POWER ELECTRONICS & DRIVES LABORATORY (PEL (P))

VI Semester : EEE							**Scheme : 2020**
Course Code	**Hours/Week**			**Credits**	**Maximum Marks**		
EE314	**L**	**T**	**P**	**C**	**Continuous Internal Assessment**	**End Exam**	**TOTAL**
	0	**0**	**3**	**1.5**	**40**	**60**	**100**

End Exam Duration: 3 Hrs

Course Outcomes : At the end of the course students will be able to

CO1: Understand I-V characteristics of SCR, MOSFET, IGBT and their gate driver circuits

CO2: Apply phase angle control for 1-Φ half and fully controlled bridge converters, 1-ϕ dual converter, 1-ϕ cycloconverter and 1-ϕ, 3-ϕ AC voltage controller to control output voltage of drives

CO3: Apply duty ratio control for choppers and inverters to control output voltage

CO4: Understand control signals generation using digital controllers for a drive

List of Experiments

Note : At least 8 of the following experiments shall be conducted

1. Steady state characteristics of SCR, IGBT and MOSFET
2. Single phase fully controlled bridge converter
3. Single phase semi controlled bridge converter
4. Single phase dual converter
5. Single-phase mid-point cycloconverter
6. Single-phase AC voltage controller
7. Three-phase AC voltage controller
8. Single phase full bridge PWM inverter
9. Forced commutated step down chopper
10. Step up chopper
11. R, RC and digital triggering methods for SCR
12. Static Kramer Drive
13. 3-phase fully controlled rectifier / chopper fed DC motor drive
14. V/f control of induction motor using dSPACE 1104 kit.
15. Simulation of power electronic converters (Rectifiers, Choppers, Inverters) using MATLAB

TITLE: Steady state characteristics of SCR, MOSFET &IGBT

GPREC/DEEE/EXPT-PEL (P)-1

Date: 17/01/2023

OBJECTIVE:

To verify the characteristics of SCR, IGBT and MOSFET.

APPARATUS:

SCR, MOSFET & IGBT Module kit, Regulated Power Supply, Rheostat, Voltmeter, Ammeter, Connecting wires.

THEORY:

A thyristor is a four-layer p-n-p-n semiconductor device consisting of three p-n junctions. It has three terminals: anode, cathode and a gate.. When the anode voltage made positive with respect to the cathode, junctions J1 and J3 are forward biased and junction J2 is reverse biased. The thyristor said to be in the forward blocking or off-state condition. A small leakage current flows from anode to cathode and is called the off state current. If the anode voltage V_{AK} is increased to a sufficiently large value, the reverse biased junction J2 would breakdown. This is known as avalanche breakdown and the corresponding voltage is called the forward breakdown voltage V_{BO}. Since the other two junctions J1 and J3 are already forward biased, there will be free movement of carriers across all three junctions. This results in a large forward current. The device now said to be in a conducting or on state. The voltage drop across the device in the on-state is due to the ohmic drop in the four layers and is very small (in the region of 1 V).

Latching Current I_L: This is the minimum anode current required to maintain the thyristor in the onstate immediately after a thyristor has been turned on and the gate signal has been removed. If a gate current, greater than the threshold gate current is applied until the anode current is greater than the latching current IL then the thyristor will be turned on or triggered.

Holding Current I_H: This is the minimum anode current required to maintain the thyristor in the on state. To turn off a thyristor, the forward anode current must be reduced below its holding current for a sufficient time for mobile charge carriers to vacate the junction. If the anode current is not maintained below IH for long enough, the thyristor will not have returned to the fully blocking state by the time the anode-to cathode voltage rises again. It might then return to the conducting state without an externally applied gate current.

Reverse Current I_R: When the cathode voltage is positive with respect to the anode, the junction J2 is forward biased but junctions J1 and J3 are reverse biased. The thyristor is said to be in the reverse blocking state and a reverse leakage current known as reverse current IR will flow through the device.

Once the thyristor is turned on by a gate signal and its anode current is greater than the holding current, the device continues to conduct due to positive feedback even if the gate signal is removed. This is because the thyristor is a latching device and it has been latched to the on state.The turn on and turn off process of thyristor depends on anode current hence it is a current controlled device.

CIRCUIT DIAGRAM:

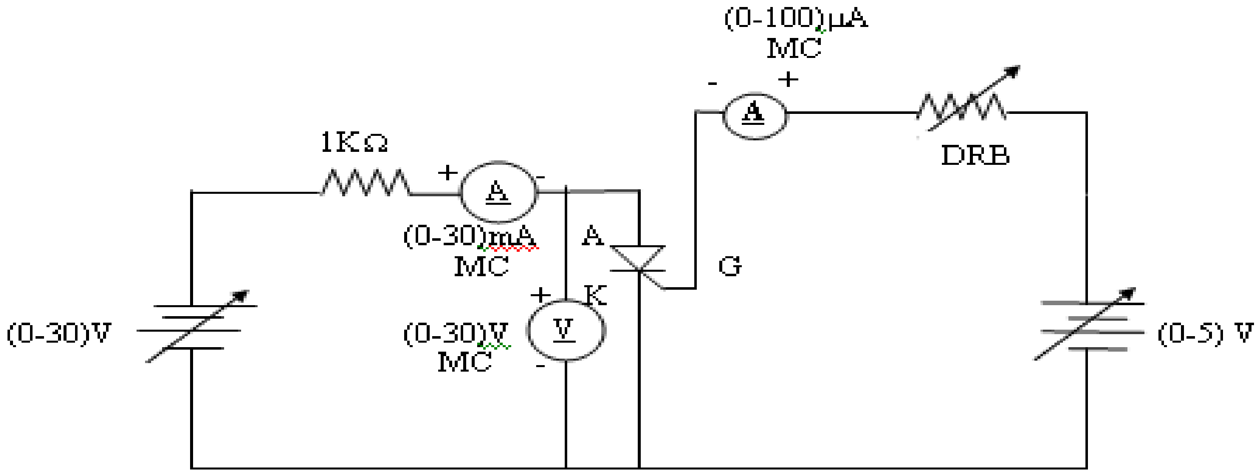


Fig.1 Circuit diagram of SCR

PROCEDURE:

1) Make the connections as per the circuit diagram.
2) Switch on the supply
3) Set the gate current at a fixed value by varying RPS on the gate-cathode side.
4) Increase the voltage applied to anode-cathode side from zero until breakdown occurs.
5) Note down the breakdown voltage.
6) Draw the graph between anode to cathode voltage (V_{AK}) and anode current (I_A)

OBSERVATIONS:

S.No.	I_G =….(μA)		I_G =….(μA)	
	V_{AK} (V)	I_A (mA)	V_{AK} (V)	I_A (mA)

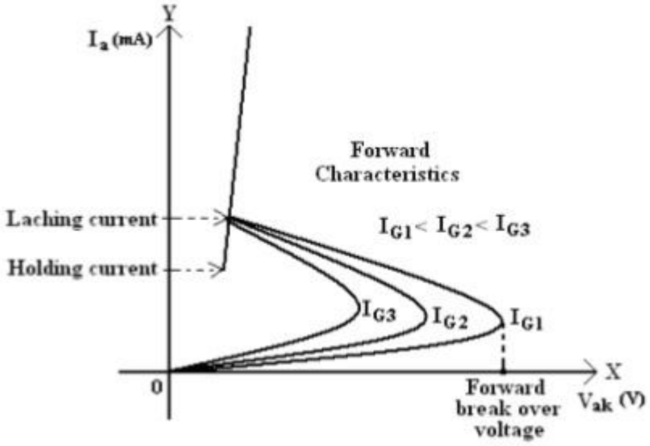


Fig.2 V-I Characteristics of SCR

MOSFET:

A metal oxide semi conductor field effect transistor is a recent device developed by combining the areas of field effect concept and technology. It has three terminals called drain, source and gate. MOSFET is a voltage controlled device. As its operation depends upon the flow of majority carriers only MOSFET is unipolar device. The control signal or gate current less than a BJT. This is because of fact that gate circuit impedance in MOSFET is very high of the order of $10^9\Omega$. This larger impedance permits the MOSFET gate be driven directly from micro electronic circuits. Power MOSFETs are now finding increasing applications in low power high frequency converters.

