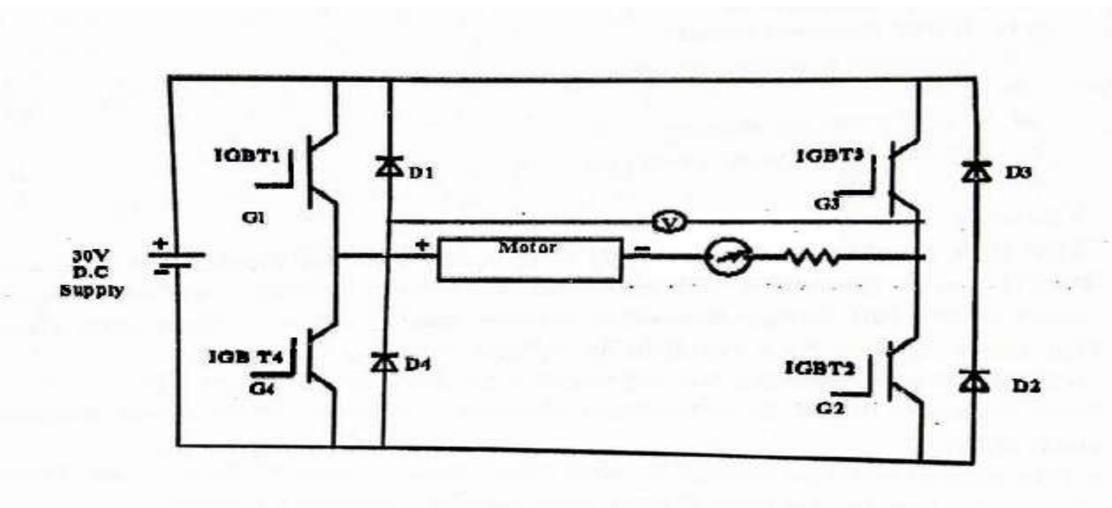
Open Loop and Closed loop of DC motor using IGBT based 4 Quadrant Chopper

Aim: To study the operation of four quadrant chopper with bipolar and unipolar voltage switching and draw the voltage and current waveforms.

Apparatus:

1. IGBT power module.
2. Chopper control Module
3. CRO
4. PMDC motor rating 25W, 12V,2.6A,1500rpm

Circuit diagram:



Theory:

The four-quadrant chopper with four IGBT's where diodes are connected in anti-parallel with the IGBT's is also referred to as full bridge converter topology. The input to the full bridge converter is fixed magnitude dc voltage Vdc. The output of the converter can be a variable dc voltage with either polarity.

Switching Modes of four quadrant chopper

The switches in the four-quadrant chopper can be switched in two different modes such that:

- The output voltage swings in both directions i.e., from +Vdc to -Vdc. This mode of switching is referred to as PWM with bipolar voltage switching.
- The output voltage swings either from -zero to + Vdc or zero to -Vdc. This mode of switching is referred to as PWM with unipolar voltage switching.

Bipolar voltage switching:

The operation of the circuit as a four quadrant chopper with bipolar voltage switching is explained, referring to the circuit diagram of Fig 1.2 when the switches T1 and T4 are turned ON by applying gating signals simultaneously, the load voltages Vdc with terminal ‘A’ positive and the load current I_L flows in the direction from A to B. Because of the load inductance, the current cannot change instantaneously.

The load voltage V will now be -Vdc since the conduction of the diode D3 will connect the load terminal B to the (+) ve terminal of the source. As the load voltage is negative and the current is still positive , the power is negative. The power now flows from the load to the source. This corresponds to the operation of chopper circuit in the fourth quadrant. This operation in the fourth quadrant will continue as long as the current is positive. When T1 and T4 are off , T3 and T2 can be turned ON . when the current passes through zero, the devices T3 and T2 can be turned ON, and the load current becomes negative. The load current now passes through T3 and T2 with current direction in the load as from B to A. This brings the operation of the chopper in the third quadrant. Turning of the T3 and T2 will bring in the conduction of the diode D1 and D4 and the operation of the chopper circuit in the second quadrant. The operation of the chopper in the first and third quadrant corresponds to power flow from the source to the load, and is considered to be forward power flow. The operation in the fourth and second quadrant corresponds to reverse power flow.

Procedure:

1. Make the connections.
2. Switch the trigger circuit module.
3. Set the knob for different duty cycles and note down the output voltage.
4. By varying the weight, note down the torque and speed values.
5. Verify the theoretical and practical values.
6. Draw the output voltage wave forms from the CRO.

Tabular column:

Forward motoring:

Ton	Toff	Duty Cycle	S1-S2	Torque (N-m)	Speed	Output voltage (theoretical)	Output voltage (Practical)	Current(I_o)
1.6*2	0.4*2	53%	50g	0.005	550	5.735	5.1	0.55
1.7*2	0.3*2	61%	100g	0.011	550	5.84	5.25	0.59
1.8*2	0.2*2	77%	150g	0.016	550	5.992	5.3	0.64

$$V_o = \frac{1}{5.1}\left[\int_0^{1.6}(2.5\times5)\,dt - \int_{1.6}^{2}(0.8\times5)\,dt + \int_{2}^{5.1}(0.7\times5)\,dt\right]$$

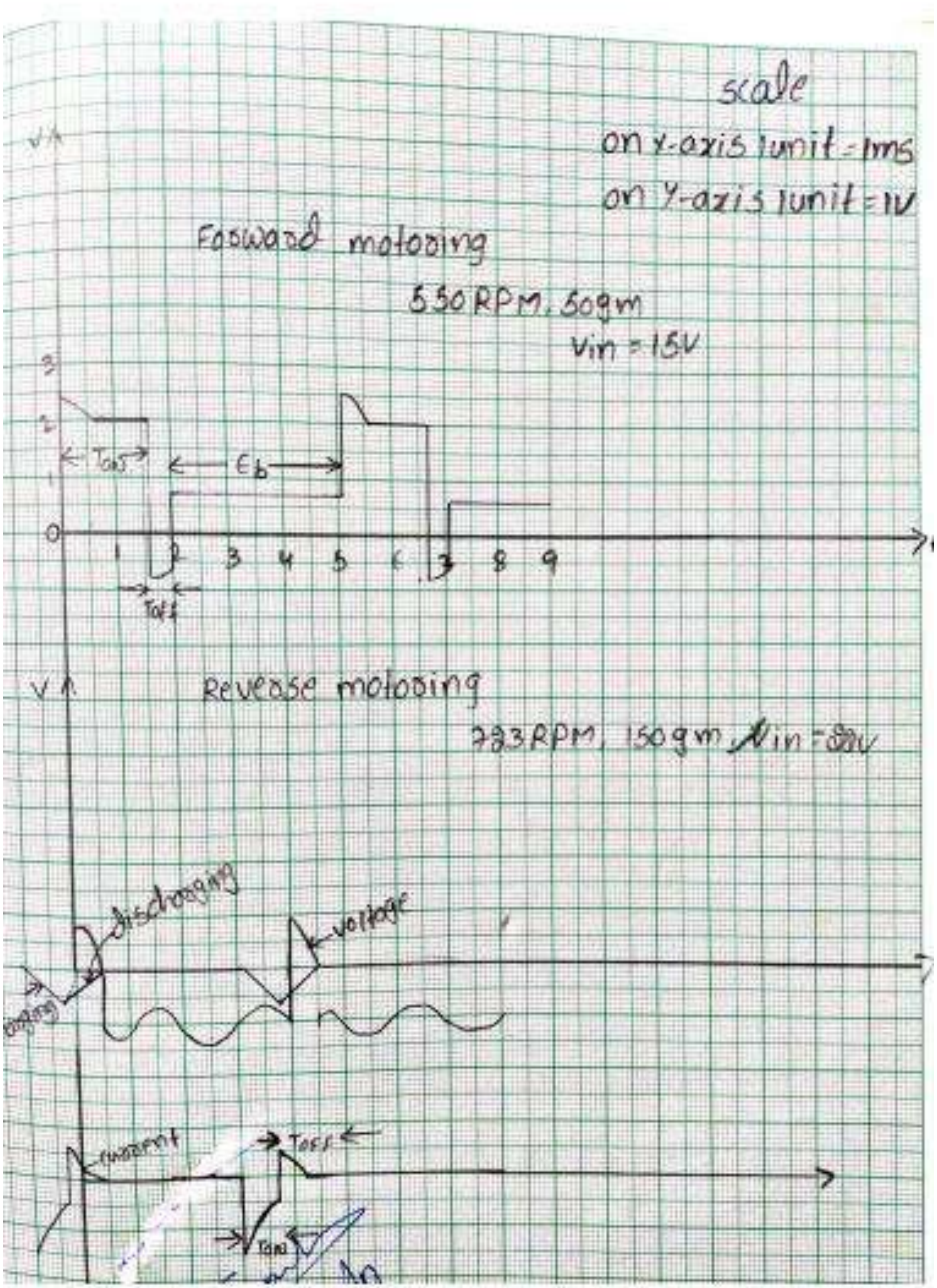
$$= 5.735V$$

Reverse motoring:

Ton	Toff	Duty Cycle	S1-S2	Torque (N-m)	Speed	Output voltage (theoretical)	Output voltage (Practical)	Current(I_o)
0.8*2	0.6*2	57%	50g	0.05	723	7.233V	6V	0.49
0.9*2	0.5*2	64%	100g	0.011	723	7.32V	6V	0.56
1*2	0.4*2	71%	150g	0.0167	723	7.41V	6V	0.63

$$V_o = \frac{1}{4}\left[\int_0^{0.8}(0.9\times5)\,dt - \int_{0.8}^{1.4}(0.6\times5)\,dt + \int_{1.4}^{4}(1\times5)\,dt\right]$$

$$= 7.233V$$


scale
on x-axis 1unit = 1ms
on Y-axis 1unit = 1V
Forward motoring
530 RPM, 50gm
Vin = 15V
Reverse motoring

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Result:

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Experiment 4

V/F control of 3 phase induction motor drive

Aim: to control the speed of 3-phase induction motor using v/f PWM control technique.

Apparatus required:

1. Circuit kit- closed loop induction motor control unit 3-phase -440V-3Hp
2. Multimeter
3. Connecting wires

Name plate details:

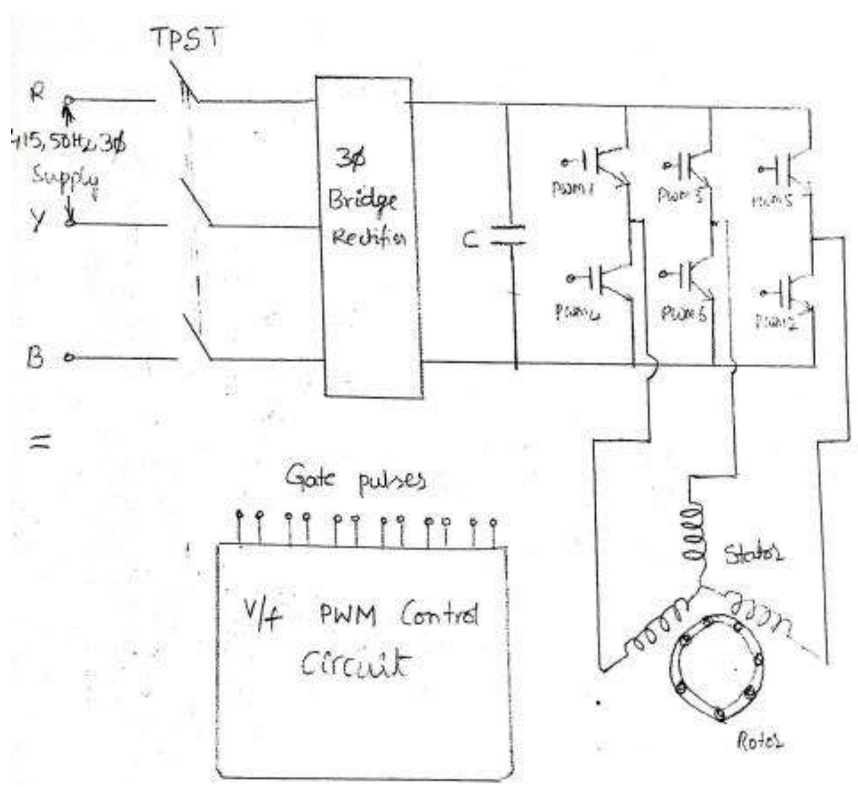
Voltage:450V

Power :3KW

Current:5A

Speed : 1400rpm

Circuit diagram:



Theory:

The voltage/ frequency control method is one of the methods of speed control of three phase induction motor. The increase in the voltage causes increase in the maximum torque of the motor.

1. F increases N increases T_{max} decreases.
2. Voltage increases T_{max} increases.

If these two features are combined, we can control such that the speed increases and the torque is kept the same. This is known as V/F control.

The change in voltage and frequency is a powerful method for speed control of induction motor. There are several variations where the v/f ratio is also adjusted to provide a special operating performance. The most common method is the fixed V/F ratio.

The relation between maximum torque and V/F is

$$T_{max} = k(\frac{v}{f})^2$$

From this equation v/f is maintained constant T_{max} also remain constant and airgap flux is also constant.

The low frequency operation at a constant v/f ratio is not satisfactory at low frequency the starting and breakdown torques considerably decreases and no load current increases. The air-gap flux cannot be maintained constant low-frequency maintaining a constant v/f ratio. Therefore to maintain the v/f ratio constant, the supply voltage should be increased.

The v/f control method, one must be careful not ot increase the voltage magnitude beyond the rating of the motor. The increased voltage can cause instant damage to the insulations of the motors, windings, leading to shorts and internal faults, normally the voltage should be kept below 110% of the rated value. The voltage at variable frequency can be obtained from three phase inverters or cycloconverter.

The main features are

1. The maximum torque should be constant.
2. The starting current is also constant.

Procedure:

1. Make the connections as per circuit diagram
2. Enter the command mode and choose the terminal to a board(0) or operational panel
3. Select the automatic acceleration / deceleration mode
4. Keep the frequency variable knob in anti-clock wise direction.
5. Run the motor at rated speed by controlling the frequency Knob.
6. By varying the frequency note down the voltage across the terminals and frequency.

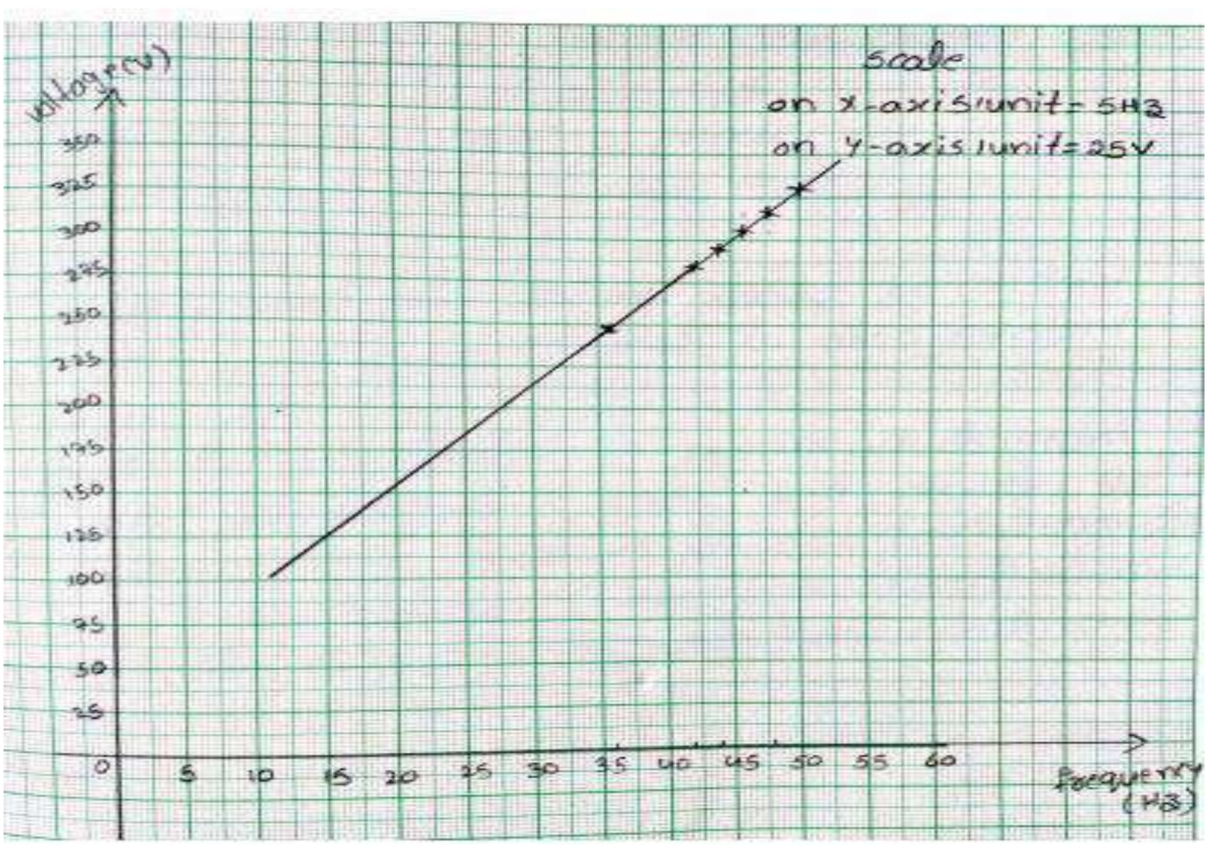
7. Draw the graph between frequency Vs voltage.

Tabular Column:

Input voltage=415V

S.No	Frequency(Hz)	Output Voltage(V)	Speed(RPM)
1	36	248	1088
2	40	268	1205
3	42	280	1260
4	44	292	1316
5	46	304	1374
6	48	312	1422
7	50	328	1466

Modal graph:



Precautions:

The motor voltage should not be increased above the rated value.

Result:

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Experiment 5

AC single phase motor speed control using TRIAC

AIM:

To construct a single phase AC voltage controller & to observe the output wave forms with

1. R load
2. Motor load

APPARATUS: 230V input 0-30V-60V output AC step down transformer or auto transformer, power module, firing unit, loading rheostat, 100 Ohm/5 W, Inductor 100mH/2A(for RL loads), AC induction motor/Universal motor, patch cards etc.

THEORY: AC voltage controller converts fixed AC supply to variable AC supply. With thyristor, variable AC supply 0V to maximum can be obtained from a fixed AC source by triggering (turning ON) thyristor i.e. by applying gate current to the thyristor at any desired instant when the thyristor is applied with positive voltage to anode. Unlike diode, thyristor can block the forward voltage when gate current is not supplied

AC VOLTAGE CONTROLLER WITH R LOAD.

In a single phase AC voltage controller with triac feeding power to resistive load triac conducts during positive and negative half cycles. During positive half cycle, MT2 become forward biased w.r.t. MT1. Triac starts conducting and source voltage applied to load from α to ∏. At n onwards MT2 subjected to reverse biased, it is therefore turned off. During negative half cycle, MT1 become forward biased & triac is triggered at ∏ + α. triac conducts from ∏ + α to 2∏. Soon after MT1 subjected to reverse biased, it is therefore turned off.

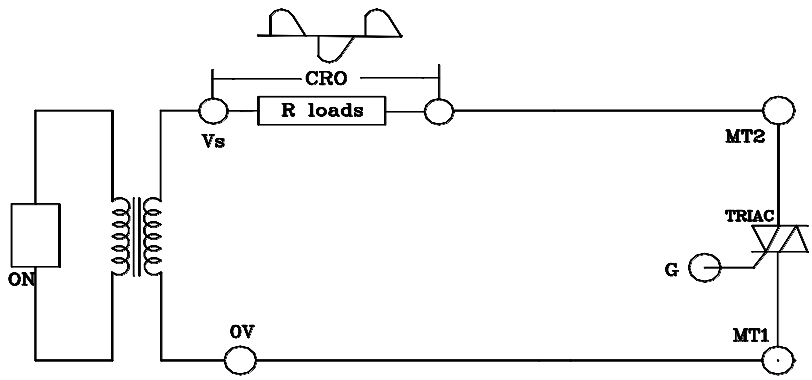
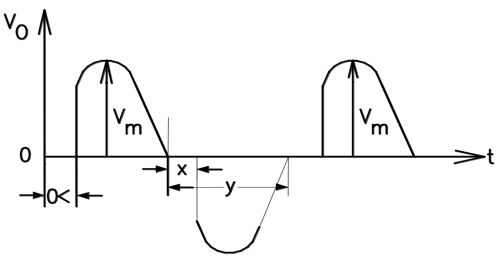


Fig.1.1 TRIAC based AC Voltage Controller



Firing Angle = [X/Y]180
Fig.1.2 Load Voltage for R load

AC VOLTAGE CONTROLLER WITH R-L / MOTOR LOAD.

In a single phase AC voltage controller with triac feeding power to inductive load triac conducts during positive and negative half cycles. During positive half cycle, MT2 become forward biased w.r.t. MT1. Triac starts conducting and source voltage applied to load from α, at ∏ load current is not zero therefore triac conducts beyond ∏ till β (beta). At β load current reduced to zero therefore triac is turned off. During negative half cycle, MT1 become forward biased & triac is triggered at ∏ + α. Triac conducts from ∏ + α to 2 β. Soon after triac is subjected to reverse biased, at 2 β it is therefore turned off.

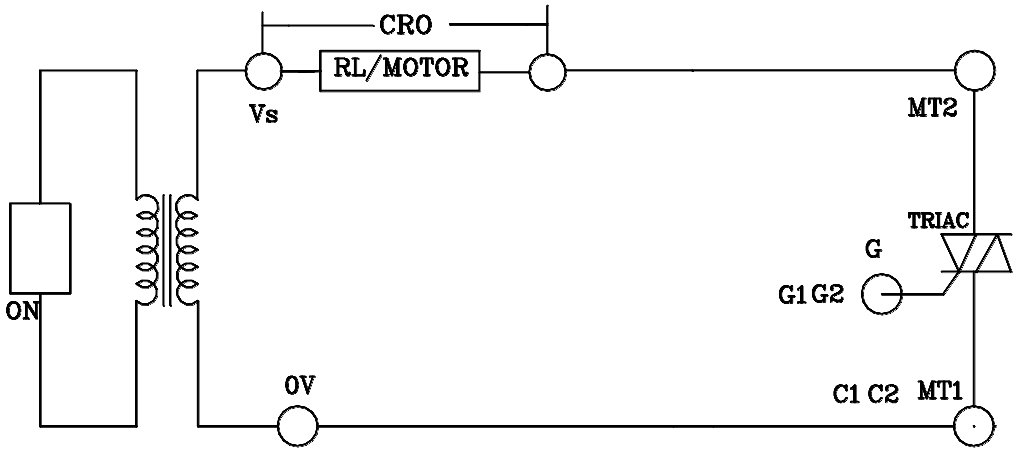
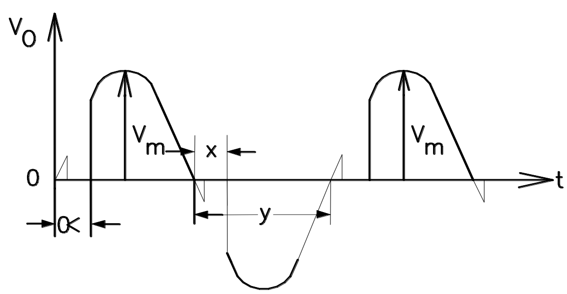


Fig.1.3 TRIAC based AC Voltage Controller



Firing Angle = [X/Y]180

Fig.1.4 Load Voltage for RL load

PROCEDURE:

Procedure for R loads

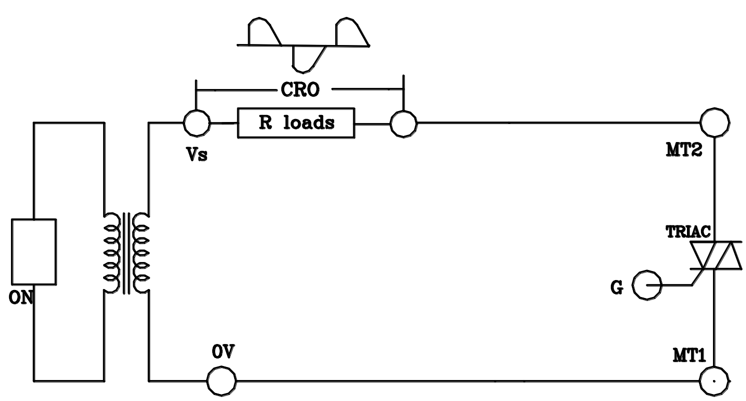


Fig.1.1 TRIAC based AC Voltage Controller

1. The connections are made as shown in the circuit of single phase AC voltage controller with R(100 Ohm/2A) load using an isolation transformer.
2. The gate cathode terminal of the TRIAC is connected to the respective points on the firing module.
3. **Check all the connections and confirm connections made are correct before switching on the equipments.**
4. **Keep the firing angle knob at 180^0 degree (minimum position). Switch ON the firing unit.**
5. **Now switch ON the power circuit.**
6. The firing angle is varied output wave form is seen on a CRO.
7. The firing angle is varied and AC output voltage is noted using multimeter.
8. Tabulate the practical values. (Refer given table).
9. **Keep the firing angle knob at 180^0 degree (minimum position). Switch OFF the power circuit & then firing unit. Remove the patch cords**

Procedure for motor loads

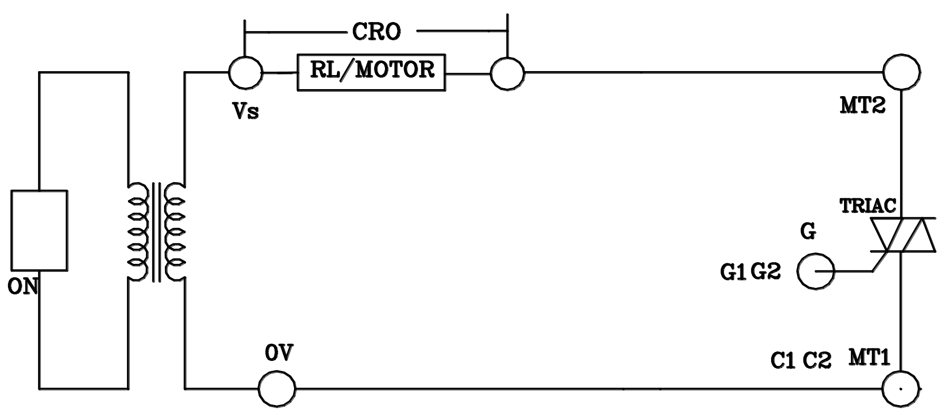


Fig.1.3 TRIAC based AC Voltage Controller

1. The connections are made as shown in the circuit of single phase AC voltage controller with universal/induction motor load using an isolation transformer.