Transfer characteristics: Fig.4(b) shows the transfer characteristics of MOSFET. Threshold voltage V_{th} is an important parameter of MOSFET. V_{th} is the minimum positive voltage between gate and source to induce n-channel. Thus for threshold voltage below $V_{th,}$ device is in the off-state. Magnitude of V_{th} is of the order of 2 to 3 V.

Output characteristics: Fig.4(a) shows the variation of drain current I_D as a function of drain-source voltage V_{DS} , with gate-source voltage V_{GS} as a parameter. For low values of $V_{DS,}$the graph between I_D-V_{DS} is almost linear; this indicates a constant value of on-resistance $R_{DS}= V_{DS}/ I_{D.}$ For given V_{GS}, if V_{DS} is increased, output characteristic is relatively flat, indicating that drain current is nearly constant. A load line intersects the output characteristics at A and B. Here A indicates fully-on condition and B fully-off state. PMOSFET operates as a switch either at A or at B just like a BJT.

When PMOSFET is driven with large gate-source voltage, MOSFET is turned on, $V_{DS.ON}$ is small. Here, the MOSFET acting as a closed switch, is said to be driven into ohmic region. When device turns on, PMOSFET traverses I_D- V_{DS} characteristics from cutoff to active region and then to ohmic region Fig.4(a). When PMOSFET turns off , it takes backward journey from ohmic region to cutoff state.

CIRCUIT DIAGRAM (MOSFET):

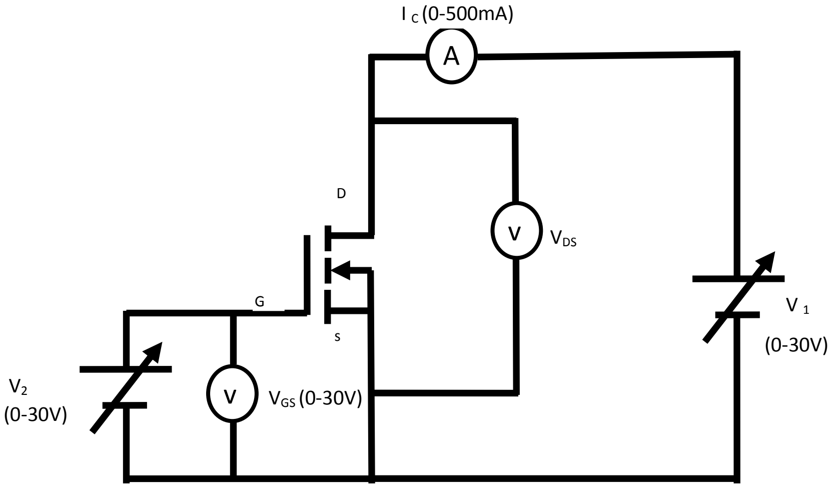


Fig.3 Circuit diagram of MOSFET

PROCEDURE:

Drain Characteristics:

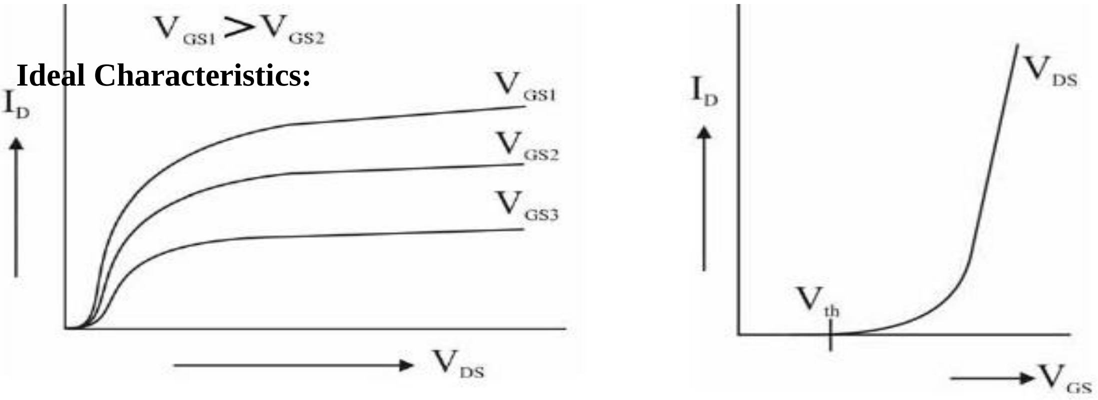
1) Make the connections as per the circuit diagram.
2) Switch on the supply.
3) Adjust the value of V_{GS} slightly more than threshold voltage V_{th}
4) By varying V_1, note down I_D & V_{DS} and are tabulated in the tabular column
5) Repeat the experiment for different values of V_{GS} and note down I_D v/s V_{DS}
6) Draw the graph of I_D v/s V_{DS} for different values of V_{GS}.

Transconductance Characteristics:

1. Connections are made as shown in the circuit diagram.

2. Initially keep V_1 and V_2 zero.
3. Set V_{DS} = say 0.6 V
4. Slowly vary V_2 (V_{GE}) with a step of 0.5 volts, note down corresponding I_D and V_{DS} readings for every 0.5V and are tabulated in the tabular column
5. Repeat the experiment for different values of V_{DS} & draw the graph of I_D v/s V_{GS}
6. Plot the graph of V_{GS} v/s I_D

Ideal Characteristics:



a) Output characteristics **b)Transfer characteristics**

Fig.4 Ideal characteristics of MOSFET

TABULAR COLUMN (MOSFET):

Transfer Characteristics:

S.No	**V_{GS} =….(V)**		**V_{GS} =….(V)**	
	V_{DS} (mV)	**I_D (mA)**	**V_{DS} (mV)**	**I_D (mA)**

Drain Characteristics:

S.No	V_{DS} =….(V)	
	V_{GS} (mV)	I_D (mA)

IGBT:

The Insulated Gate Bipolar Transistor, (IGBT) uses the insulated gate technology of the MOSFET with the output performance characteristics of a conventional bipolar transistor. IGBT has the output switching and conduction characteristics of a bipolar transistor but is voltage-controlled like a MOSFET. IGBT is a three terminal, transconductance device that combines an insulated gate N-channel MOSFET input with a PNP bipolar transistor output connected in a type of Darlington configuration. As a result the terminals are labelled as: **Collector**, **Emitter** and **Gate**. Two of its terminals (C-E) are associated with the conductance path which passes current, while its third terminal (G) controls the device.

- IGBT has a much lower “on-state” resistance, R_{ON} than an equivalent MOSFET. The forward blocking operation of the IGBT transistor is identical to a power MOSFET.
- When used as static controlled switch, the IGBT has voltage and current ratings similar to that of the bipolar transistor. An IGBT is simply turned “ON” or “OFF” by

activating and deactivating its Gate terminal. Applying a positive input voltage signal across the Gate and the Emitter will keep the device in its "ON" state, while making the input gate signal zero or slightly negative will cause it to turn "OFF" in much the same way as a bipolar transistor or MOSFET

- IGBT is a voltage-controlled device, it only requires a small voltage on the Gate to maintain conduction through the device unlike BJT's which require that the Base current is continuously supplied in a sufficient enough quantity to maintain saturation.
- IGBT is a unidirectional device, meaning it can only switch current in the "forward direction", that is from Collector to Emitter unlike MOSFET's which have bi-directional current switching capabilities.

Transfer characteristics: Fig 6(b) shows the transfer characteristics. This characteristic is identical to that of power MOSFET. When V_{GE} is less than threshold voltage V_{GET}, IGBT is in the off state.

Static V-I characteristics: Static V-I or output characteristics of an IGBT show the plot of collector current I_c verses V_{CE} for various values of gate- emitter voltages $V_{GE1,}$ V_{GE2}. These characteristics are shown in Fig 6(a). In the forward direction, the shape of the output characteristics is similar to that of BJT. But here the controlling parameter is gate –emitter voltage V_{GE} because is a voltage controlled device. When the device is off, junction J_2 blocks forward voltage and in case reverse voltage appears across collector and emitter, junction J_1 blocks it.

CIRCUIT DIAGRAM (IGBT) :

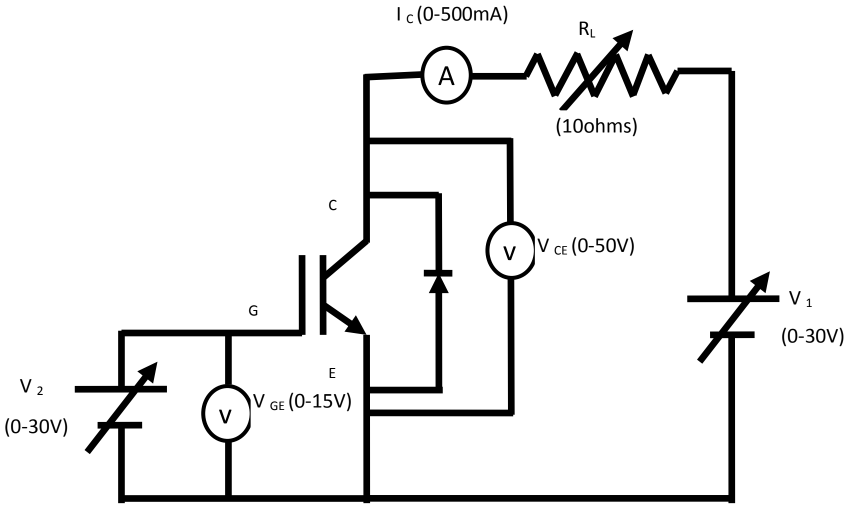


Fig.5 Circuit diagram of IGBT

PROCEDURE:

V-I Characteristics:

1. Connections are mode as shown in the circuit diagram.
2. Initially set V_2 to V_{GE1} = 5V (slightly more than threshold voltage)
3. Slowly vary V_1 and note down I_C and V_{CE}
4. For particular value of V_{GE} there is pinch off voltage (V_P) between collector and emitter
5. Repeat the experiment for different values of V_{GE} and note down I_C v/s V_{CE}
6. Draw the graph of I_C v/s V_{CE} for different values of V_{GE}.

Transfer Characteristics:

1. Connections are mode as shown in the circuit diagram.
2. Initially keep V_1 and V_2 at zero.
3. Set V_{CE1} = say 0.8 V
4. Slowly vary V_2 (V_{GE}) and note down I_C and V_{GE} readings for every 0.5V and enter tabular column.
5. Repeat the experiment for different values of V_{CE} and draw the graph of I_C v/s V_{GE}.

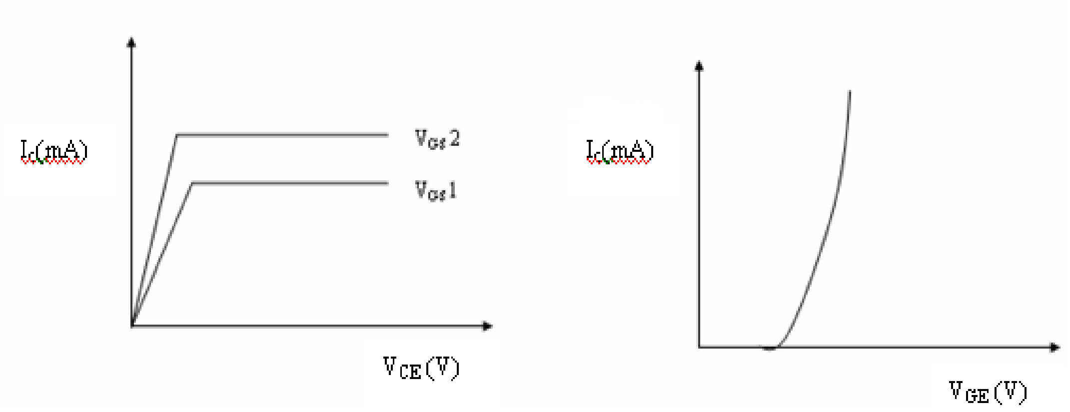
TABULAR COLUMN (IGBT):
V-I Characteristics:

S.No	**V_{GE} =….(V)**		**V_{GE} =….(V)**	
	V_{CE} (V)	**I_C (mA)**	**V_{CE} (V)**	**I_C (mA)**

Transfer Characteristics:

S.No	**V_{CE} =….(V)**	
	V_{GE} (V)	**I_C (A)**

MODEL GRAPH (IGBT)



a) Static V-I Characteristics **b) Transfer Characteristics**

Fig.6 Characteristics of IGBT

RESULT:

Thus the Characteristics of SCR, MOSFET & IGBT were obtained.

TITLE: Steady state characteristics of SCR, MOSFET &IGBT
GPREC/DEEE/EXPT-PEL (P)-1
Date: 17/01/2023

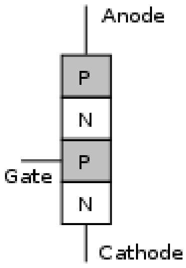
Viva questions:

1. What is a thyristor?

   a) A thyristor is a solid-state semiconductor device with four layers of alternating N and P-type material. It acts exclusively as a bistable switch,

2. Draw the structure of thyristor?

   a)

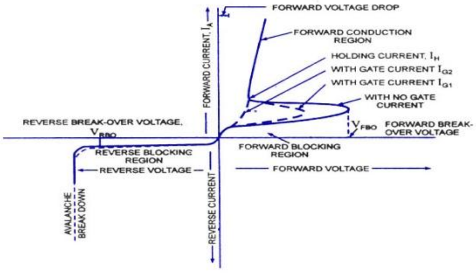


3. What are the different methods for turning on SCR?
   - a) Gate triggering
   - b) dv/dt triggering
   - c) Forward voltage triggering
   - d) Light triggering

4. W hat is the difference between MOSFET and BJT?

   a) MOSFET is a voltage controlled device and BJT is a current controlled device

5. Draw the V-I characteristics of SCR?



V-I Characteristics of SCR

G. Pulla Reddy Engineering College (Autonomous): Kurnool
Department of Electrical & Electronics Engineering
B.Tech EEE – VI Semester (Scheme: 2020)
Power Electronics & Drives Laboratory (PEL (P))

TITLE: SINGLE PHASE FULLY CONTROLLED BRIDGE CONVERTER

. GPREC/DEEE/EXPT-PEL (P)-2

Date: 17/01/2023

OBJECTIVE:

To verify and compare theoretical and experimental results of 1-ϕ fully controlled bridge converter with R & RL loads.

APPARATUS:

SCRs, SCR firing circuit,1:1 isolation Transformer, Rheostat, Inductor, Voltmeter, Ammeter, Connecting wires.