2. The gate cathode terminals of the 2 SCR's are connected to the respective points on the firing module.
3. **Check all the connections and confirm connections made are correct before switching on the equipments.**
4. **Keep the firing angle knob at 180^0 degree (minimum position). Switch ON the firing unit.**
5. **Now switch ON the power circuit.**
6. The firing angle is varied and the variation of the motor speed is observed.
7. Tabulate the speed in rpm for different firing angles. (Refer given table).
8. **Keep the firing angle knob at 180^0 degree (minimum position). Switch OFF the power circuit & then firing unit. Remove the path cards.**

OBSERVATIONS:

For motor loads:

Sl. No..	Firing Angle α In degrees	Speed in rpm	Output Voltage(V)
1.	180^0	0	0
2.	180^0-150^0	306	12
3.	150^0	950	26
4.	150^0-120^0	1426	47
5.	120^0	1454	71

RESULT: Speed control of single phase AC motor using TRIAC is performed and its performance with Motor load is observed.

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Experiment 6

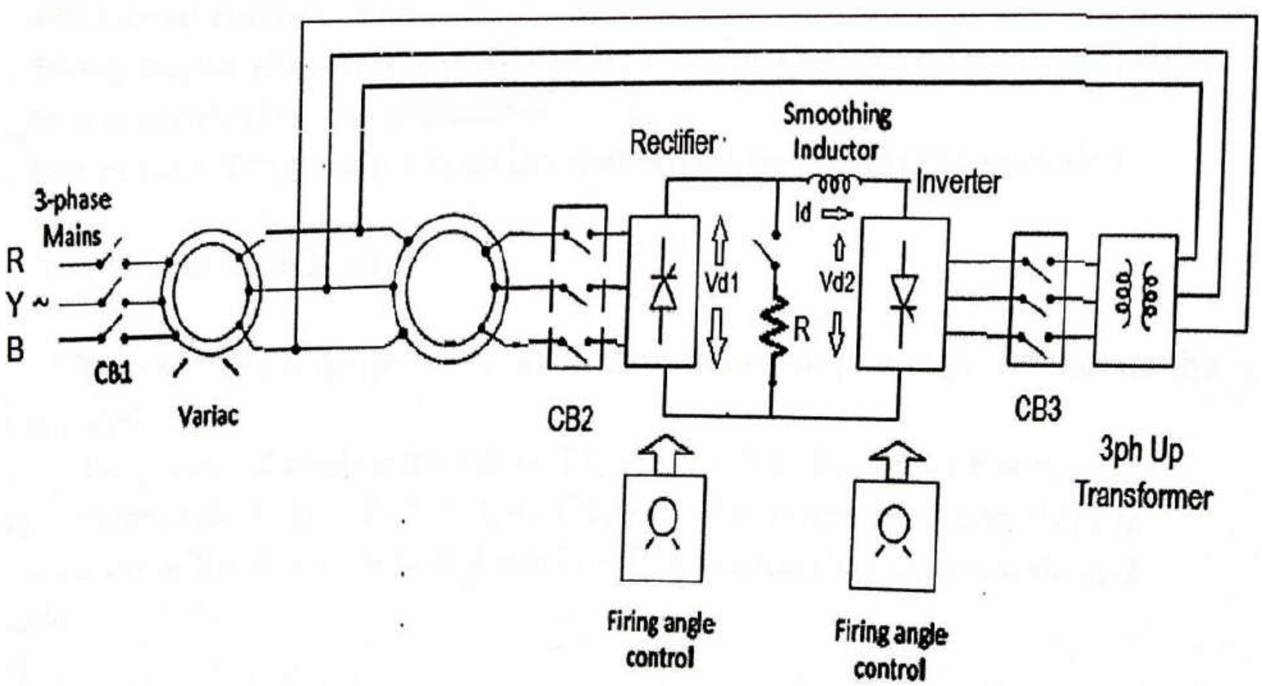
Speed control of three phase wound rotor induction motor using slip power Recovery scheme

Aim: To control the speed of induction motor using slip power recovery scheme.

Apparatus:

1. 3-phase wound rotor induction motor-430V,3Hp,1500rpm
2. Three phase power module
3. Three phase firing module
4. Resistance-100 ohms/2A
5. Smoothing Inductor-100mH-0-100mH/4A
6. Three phase dimmer (Variac)-1
7. Three phase transformer Input:0-415V, output:0-10V-20V-30V transformer provided.

Circuit diagram:



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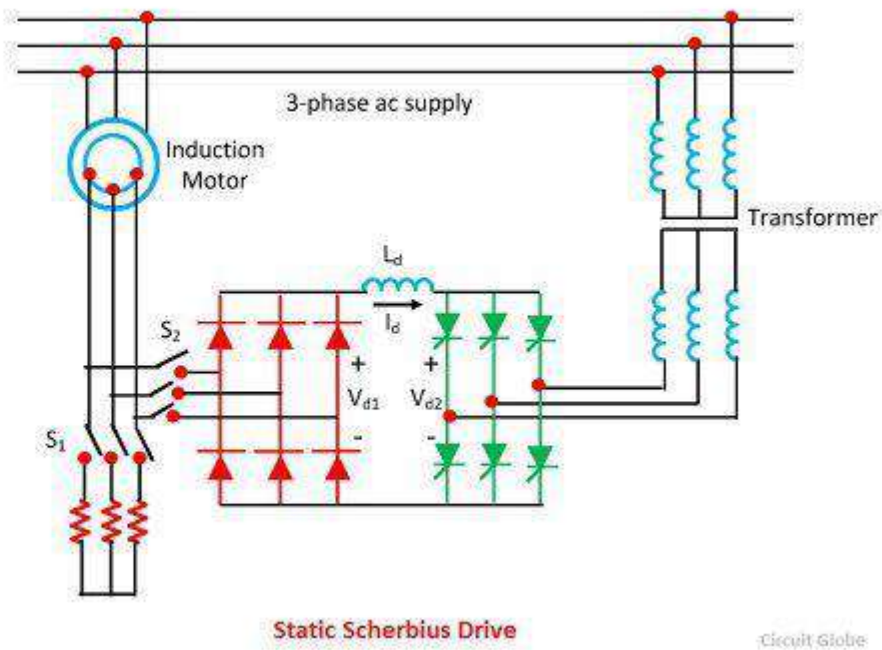

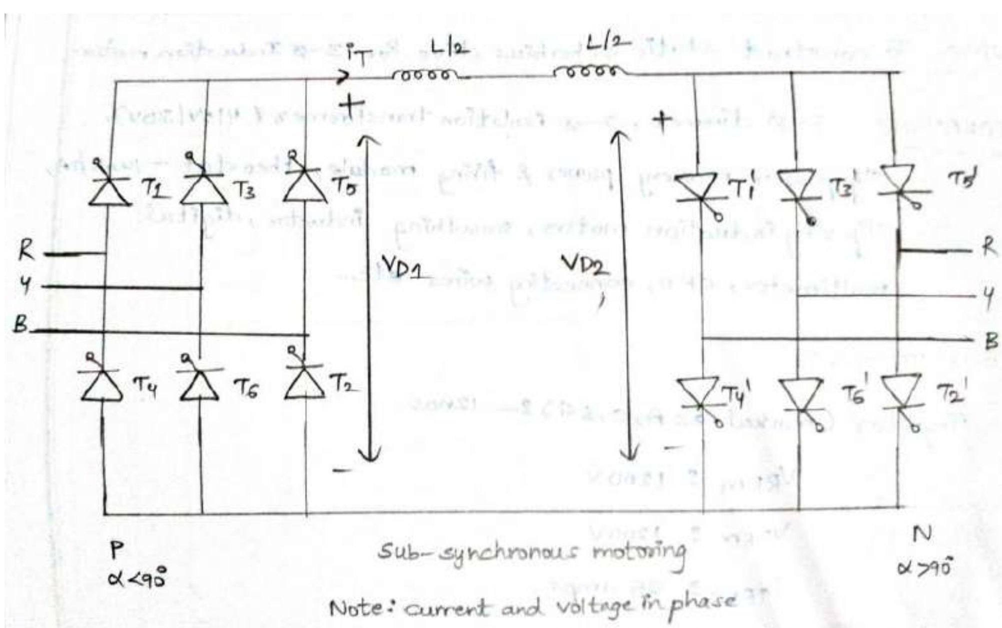

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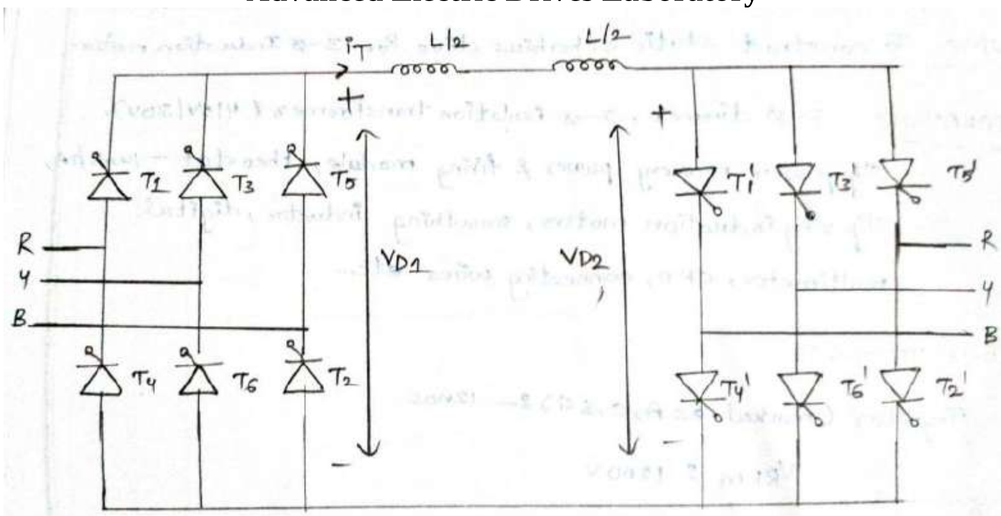
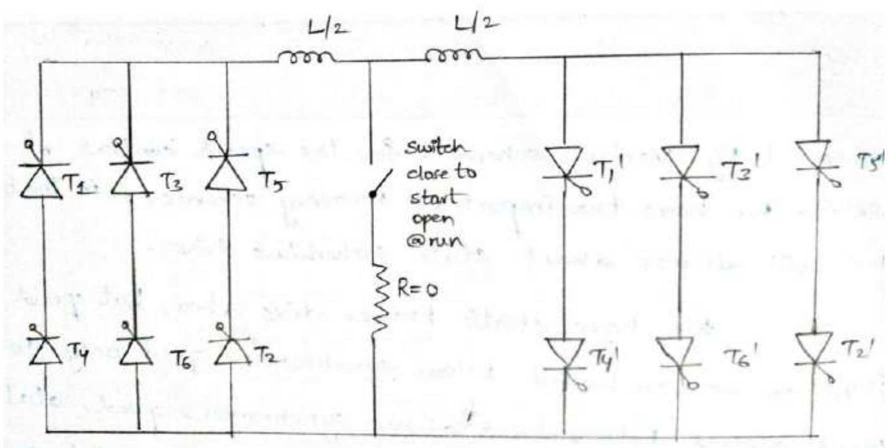


Super synchronous Mode

Note: Current and Voltage are out of phase

P ($\alpha=180^0$) N ($\alpha=90^0-0^0$)



Specification:

1. Thyristor (marked as A,C &G) : 12No's

VRRM :	1200V
VDRM :	1200V
ITRMS:	25A
ITAV:	16A

2. Fuse:
   5A on MF-20sockets provided at the back side of the instrument and are replaceable.
3. Protection:
   For input power protection, 6A three phase MCB's is provided for the two converters. A well-designed snubber network is provided for each device for dv/dt and reversal voltage protection. The devices are mounted on individual heat sinks. Twelve fuses are provided for each device for short circuit protection.
4. Inductor:
   100-0-100mH inductor with mid-point 0.
5. Input power supply for triggering circuit :415V AC from mains for synchronization and power supply through fuse protection.
6. Triggering circuit output:
   Twelve pairs isolated gate signals for triggering thristor.
7. Gate drive current:200mA
8. Firing angle:180^0 to 0^0 for converter#1(0^0 to 180^0 for converter#2) firing angle is controlled by potentiometer.
9. Test points:
   Triggering circuit internal circuit test points are provided.

Front panel Details:

1. Two MCB's 6 A, are provided for the input power protection on the front panel.
2. Terminals of twelve thyristors T1,T2,T3,T4,T5,T6 of rectifier (converter#1) and $T1^1$, $T2^1$,$T3^1$,$T4^1$,$T5^1$,$T6^1$ of inverter (converter#2) are brought on to the front panel and marked their terminals gate, cathode and anode.
3. 100-0-100mH inductor is placed inside(outside inductor may also be used) the box and the terminals are connected on to the front panel and marked as L/2 & L/2.
4. Testing points.
5. Firing angle variable knob.

Firing Circuit:

This unit gives 12-No's of thyristor trigger pulses. 6-No's for rectifier and other 6-No's for inverter. The firing angle is controlled by the potentiometer provided for rectifier and inverter commonly.

Procedure:

1. The connections are made as shown in the circuit of three phase dual converter with R load (rheostat) connected and isolation transformer at line side.
2. Connect input terminals N,R,Y&B of isolation transformer (415V/30V) to respective terminals N,R,Y&B of three phase auto transformer.

3. Connect output terminals R,Y&B of isolation transformer to respective terminals R,Y&B of power module inverter(line side converter)
4. Connect input terminals N,R,Y&B of isolation transformer to respective terminals N,R,Y&B of firing circuit.
5. The gate cathode terminals of all the 12SCR's of power circuit are connected to the respective points on the firing circuit.
6. Keep the rheostat at minimum position (zero resistance).
7. Check all the connections and conform connections made are correct before switching on the instrument.
8. Keep the P-firing angle knob (rectifier) at 180^0. N-firing angle knob (inverter) at 90^0
9. Keep dimmer at minimum position.
10. Keeping all MCB on position, switch on three phase supply, power unit as well as firing circuit.
11. Vary dimmer gradually, motor start rotating.
12. Now remove the rheostat.
13. Keep the firing angle knob of rectifier at 180^0, firing angle of inverter (line side converter) is varied from 90^0 to 0^0.
14. Note down speed for different firing angles of line side converter(inverter).
15. Reduce the dimmer voltage and switch off supplies.

Note: For sub synchronous speed: Keep the firing angle knob of rectifier at 0^0, firing angle of inverter (line side converter) is varied from 90^0 to 180^0.

Observations:

Super synchronous speed

P-Firing angle =180^0

N-firing angle	Speed in rpm	Voltage at rectifier side	Voltage at inverter side
90^0	1498	2V	12V
75^0	1445	2V	12V
60^0	1335	2V	12V
45^0	1294	2V	12V
30^0	1209	2V	12V

Sub-Synchronous Speed:

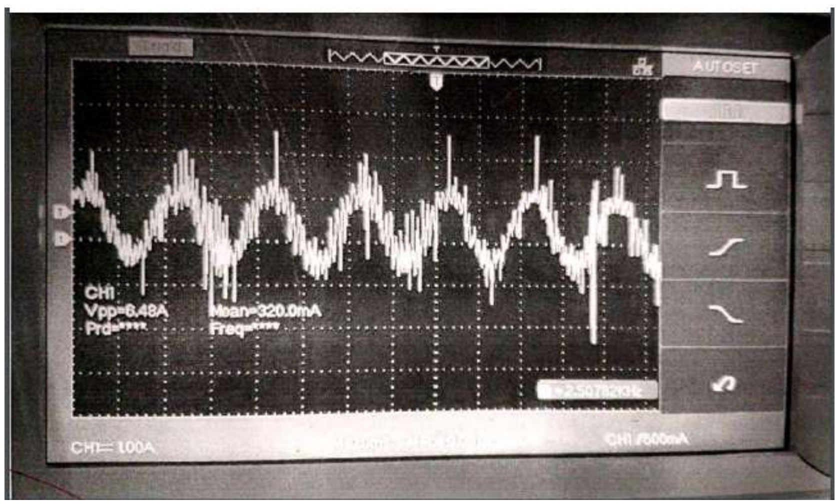
P-Firing angle =0^0

N-firing angle	Speed in rpm	Voltage at rectifier side	Voltage at inverter side
90^0	1258	20.9	17.6
120^0	1094	20.9	17.6
150^0	910	20.9	17.6

180^0	874	20.9	17.6

Precautions:

1. Connections as per the circuit diagram.
2. Gate pulses must be connected to corresponding circuits only.
3. Make sure that B-phase sequence and neutral is connected to firing module.
4. No additional power supply or power cables are not connected to power and firing module.
5. All MCB’s and firing module switches must be on position before giving supply.
6. Three phase dimmer must be in minimum position before switch on the supply.
7. Smoothing inductor must be used.



Result:

Faculty signature:

Date:

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Experiment 7

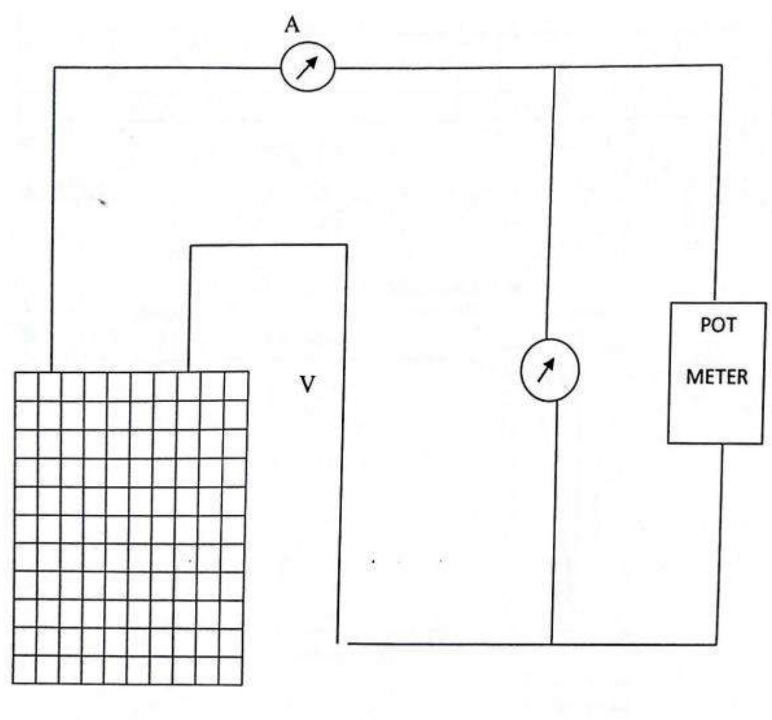
Characteristics of solar P-V system

Aim: To demonstrate I-V and P-V characteristics of PV module with varying radiation and temperature level.

Apparatus:

1. Solar panel
2. Solar control board
3. Patch chords

Circuit diagram:



P-V MODULE

Theory:

The electrical I-V characteristics of a solar cell or panel is critical in determining the device's output performance and solar efficiency. Photovoltaic solar cells converts the sun's radiant light directly into electricity. With increasing demand for a clean energy source and the sun's potential as a free energy source, has made solar energy conversion as part of a mixture of renewable energy sources increasingly important. The main electrical characteristics of a PV cell or module are summarized in the relationship between the current and voltage produced on a typical solar cell I-V characteristic curve.

The intensity of the solar radiation (insolation) that hits the cell controls the current (I) , while the increase in the temperature of the solar cell reduces its voltage (V). Solar cells produce direct current (DC) electricity and current times voltage equals power, so we can create solar cell I-V curve representing the current versus the voltage for a photovoltaic device.

Solar cell I-V characteristics curves are basically a graphical representation of the operation of a solar cell or module summarizing the relationship between the current and voltage.

V-I curves provide the information required to configure a solar system so that it can operate as close to its optimal peak power point (MPP) as possible.

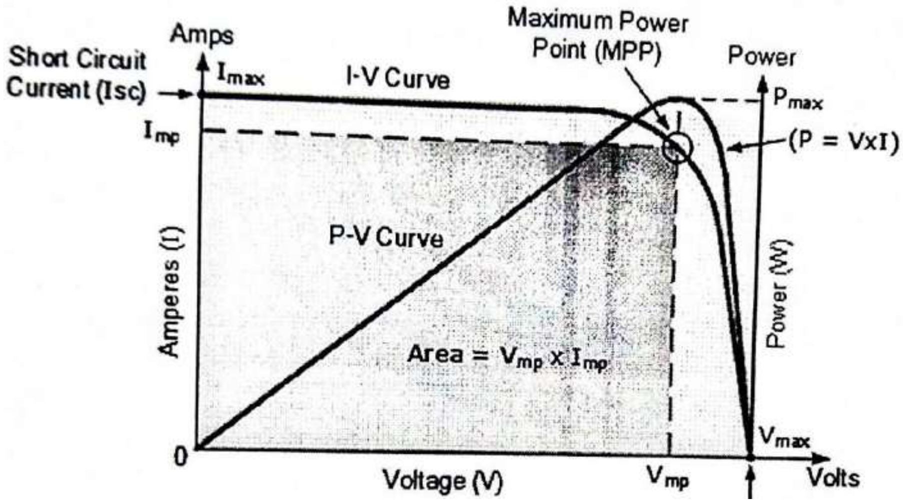
Procedure:

1. Make the connections as per the circuit diagram
2. Switch on the control circuit board.
3. Adjust the intensity of radiation at a particular temperature and note down the values.
4. By varying pot meter note down the readings of module voltage and current.
5. Draw I-V and P-V waveforms.

Tabular column:

S.No	Radiation	Temperature	Voltage(V)	Current (A)	Power (w)
1	157.5	28.3	18.1	0.07	1.267
2	157.5	29.4	16.2	0.11	1.782
3	157.5	30.6	14.3	0.12	1.716
4	157.5	31.5	10.1	0.13	1.313
5	157.5	32.3	7.6	0.13	0.988
6	157.5	32.7	4.6	0.14	0.644

Graphs:



I-V & P-V curves of PV module

Precautions:

1. Readings for one set should be taken within one to two minutes (for indoor experiment) otherwise temperature of the module may vary as radiation source used is halogen lamp.
2. Halogen position should not be changed during one set otherwise radiation on module will change.
3. Connections should be tight.

Result: Hence V-I and P-V characteristics of PV module with varying radiation and temperature level are demonstrated.

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Experiment -8

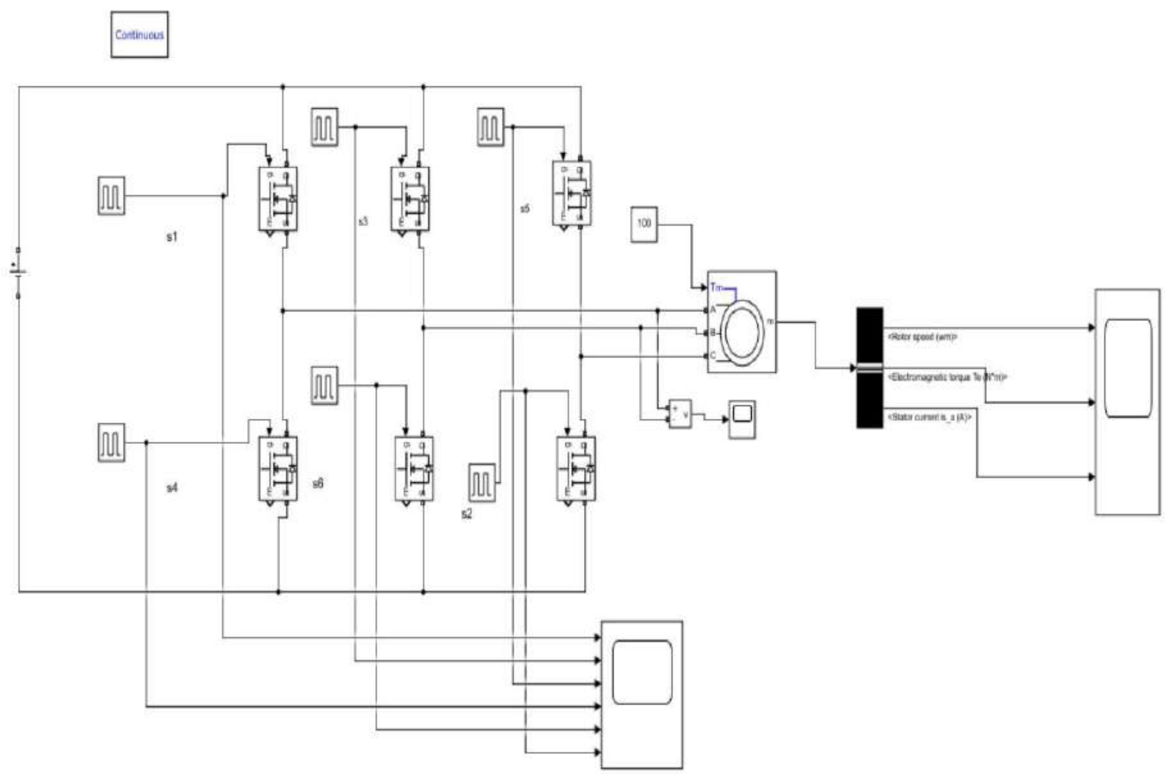
VSI Fed Indcution Motor Drive Using MATLAB Software

Aim: To control the speed of induction motor using Voltage source inverter with help of mat lab of software.