CIRCUIT DIAGRAM :(FULL CONVERTER)

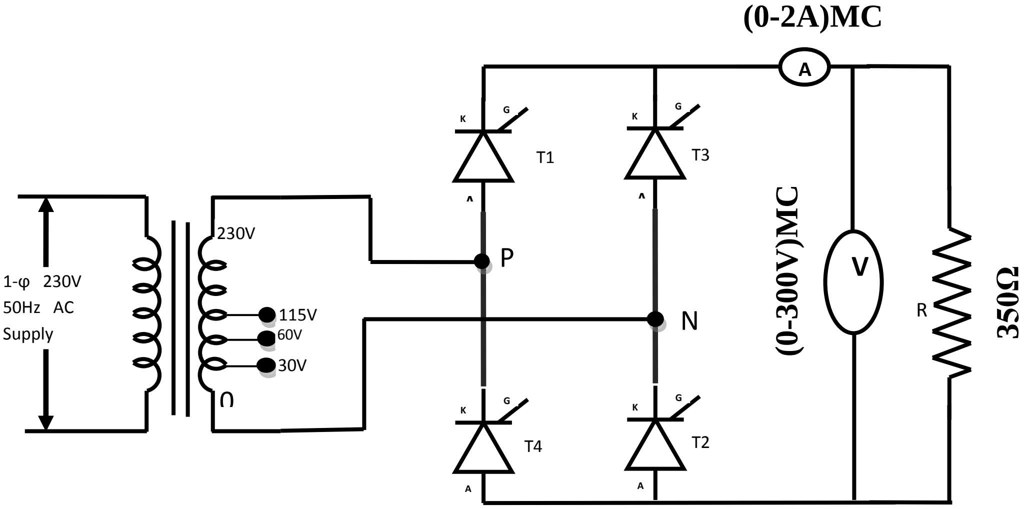


Fig. 1: 1-ϕ fully controlled bridge converter with R-Load

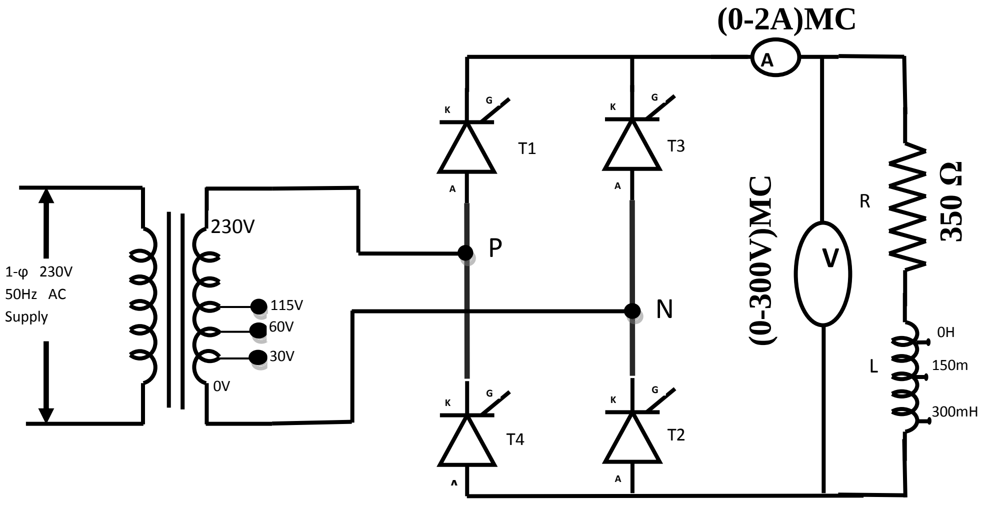


Fig.2 : 1-ϕ fully controlled bridge converter with RL-Load

THEORY:

FULL CONVERTER: (R-Load)

A fully controlled converter or full converter uses thyristors only as shown in Fig.1 and Fig.2. During the positive half cycle, SCRs T1 and T2 are forward biased. At ωt = α, SCRs T1 and T2 are triggered, then the current flows through the P – T1- R load – T2 – N. At ωt = π, supply voltage falls to zero and the current also goes to zero at the same instant because of R load. Hence SCRs T1 and T2 are line commutated. During negative half cycle (π to 2π), SCRs T3 and T4 are forward biased. At ωt = π + α, SCRs T3 and T4 are triggered, then current flows through the path N – T3 – R load- T4 – P. At ωt = 2π, supply voltage and current goes to zero, SCRs T3 and T4 are line commutated. Here, in the entire range of firing angle output voltage is positive and current flows only in one direction (current is positive). Hence first quadrant operation is achieved in entire range of firing angle.

RL-Load:

During the positive half cycle, SCRs T1 and T2 are forward biased. At ωt = α, SCRs T1 and T2 are triggered, then the current flows through the P – T1- R-L load – T2 – N. At wt= π, supply voltage reverses but output current is still positive and continues to flow upto wt = β. So from ωt = α to π both output voltage and output current are positive, whereas from ωt= π to ωt = β output voltage is negative but output current is still positive. At wt = β SCRs T1 and T2 are line commutated. During negative half cycle, SCRs T3 and T4 are forward biased. At ωt = π + α, SCRs T3 and T4 are triggered, then current flows through the path N – T3 – R-L load- T4 – P. At ωt = π+ β, SCRs T3 and T4 are line commutated.

If continuous conduction is assumed in the firing angle range 0 to 90 average output voltage is positive and 90 to 180 average output voltage is negative, but average current is positive in the entire firing angle range (0 to 180). Hence in the firing angle range 0 to 90 voltage positive and current positive first quadrant operation and 90 to 180 voltage negative and current positive fourth quadrant operation is achieved. Hence two quadrant operation is achieved.

WAVE FORMS:

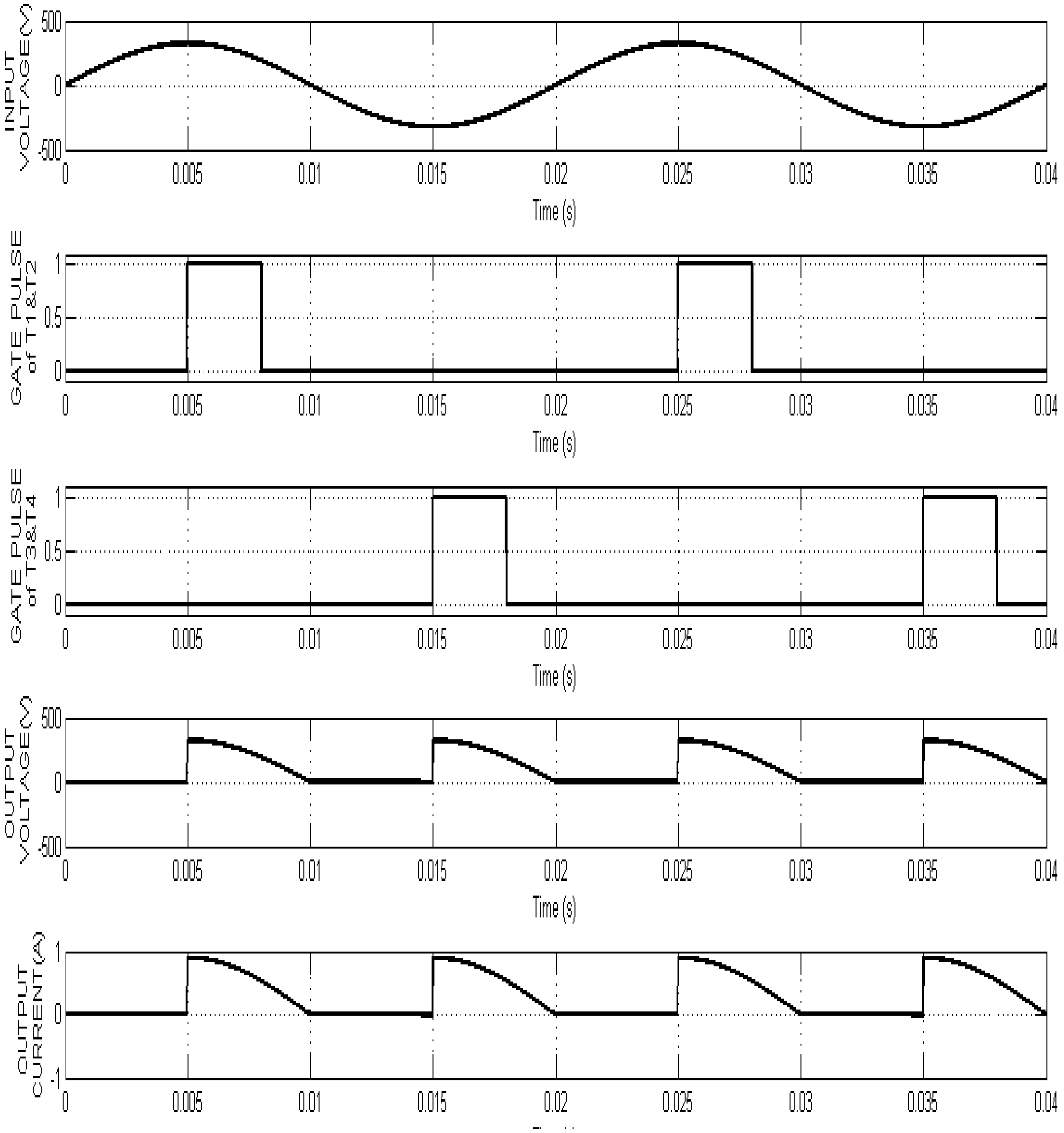


Fig.5: Wave forms 1-ϕ Full wave rectifier R-Load

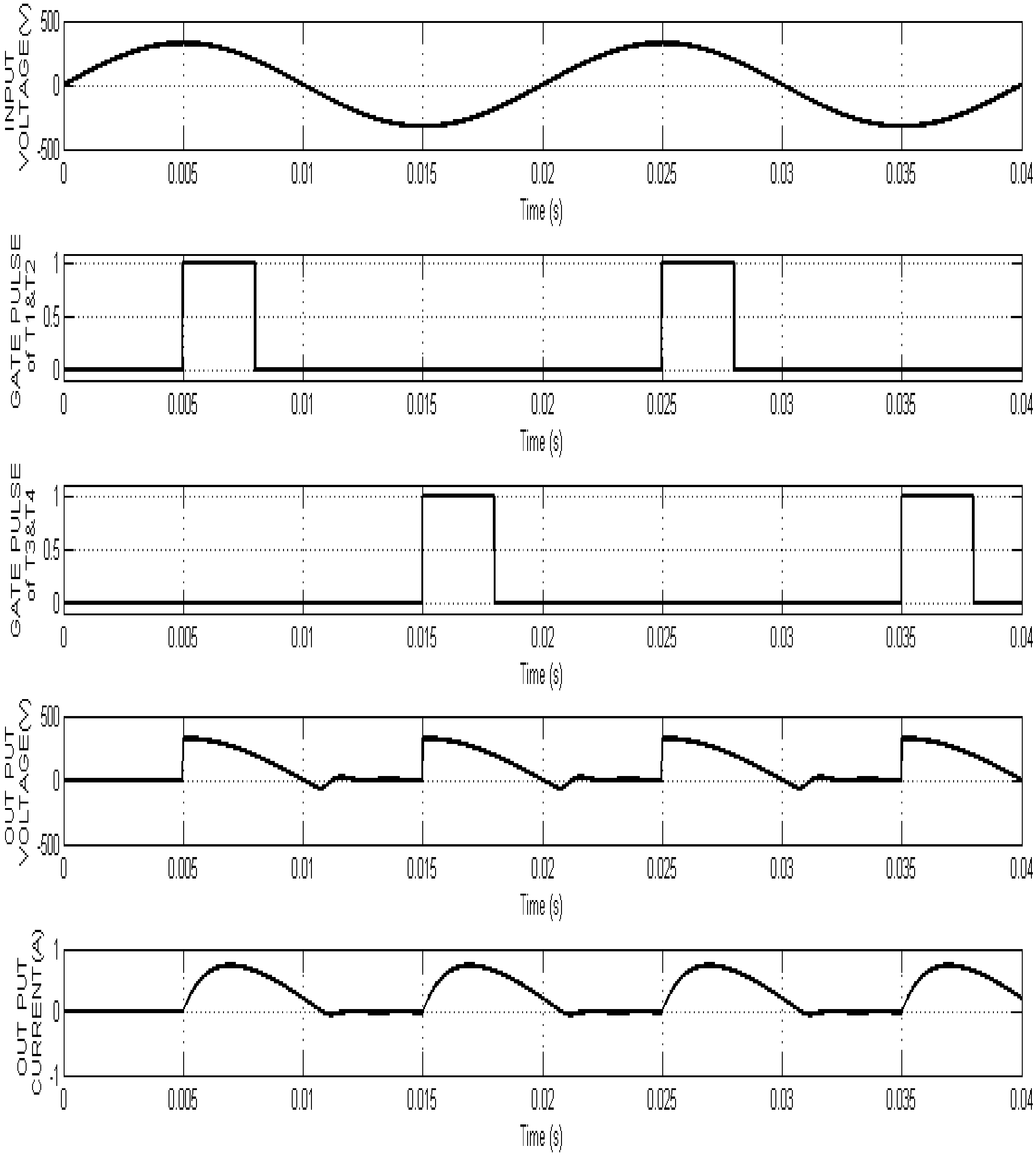


Fig.6: Wave forms 1-ϕ Full wave rectifier RL-Load

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Connect 30V tapping of the isolation transformer secondary to the input terminals of the power module initially.
3. Connect the gate signal terminals of the firing circuit to the SCRs.
4. Connect one channel to the oscilloscope to the input terminals and another channel to the output terminals.
5. Switch ON the power supply and observe the wave forms.
6. Now switch OFF the supply and connect 230V tapping of the isolation transformer to the input terminals of the power module.
7. Switch ON the power supply and note down average output voltage and current by changing the firing angle insteps.
8. Draw the waveforms of input and output voltages along with the gate pulses of the SCRs on the graph sheet.

OBSERVATIONS:

Firing Angle (α)	Average output voltage (Vo) in volts		Average output current (Io) in Amperes	
	Theoretical values	Practical values	Theoretical values	Practical values

FORMULAE USED:

For R-Load

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

$$I_{O\ avg} = \frac{Vo_{\ avg}}{R}$$

For RL-Load

$$V_{o\ avg} = \frac{1}{\pi}\int_{\alpha}^{\beta} V_m \sin(\omega t)\, d(\omega t) = \frac{V_m}{\pi}(cos\alpha - cos\beta)$$

$$I_{O\ avg} = \frac{Vo_{\ avg}}{R}$$

$\sin(\beta - \phi) = \sin(\alpha - \phi)e^{\frac{-R}{\omega L}(\beta - \alpha)}$ (or) $\beta = \pi + \phi$ and $\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$

RESULT:

The theoretical and experimental output wave forms and values of voltage and current of 1-ϕ fully controlled bridge converter with R and RL-Load are verified.

Viva questions:

1. What is a full controlled rectifier?
2. What are the differences between half wave and full wave rectifier?
3. What is the purpose of isolation transformer?
4. Give the voltage and current expression for half controlled and fully controlled rectifiers?
5. What are the applications of fully controlled rectifiers?