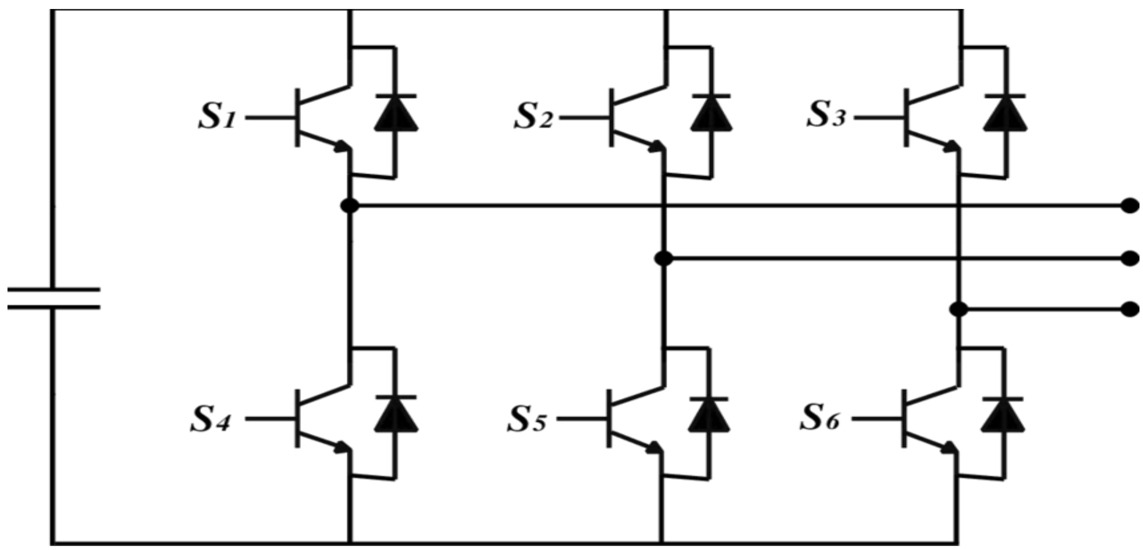
Apparatus:

MATLAB Simulink

Circuit Diagram:



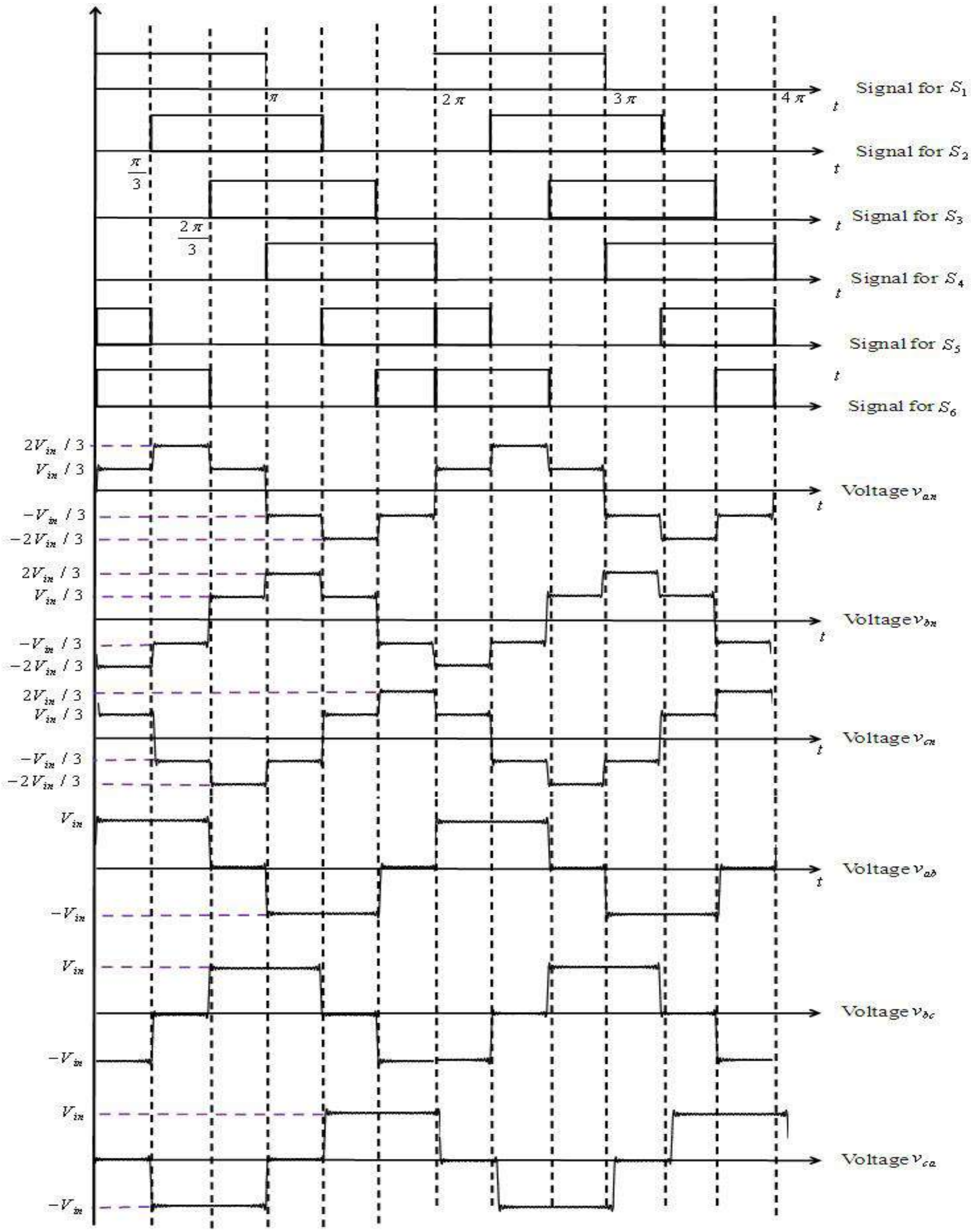
Theory:



180 Degrees mode: In the three phase inverter each scr conducts for 180 degrees of a cycle thyrsitor pair in each arm T1,T4,T3,T6 and T5,T2 are turned on with a time interval of 180. It means that T1 conducts for 180 and T4 for the next 180 of a cycle. Thyristors in the upper group T1,T3,T5 Conducts at an interval of 120 . It implies that if T1 is fired at wt=0 then T3 must be fired at wt=120 and T5 at wt=240same is true for lower group of scrs.

Switching sequence

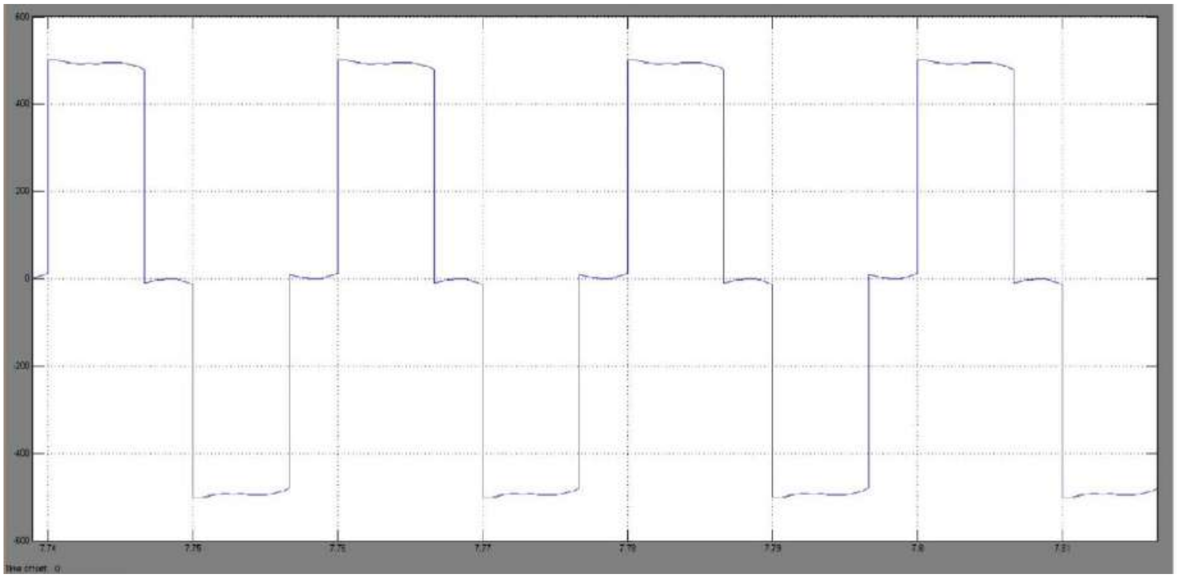
T1	T2	T3	T4	T5	T6
0	(0.01/3)	(0.02)/3	0.01	(0.04)/3	(0.05/3)



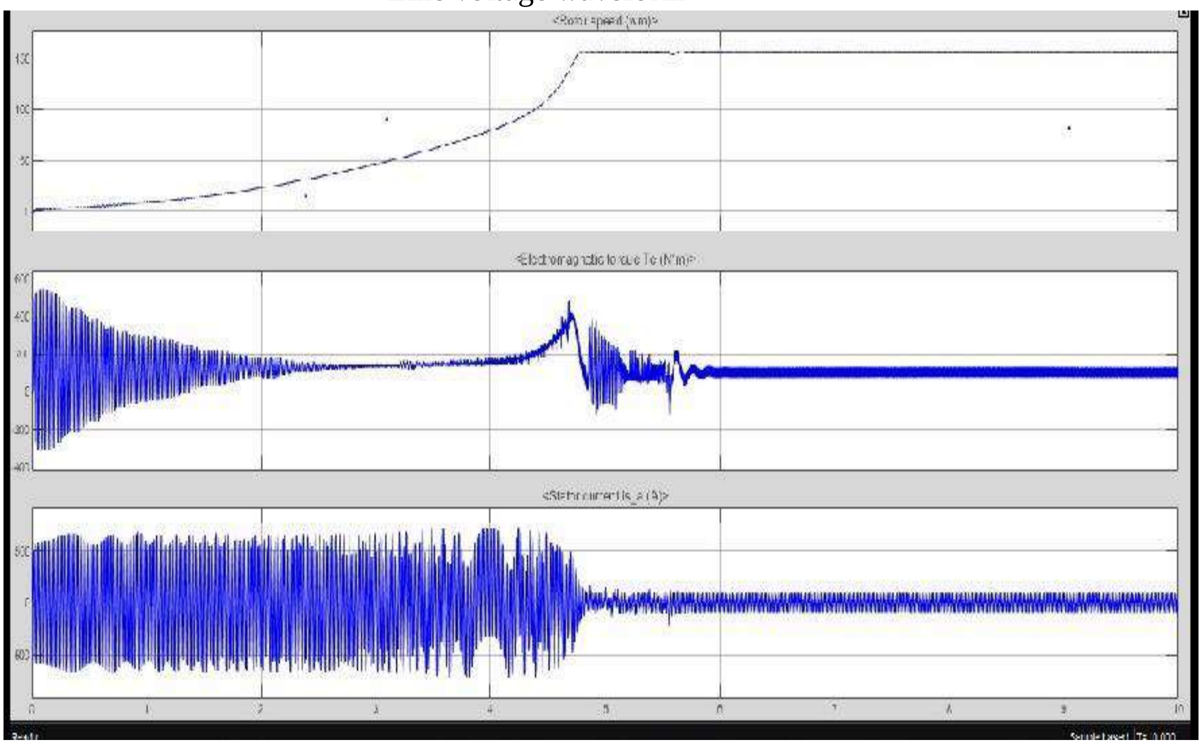
Signal for S_1
Signal for S_2
Signal for S_3
Signal for S_4
Signal for S_5
Signal for S_6
π
2π
3π
4π
$\frac{\pi}{3}$
$\frac{2\pi}{3}$
t
$2V_{in}/3$
$V_{in}/3$
$-V_{in}/3$
$-2V_{in}/3$
V_{in}
$-V_{in}$
Voltage v_{an}
Voltage v_{bn}
Voltage v_{cn}
Voltage v_{ab}
Voltage v_{bc}
Voltage v_{ca}

Procedure:

1. Simulate the circuit in the MATLAB simulink.
2. Observe the output waveform.



Line voltage waveform



Speed, Torque, stator current waveforms

Result:

Faculty Signature:

Date:

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Experiment 9

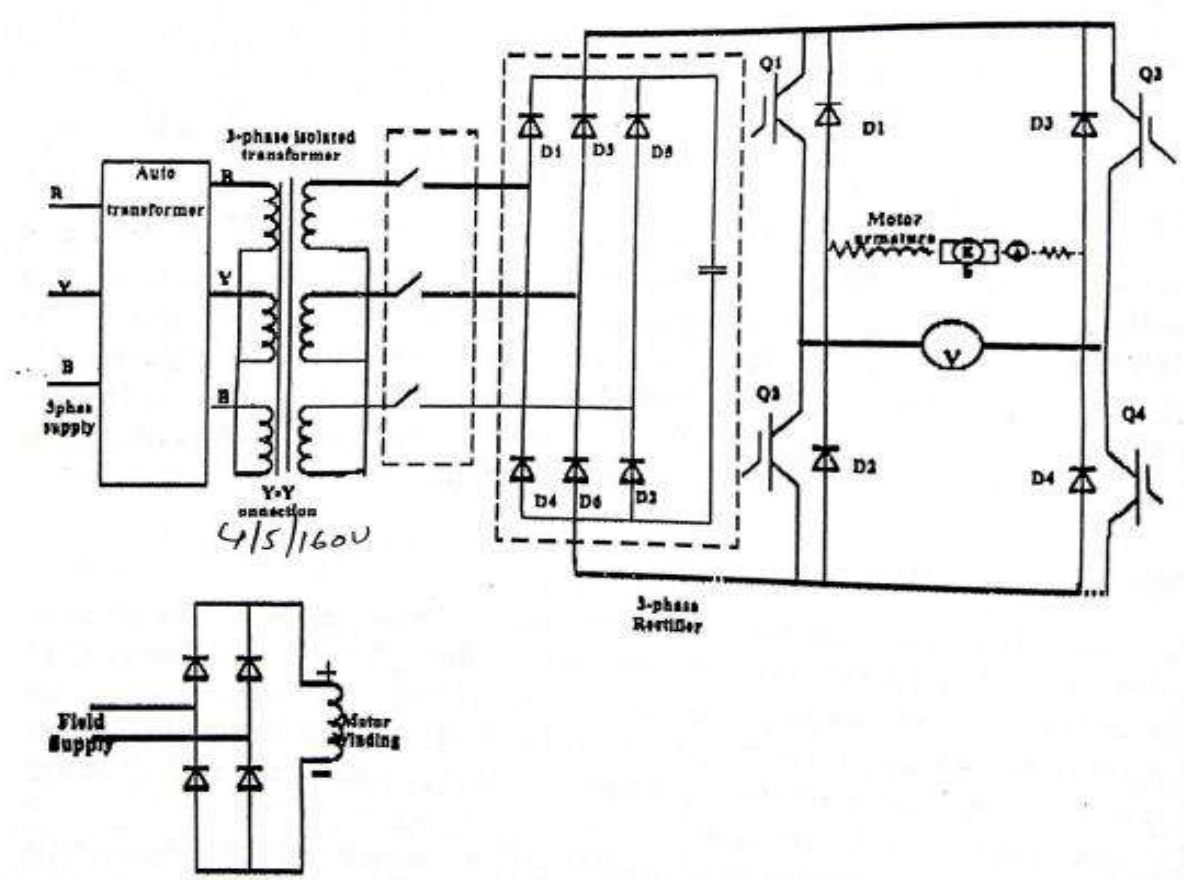
Three phase input IGBT Based four-quadrant chopper drive for DC Motor with closed loop control

Aim: To construct three phase fed closed loop four quadrant chopper drive circuit and to control the speed of the separately excited DC motor.

Apparatus:

1. Chopper power module
2. Chopper firing circuit
3. Three phase auto transformer
4. Isolation transformer
5. CRO
6. Patch chords

Circuit diagram:



Theory:

This speed control unit is based on PID controller. This unit generates four triggering pulses. Speed can be set through knob provided on the unit. Unit is programmable to adjust the duty cycle. This unit generates four chopper triggering pulses. CH1,CH2,CH3 and CH4. Triggering pulses are generated to operate the chopper in all four quadrants. The unit is programmed to adjust its firing pulses width keeping frequency constant.

Forward motoring mode:

During this mode or first quadrant operation chopper , when the supply is given to the circuit the CH1 and CH4 is ON, current flowing through the path(Vdc+)-CH1 -Load(A-B)-CH4-(Vdc-). Hence both current and voltage are positive. During this condition, the inductance get charged to positive polarity. When CH1 is turned off, positive armature current free wheels and decreases as it flows through CH4-D2, the first quadrant operation can be achieved.

Forward regenerative braking mode:

A DC motor can work in the regenerative breaking mode only if the generated emf is made to exceed the DC source voltage. For obtaining this mode, CH1, CH3 and CH4 are kept off whereas CH2 is operated. When CH2 is turned ON, negative armature current rises through CH2 -D4- E_a,-L_a-R_a. When CH2 is turned OFF, diodes D1,D4 are turned ON.

Reverse motoring mode:

This operating mode is opposite to forward motoring mode. Chopper CH1, CH4 are kept OFF. CH2 is kept ON. When CH2 and CH3 are ON, the armature gets connected to source voltage so that both armature voltage and armature current is reversed. Motor torque is reversed and consequently motoring mode in the third quadrant is obtained.

Reverse regenerative braking mode:

As in forward braking mode, reverse regenerative braking mode is feasible only if motor generated emf is made to exceed the source voltage. For this operating mode,CH1, CH2 and CH3 are kept OFF whereas CH4 is operated. When CH4 is turned ON positive armature current I_a rises through CH4-D2-R_a-L_a-E_a.

Procedure:

1. Connect the motor terminal to respective points in the power circuit and speed sector to feed back terminal socket.
2. Circuit connections are made as shown in figure.
3. Keep stop/start switch in stop position.
4. FM/RM at FM position.
5. Connect spin power chords from power unit to main supply.
6. Switch on the field supply of motor.

7. Keeping auto transformer at minimum position switch ON the three phase power unit.
8. Switch ON the power circuit through MCB
9. Switch on the firing circuit.
10. Set the rpm through the knob.
11. Adjust the auto transformer for suitable voltage up to a maximum of 80%
12. Load the motor up to 0.2A load, Note down the speed for different loads.
13. Remove the load. Keep stop/start switch to stop position, reduce the auto transformer voltage to minimum value. Switch OFF the power circuit by MCB. Switch OFF the three phase main supply and firing circuit.
14. The above experiment may be repeated for reverse rotation of the motor by keeping RM/FM switch to RM position.

Tabular column:

Forward motoring mode:

Ton	Toff	Duty cycle	S1-S2	Torque(N-m)	Speed	Output voltage(theoretical)	Output voltage(Practical)	Current(I_0)
2.4	7.6	20.17	0	0	705	115.2	106	0.25
4.8	5.2	34.16	1	65.53	710	115.2	112	0.75
6	3	38.14	1.5	98.29	714	115.2	112	0.9
7.5	2.5	34.14	2	131.06	714	115.2	117	2.8

V_0=115.2V

Reverse Motoring Operation:

Ton	Toff	Duty cycle	S1-S2	Torque(N-m)	Speed	Output voltage(theoretical)	Output voltage(Practical)	Current(I_0)
2.5	7.5	21.31	0	0	612	-115.2	93	0.2
3	7	30.36	0.4	26.21	616	-115.2	95	0.5
3.5	6.5	34.72	1.2	78.63	625	-115.2	96	0.7
4.2	5.8	39.48	1.8	117.95	623	-115.2	98	1.2
4.25	5.78	42.01	2	131.06	620	-115.2	102	2.5

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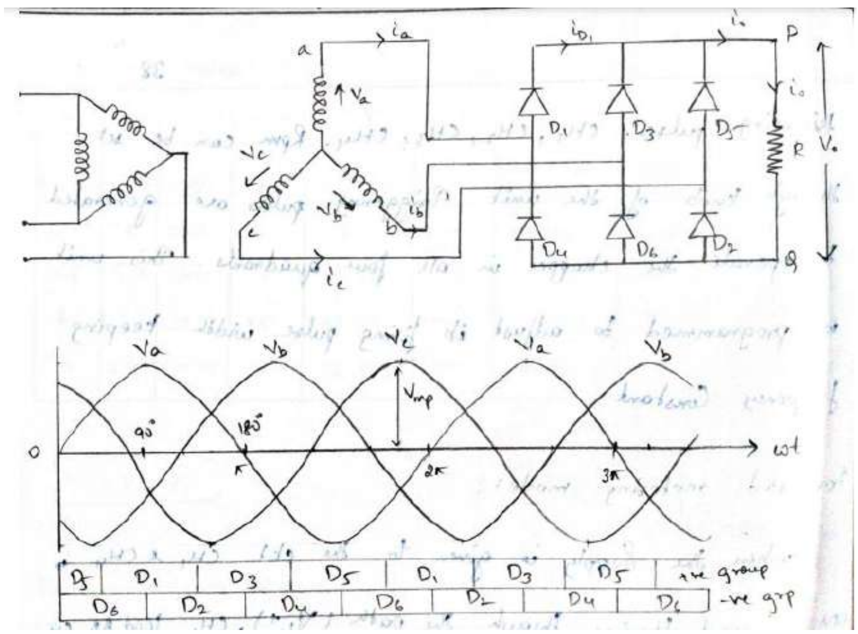

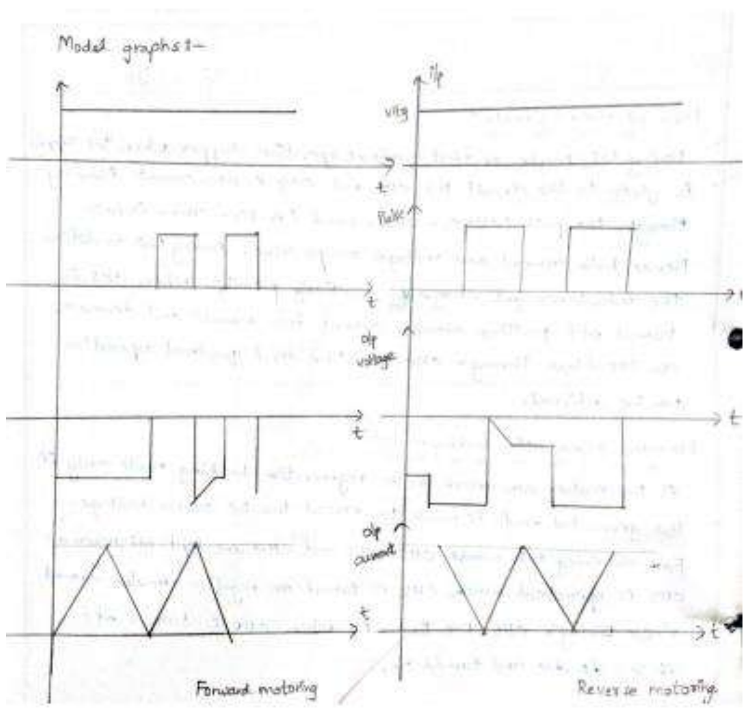

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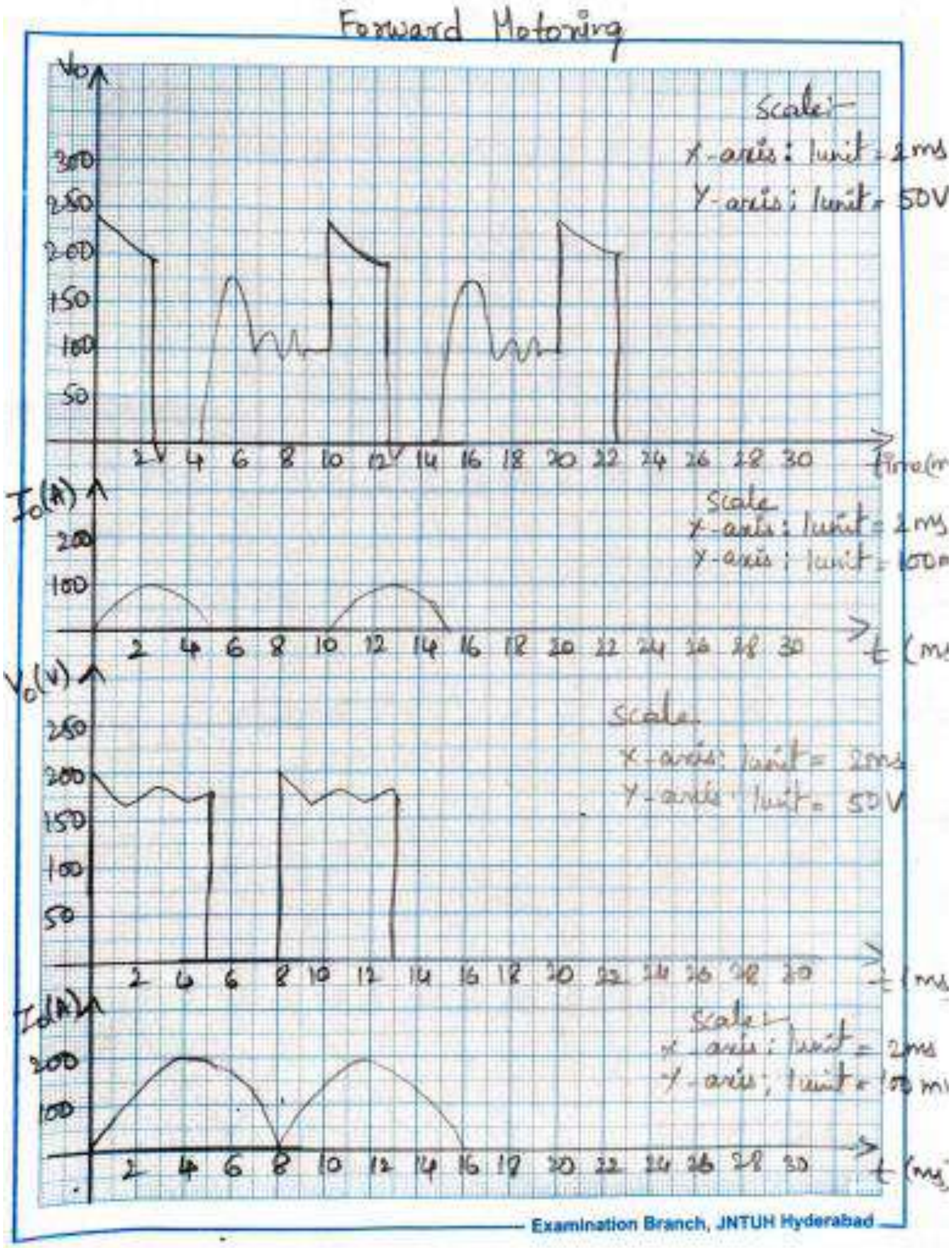