G. Pulla Reddy Engineering College (Autonomous): Kurnool
Department of Electrical & Electronics Engineering
B.Tech EEE – VI Semester (Scheme: 2020)
Power Electronics & Drives Laboratory (PEL (P))

TITLE: SINGLE PHASE SEMI CONTROLLED BRIDGECONVERTER
. **GPREC/DEEE/EXPT-PEL (P)-3**
Date: 17/01/2023

OBJECTIVE:

To verify and compare theoretical and experimental results of 1-ϕ semi controlled Bridge converter with R & RL loads.

APPARATUS:

SCRs, SCR firing circuit,1:1 isolation Transformer, Rheostat, Inductor, Voltmeter, Ammeter, Connecting wires.

CIRCUIT DIAGRAM :(SEMI CONVERTER)

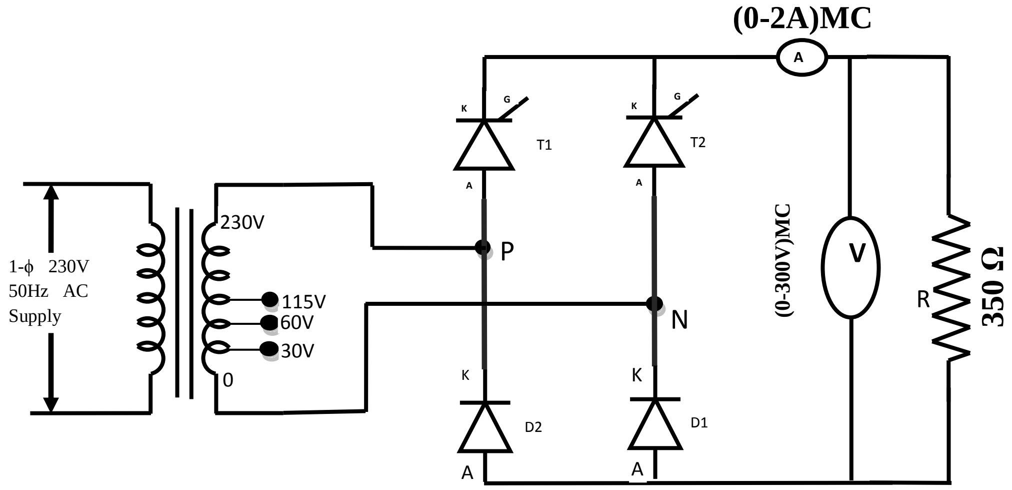


Fig. 1: 1-ϕ Semi controlled Bridge converter with R-Load

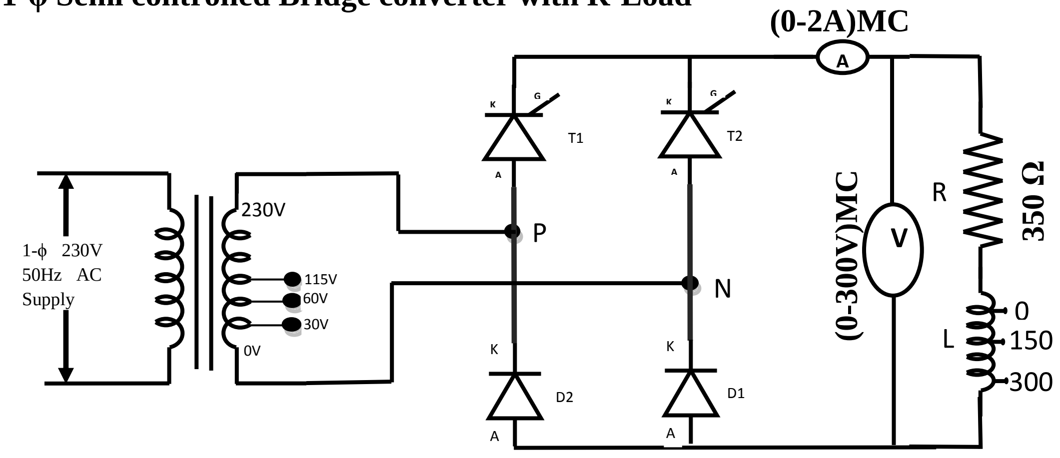


Fig. 2 : 1-ϕ Semi controlled Bridge converter with RL-Load

THEORY:

SEMI CONVERTER (With R-Load):

A single phase semi controlled bridge converter uses two diodes (D1 & D2) and two thyristors (T1 & T2) as shown Fig. 1. During the positive half cycle of the ac supply, T1 and D1 are forward biased when T1 is triggered at a firing angle $\omega t = \alpha$, load current flows from P- T1- R load –D1-N. During this period, output voltage and current are positive. At $\omega t = \pi$, the load voltage and load current reaches to zero, then T1 and D1 are commutated. During the negative half cycle of the ac supply, T2 and D2 are forward biased. When T2 is triggered at a firing angle $\omega t = \pi + \alpha$, load current flows through the path N - T2- R load – D2 -P. During this period, output voltage and output current will be positive. At $\omega t = 2\pi$, the load voltage and load current reaches to zero thereby switching off T2 and D2. Here, in the entire range of firing angle output voltage is positive and current flows only in one direction (current is positive).

With RL-Load

Fig. 2 shows semi controlled bridge converter with RL load. During the positive half cycle of the ac supply, T1 and D1 are forward biased when the T1 is triggered at a firing angle $\omega t = \alpha$, the load current flows through the path P - T1- RL load –D1 - N. During this period, output voltage and current are positive. At $wt= \pi$, supply voltage becomes zero but output current is not zero. So T1 and D1 are not commutated. Immediately after $wt= \pi$ due to negative half cycle of supply voltage diode D2 is forward biased and load current chooses low resistance path through T1 and D2. Hence the output voltage is zero during the period π to β or ($\pi+\alpha$ for continuous conduction). But load current is not zero and it flows through the path RL-Load –D2-T1-RL-load. During the negative half cycle of the ac supply, T2 will in forward blocking. When T2 is triggered at a firing angle $\omega t = \pi + \alpha$, the load current flows through the path N - T2- RL load – D2 -P. During this period, output voltage and output current will be positive. At $\omega t = 2\pi$, supply voltage becomes zero but output current is not zero so T2 and D2 are not commutated. Immediately after $wt= 2\pi$ due to positive half cycle of supply voltage diode D1 and T1(forward blocking) are forward biased and load current chooses low resistance path through T2 and D1. Hence the output voltage is zero. Here, in the entire range of firing angle output voltage is positive and current flows only in one direction (current is positive).

In single phase semi controlled bridge converter for the firing angle range 0 to 180 average output voltage positive and average current positive. Hence only one quadrant operation is achieved.