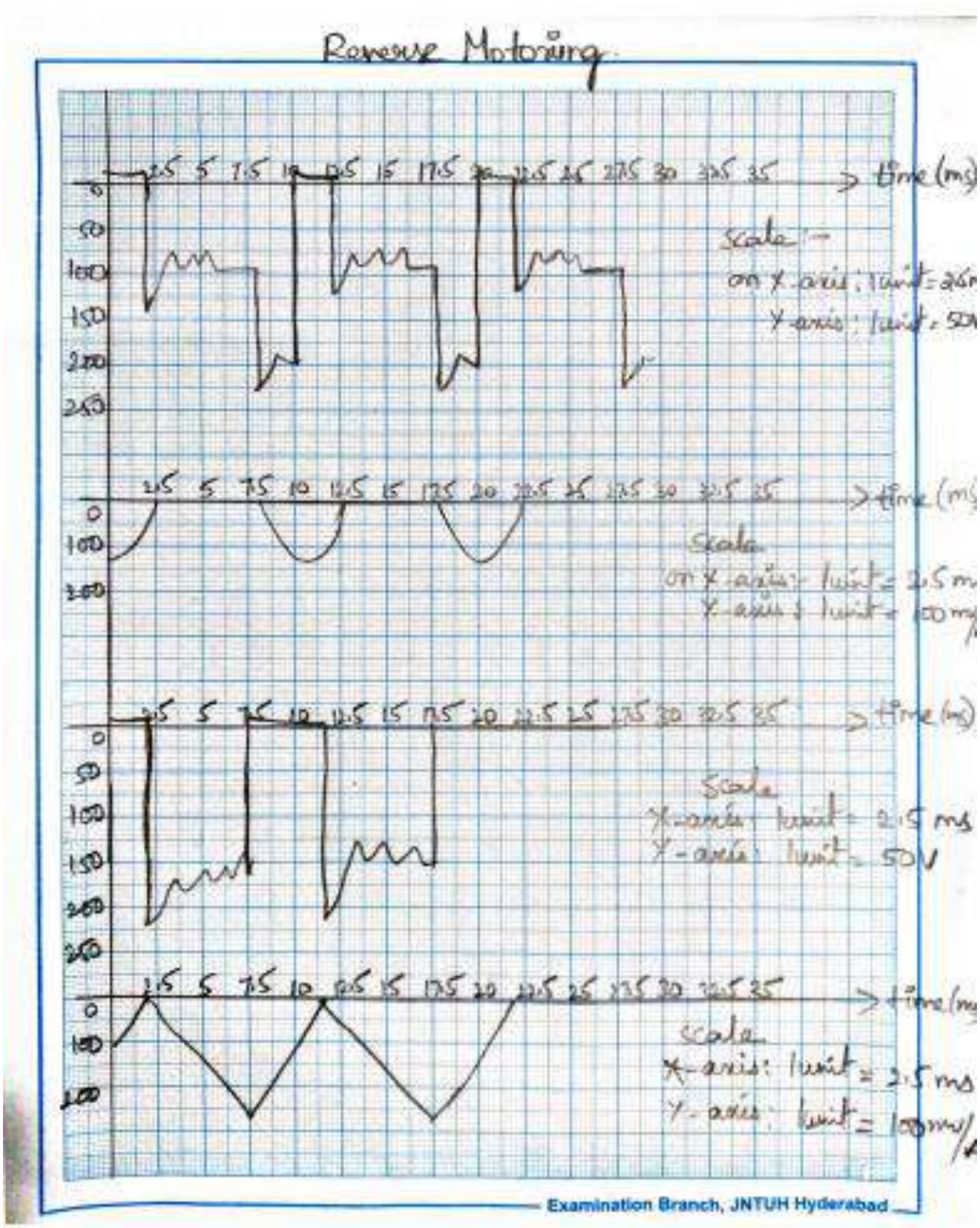
Reverse Motoring
time (ms)
Scale
time (ms)
Scale
time (ms)
Scale
X-axis: 1unit = 2.5 ms
Y-axis: 1unit = 50V
time (ms)
Scale
X-axis: 1unit = 2.5 ms
Examination Branch, JNTUH Hyderabad

Result:

Faculty signature:

Date:

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Experiment10

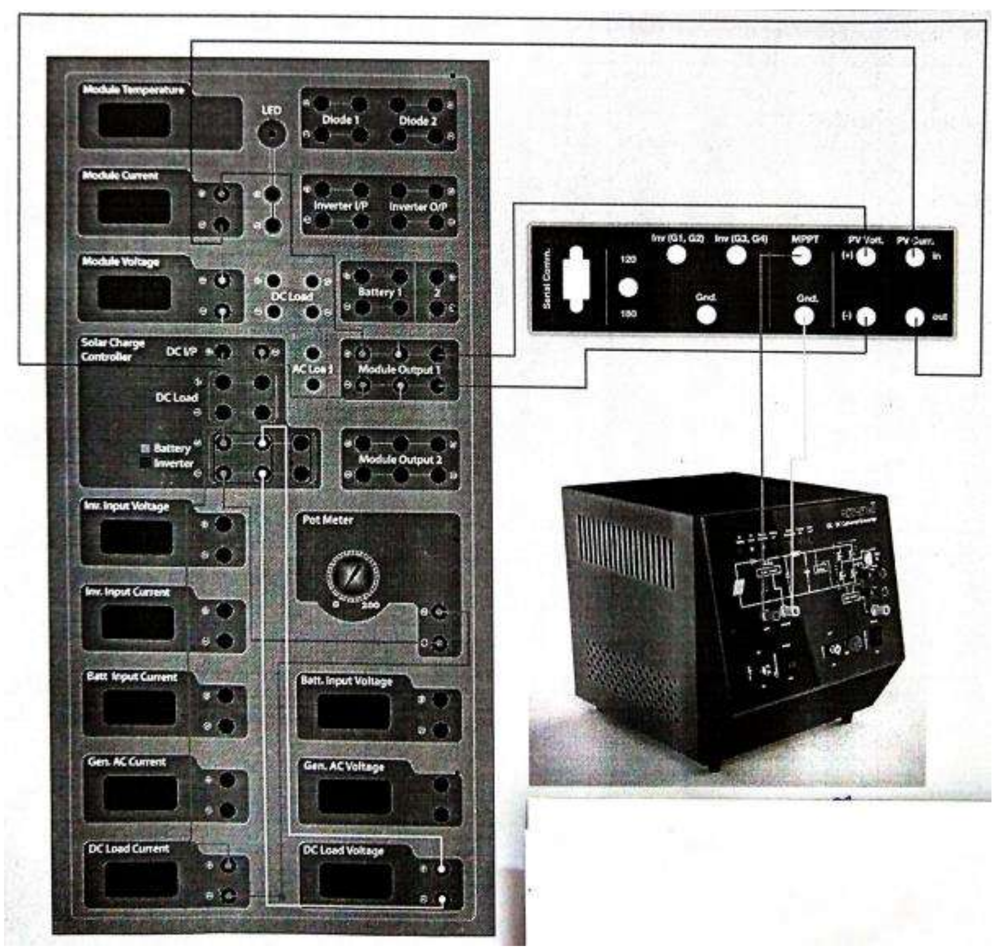
Inverter control of Solar PV based systems

Aim: Observe the Vm, Im, Pm and duty cycle at which MPP occurs, with MPP algorithm in Auto mode when MPPT is connected to DC-DC converter.

Apparatus:

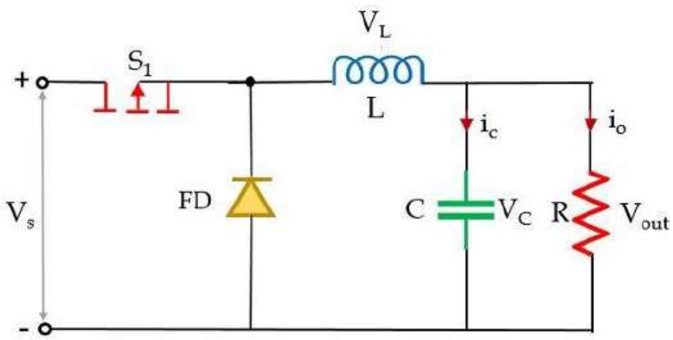
1. Solar control board
2. Patch chords
3. DC-DC Converter
4. CRO

Circuit Diagram:



Theory:

DC—DC Buck Converter:



DC-DC buck converter operates as a step down system i.e., the magnitude of the output voltage is less than the magnitude of the input voltage. The objective of the circuit is to produce a purely DC output by adding LC low pass filter to the basic circuit of this converter.

This DC-DC buck converter can be connected to low voltage DC load or battery bank from a high PV array voltage. Most of the DC-DC buck converters are used in battery charging by modulating the input voltage through PWM to generate low output voltage required by the batteries as well as MPPT in order to maximize the output power obtained from PV arrays.

Perturb and Observe Method:

P&O method is like trail and error method. It states that, when the operating voltage of PV panel in perturb by a small increment if the resulting change in delta p is positive, then are going in the direction of MPPT and we keep the perturbing in the same direction. If delta p is negative then we are going away from the direction of MPP. So the sign of perturbation supply has to be changed.

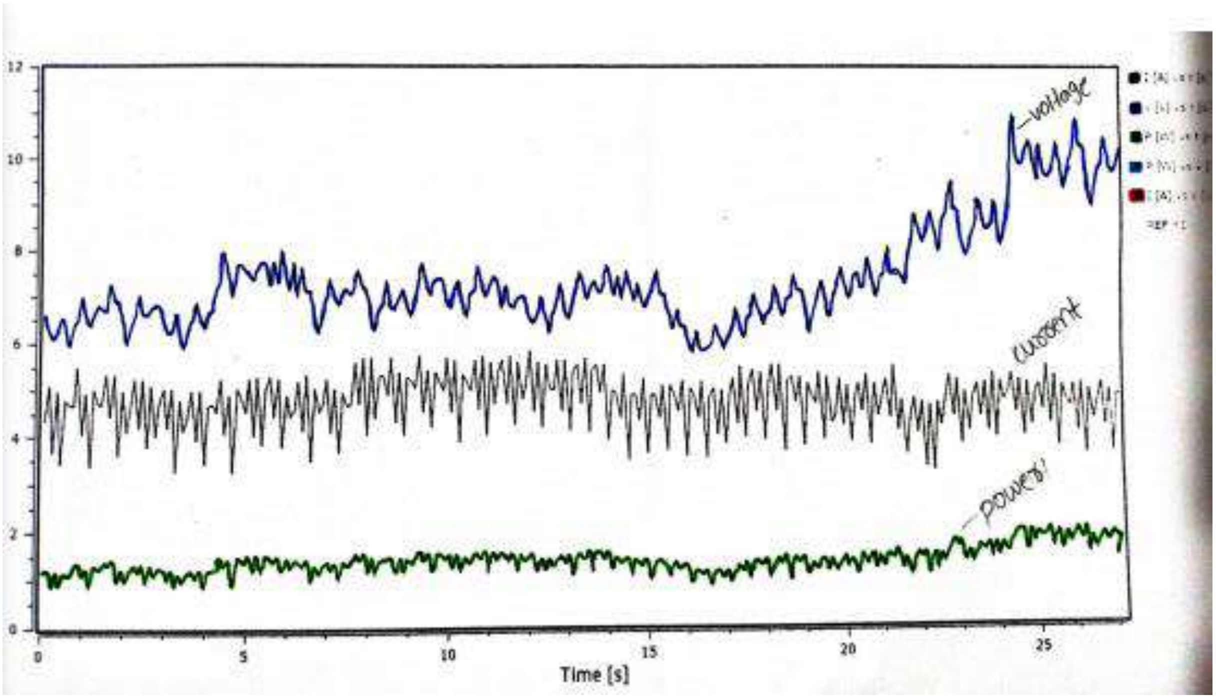
Procedure:

1. Switch over to manual mode and then switch on PV button.
2. Note down Vm, Im, Pm when irradiation is constant.
3. Identify the automatic tracking in blogger and plotter when pot meter is suddenly varied.