WAVE FORMS:

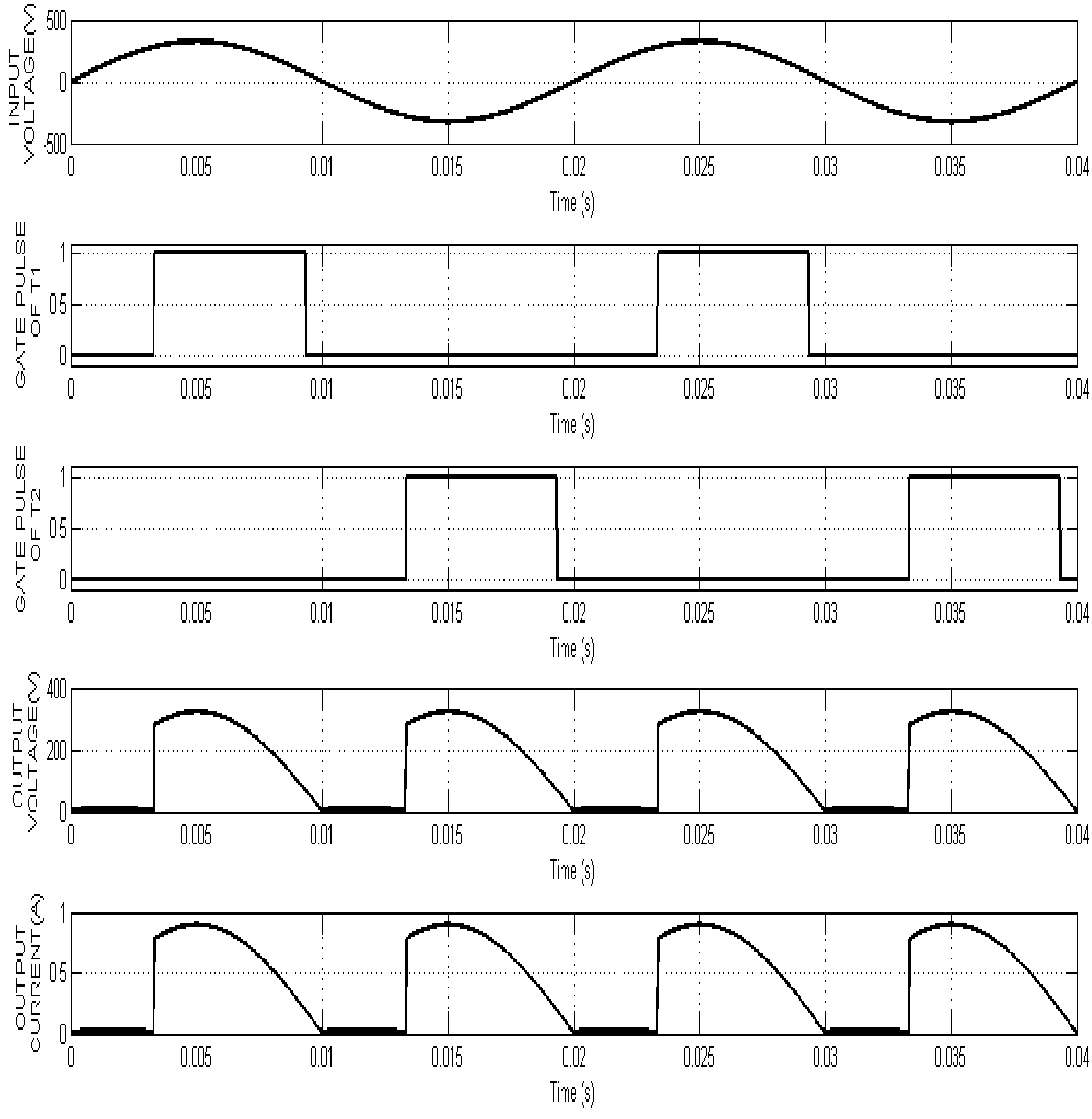


Fig. 3 :Wave forms of 1-ϕ semi controlled Bridge converter R-Load

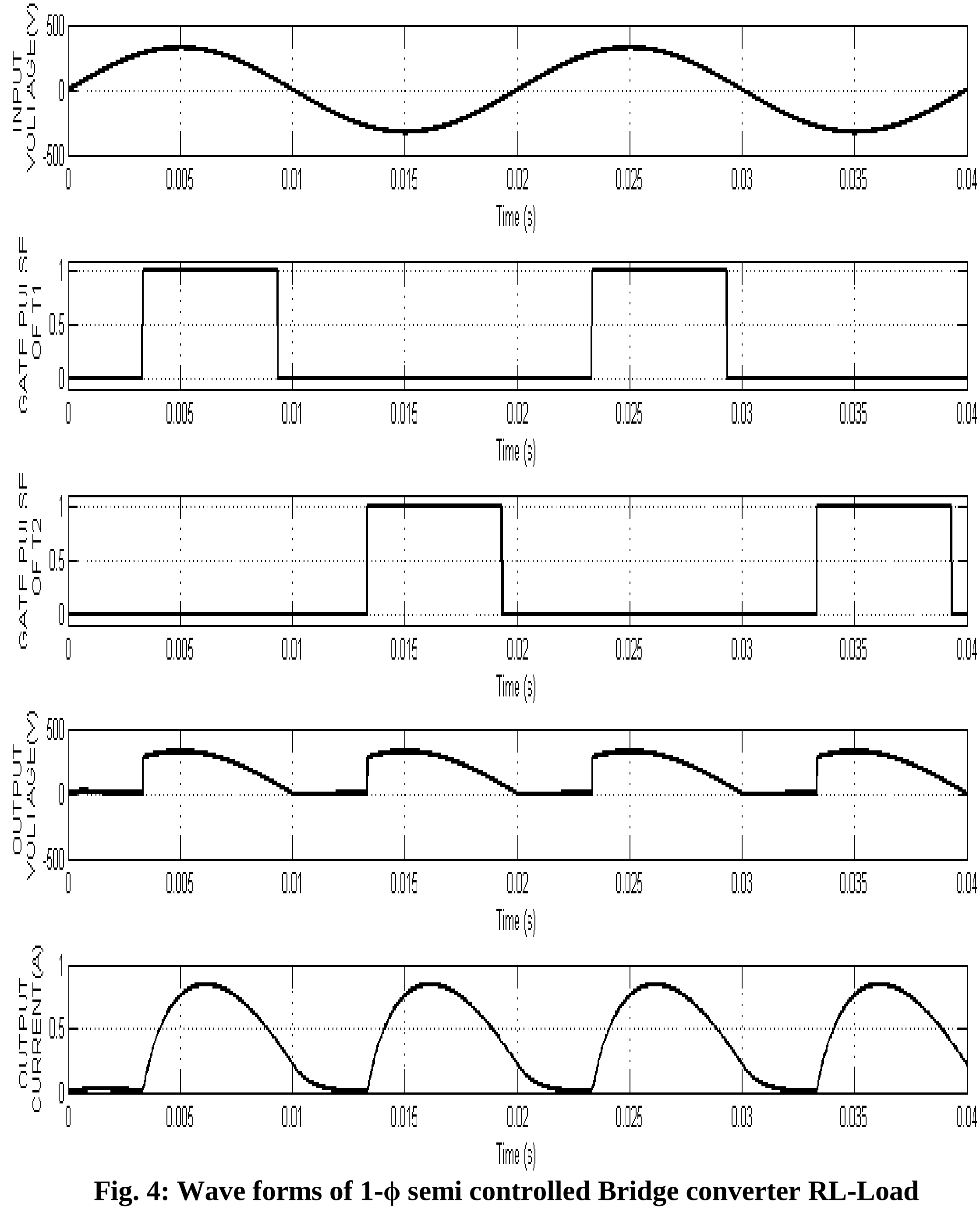


Fig. 4: Wave forms of 1-ϕ semi controlled Bridge converter RL-Load

TITLE: SINGLE PHASE SEMI CONTROLLED BRIDGECONVERTER
. **GPREC/DEEE/EXPT-PEL (P)-3**
Date: 17/01/2023

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Connect 30V tapping of the isolation transformer secondary to the input terminals of the power module initially.
3. Connect the gate signal terminals of the firing circuit to the SCRs.
4. Connect one channel to the oscilloscope to the input terminals and another channel to the output terminals.
5. Switch ON the power supply and observe the wave forms.
6. Now switch OFF the supply and connect 230V tapping of the isolation transformer to the input terminals of the power module.
7. Switch ON the power supply and note down average output voltage and current by changing the firing angle insteps.
8. Draw the waveforms of input and output voltages along with the gate pulses of the SCRs on the graph sheet.