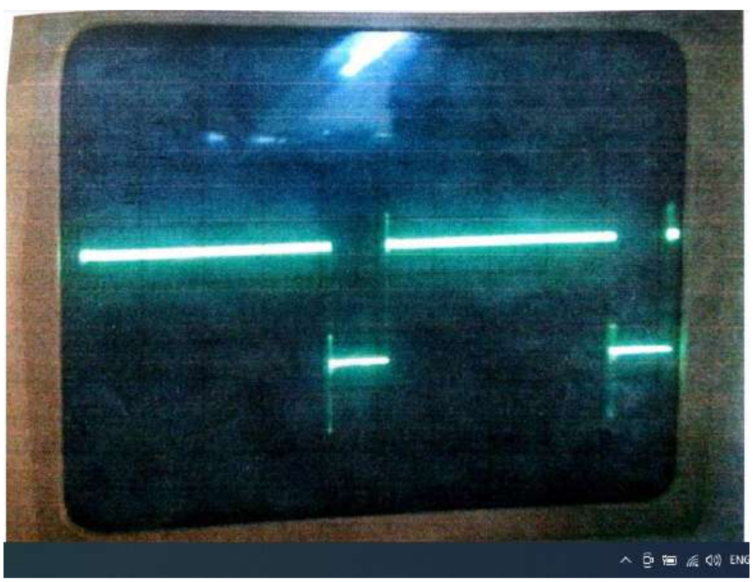
Tabular column:

S.No	V	V_m	I	I_m	P	P_m	Irradiation
1	11.23	11.77	0.197	0.197	2.215	2.321	1000
2	11.04	17.68	0.17	0.158	1.875	2.796	1000

Graph:



Duty cycle of the buck converter



Result: Hence Vm,Im, Pm and duty cycle at which MPP occurs with MPP algorithm in Auto mode when connected to DC-DC converter have been observed.

Faculty signature:

Date:

Experiment 11

Programmable Logic controller(PLC) based AC/DC motor control operation

Aim: to control the AC/DC motor usign PLC

Apparatus:

1. PLC
2. WPL software
3. AC/DC motor
4. RS 232 cable

Theory:

A PLC is a special form of microprocessor-based controller that uses programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting and arithmetic in order to control machines and processes. It is designed to be operated by engineers with perhaps a limited knowledge of computers and computing languages. They are not designed so that only computer programmers can set up or change the programs. Thus the designers of the PLC have pre programmed it so that the control program can be entered using a simple, rather intuitive form of language. The term logic is used because programming is primarily concerned with implementing logic and switching operations. For example , if A or B occurs , switch on C; if A and B occurs, switch on D. input devices(i.e., sensors such as switches) and output devices(motors, valves etc.,) in the system being controlled are connected to the PLC. The operator then enters a sequence of instructions, a program into the memory of the PLC. The controller then monitors the inputs and outputs according to this program and carries out the control rules for which it has been programmed. PLC’s have the great advantage that the same basic controller can be used with a wide range of control systems.

A PLC is a digitally operating system used to implement specific functions such as logic, sequencing, timing, counting and arithmetic. The PLC used is industrial grade consists of advanced features. All the input and output terminals are brought out to front panel with BT115 terminals. The trainer kit works with 230V,50Hz supply.

Digital input and output states are monitored by the LED indicators provided. PLC trainer kit consists of 8 inputs and 6 outputs. The input signals are switched by 4 toggle switched and 4 push to on switches. Extra terminals are also provided to realize the logic gates, Boolean algebra implementation, simplification etc., A DC motor is also provided to realize control of speed. Input and outputs have 24V logic high and 0V logic low levels.

Programs can be written in Ladder diagram. The PLC trainer kit can be connected to PC through RS232 cable and various logic functions can be implemented by online executions with WPL software provided with the kit.

SPECIFICATIONS OF PLC

Parameters		Specifications
Control Method		Stored program, cyclic scan system
I/O Processing method		Batch I/O (refresh)
Execution Speed		Basic Commands in µS Application Commands in mS
Program Languages		Ladder diagram, Instructions, SFC
Program Capacity		3792 steps
Instructions		Basic Commands: 32 Application commands: 107
Step Relay primary		10 Points (S0~S9)
Step Relay general		118 Points (S10~S127)
Auxillary Relay General		512+232Points (M000~M511+M768~M999)
Auxillary Relay Latched		256 Points (M512~M767)
Auxillary Relay Special		280 Points (M1000~M1279)
Timer Digital		64 Points (T0~T63) (100 mS time base)
		63 Points (T64~T128) (10 mS time base, when M1028 is on)
		1 Point (T127) (1 mS time base)
Counters	General	112 Points (C0~C111)
	Lathed	16 Points (C112~C127)
	High Speed	20 Points (C235~C254)
Data Registers	General	408 Points (D0~D407)
	Latched	192 Points (D408~D599)
	Special	144 Points (D1000~D1143)

Specifications of Trainer:

Digital Inputs: 8 No's each 24VDC

Digital Outputs: 6 No's each 24V Relay

Digital Input simulators: 4 Toggle switches, 4 push button switches

Output simulators: 6LED Indicators

Power supply: Inbuilt 24V/1ADC for PLC, 6V for motor

Motor: 6V/1ADC motor-1No's with relay

Built in SAP modules: Logic gate-3inputs 1 output, Boolean algebra, DC motor

PC communication: RS232 serial communication with PLC

Power supply: 230V,50Hz AC supply

To conduct experiment with PLC the PLC must be connected to PC with RS232 cable provided. Open WPL software , go to Options, click on communication setting. Click on auto-detect. If communication is not setup do the following settings.

Type:	RS232
COM port:	COMX
Data Length:	7
Parity:	Even
Stop bits:	1
Baud rate:	9600
Station address:	1
ASCII:	select
PLC setting:	select
Time of Auto-retry:	3
Time interval Auto-retry:	3

Note: COMX is the port address this must be found by device manager.

Static Application Panel:

The kit is provided with built in static application panels(SAP) or simulation module like Gates panel, Boolen algebra panel(De Morgan's theorem) and DC motor control panels. Terminals to connect input and output are brought outside the panels. These terminals help us realize gates, Bookean algebra etc., more effectively. Realization of various ladder diagrams can be done by the input toggle switches, push button switches and output LED indicators. Loagic gates and Boolean expression may be understood with or without static application panels(SAP) However for DC motor experiment output of the PLC must be connected to respective output terminal.

Connection Between PLC and SAP:

Connect respective input and output terminals of PLC to respective input and output terminals of SAP modules to execute the programs provided. Experiments can also be done without connecting input and output to SAP modules. User may select any input and any outputs to carry out the experiment depending on their ladder programs.

Digital 8 inputs are designated as follows:

PLC inputs	KIT designation

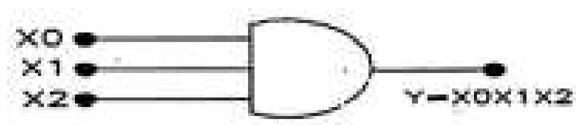
X0	DI-0
X1	DI-1
X2	DI-2
X3	DI-3
X4	DI-4
X5	DI-5
X6	DI-6
X7	DI-7

Digital 6 outputs are designated as follows:

PLC Outputs	KIT designation
Y0	DO-0
Y 1	DO -1
Y 2	DO -2
Y 3	DO -3
Y 4	DO -4
Y 5	DO -5

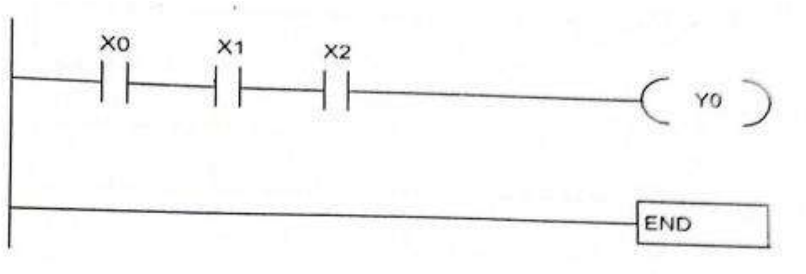
Realization of Logic gates:

1. AND gate



3 I/P AND GATE

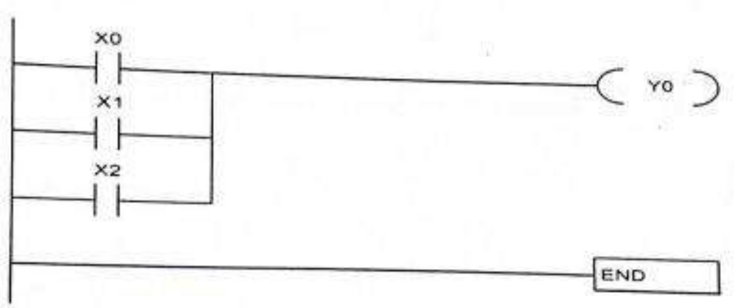
Inputs			Output
X2	X1	X0	Y0=X0X1X2
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1



Ladder diagram for AND gate

2.OR gate:

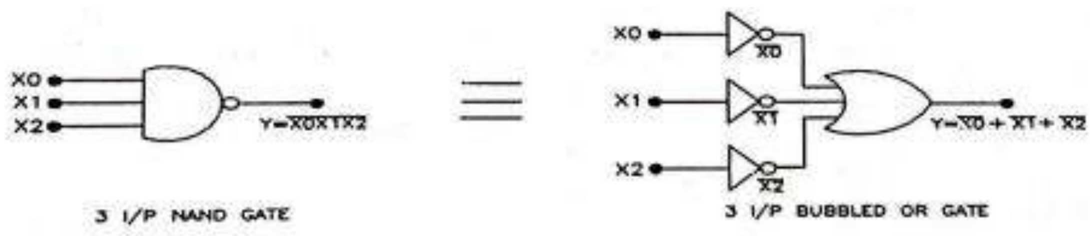
Inputs			Output
X2	X1	X0	Y0=X0+X1+X2
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1



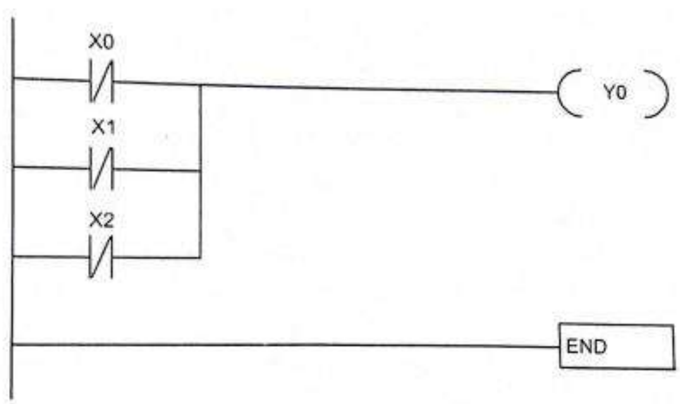
Ladder diagram for OR gate

3.NAND gate:

NAND gate can be implemented using De-Morgan's theorem. That is implemented by bubbled OR gate as shown below:



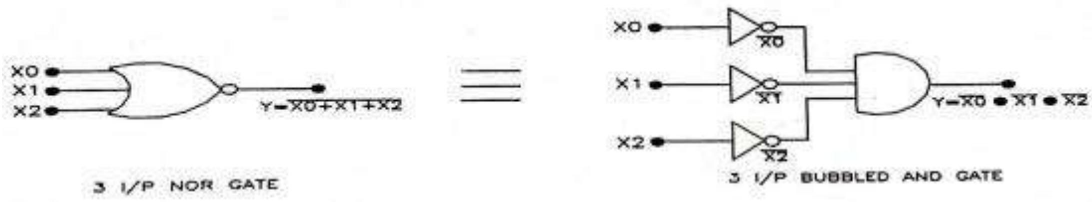
Inputs			Output
X2	X1	X0	$Y0=\overline{X0}+\overline{X1}+\overline{X2}$
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0



Ladder diagram for NAND gate

NOR Gate (Bubbled AND gate):

NOR gate can be implemented using De-Morgan's theorem. That is implemented by bubbled AND gate as shown below.



Inputs			Output
X2	X1	X0	$Y = \overline{X0} \bullet \overline{X1} \bullet \overline{X2}$
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0

Result:

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