OBSERVATIONS:

Firing Angle (α)	Average output voltage (Vo) in volts		Average output current (Io) in Amperes	
	Theoretical values	Practical values	Theoretical values	Practical values

FORMULAE USED:
For R-Load

$$V_{o\ avg} = \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin(\omega t)\, d(\omega t) = \frac{V_m}{\pi}(1 + cos\alpha) \qquad I_{O\ avg} = \frac{Vo_{\ avg}}{R}$$

For RL-Load

$$V_{o\ avg} = \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin(\omega t)\, d(\omega t) = \frac{V_m}{\pi}(1 + cos\alpha) \qquad I_{O\ avg} = \frac{Vo_{\ avg}}{R}$$

$$\sin(\beta - \phi) = \sin(\alpha - \phi)e^{\frac{-R}{\omega L}(\beta - \alpha)} \qquad \text{(or)} \qquad \beta = \pi + \phi$$

$$\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$$

RESULT:

The theoretical and experimental output wave forms and values of voltage and current of 1-ϕ semi controlled bridge converter with R and RL-Load are verified.

Viva questions:

1. What is a half controlled rectifier?
2. What are the differences between half wave and half bridge rectifier?
3. What are different names of half bridge rectifier?
4. Give the voltage and current expression for half controlled and half bridge controlled rectifiers?
5. What are the applications of half bridge controlled rectifiers?

TITLE: SINGLE PHASE DUAL CONVERTER

GPREC/DEEE/EXPT-PEL (P)-4
Date: 17/01/2023

OBJECTIVE:

To verify and compare theoretical and experimental results of Dual Converter with non-circulating and circulating modes.

.

APPARATUS:

Single phase dual converter power circuit module, Single phase dual converter control circuit module, Rheostat, Inductor, Voltmeter, Ammeter, Connecting wires.

THEORY:

Semi-converters are single quadrant converters (only first quadrant). This means that over entire range of firing angle load voltage and load current have only one polarity. This indicate rectification mode of operation and power flows from source to load, where as in full converter direction of current cannot be reversed but the direction of voltage can be reversed. Thus full converter can operate as a rectifier first quadrant for $\alpha= 0^0$ to 90^0 and as an inverter from $\alpha= 90^0$ to 180^0 in fourth quadrant. Thus a full converter is a two quadrant converter (first and fourth).

In case of four-quadrant operation is required without any mechanical change over switches, two full converters can be connected back to back to the load. Such an arrangement is called as dual converter. Converter-I operates the load in first and fourth quadrants and converter-II operates the load in second and third quadrants. The dual converter can be operated in two functional modes circulating current mode and non-circulating current mode.

In circulating mode of operation both the converters will be in operation with firing angle controlled in a manner of $\alpha_1+\alpha_2=180$. During this operation one converter with firing angle less than 90^0mwill be operating as rectifier and other converter with firing angle greater than 90^0 operates as an inverter. During this operation their average output voltages will be equal but their instantaneous output voltages V_{01} and V_{02} are out of phase. This results in a voltage difference between the converters and large circulating current flows between the two converters but not through the load. This large circulating current is limited to a tolerable value by inserting a reactor between the two converters.

In non-circulating mode of operation only one converter will be in operation at a time and it alone carries the entire load current. The other converter is blocked from operation. For such a dual converter circulating current will be absent and no reactor is required. With non-circulating current mode of dual converter the load current may be continuous or discontinuous.

TITLE: SINGLE PHASE DUAL CONVERTER

GPREC/DEEE/EXPT-PEL (P)-4

Date: 17/01/2023

CIRCUIT DIAGRAM:

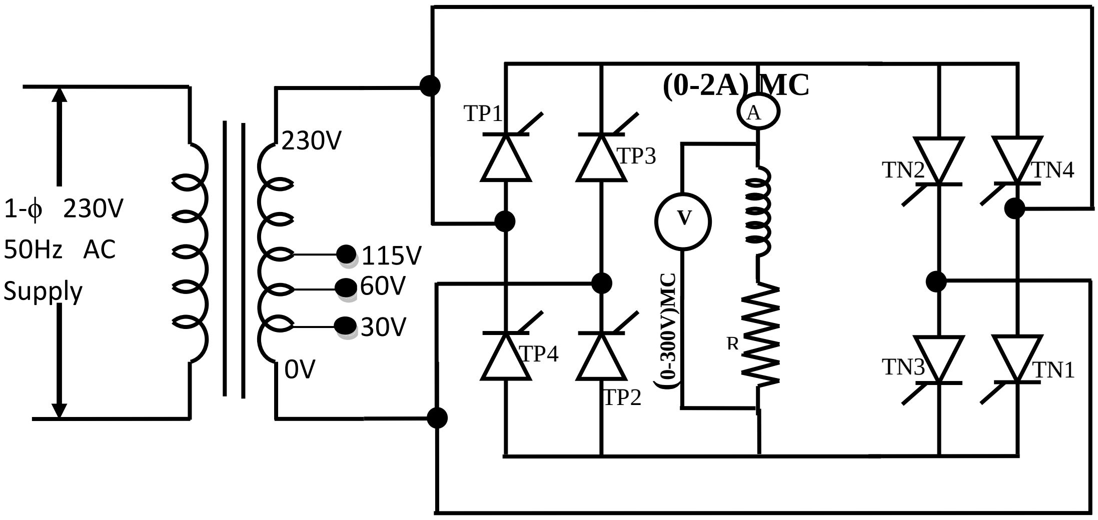


Fig.1 1-φ Dual Converter with Non-Circulating current mode

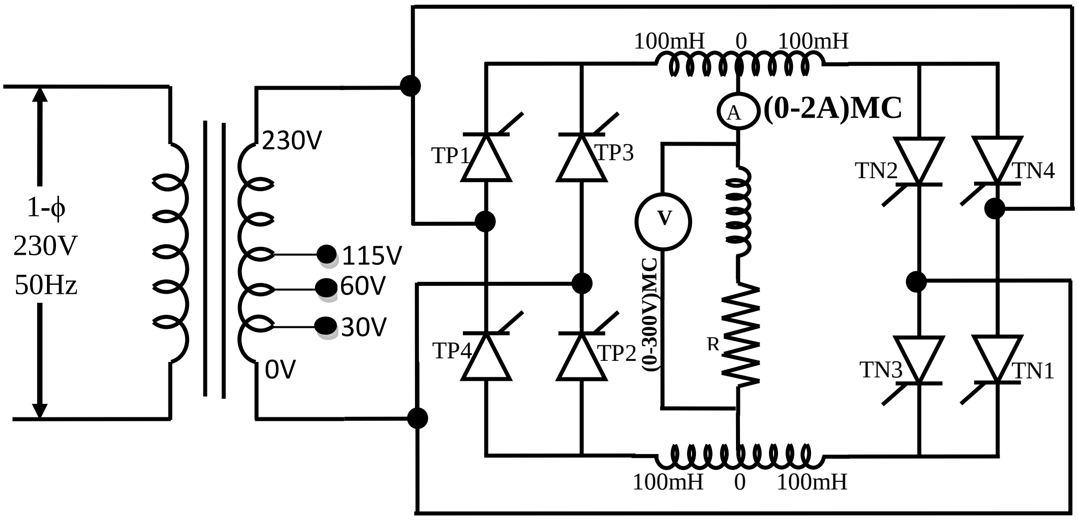


Fig.2 1-φ Dual Converter with circulating current mode

TITLE: SINGLE PHASE DUAL CONVERTER

GPREC/DEEE/EXPT-PEL (P)-4
Date: 17/01/2023

PROCEDURE:

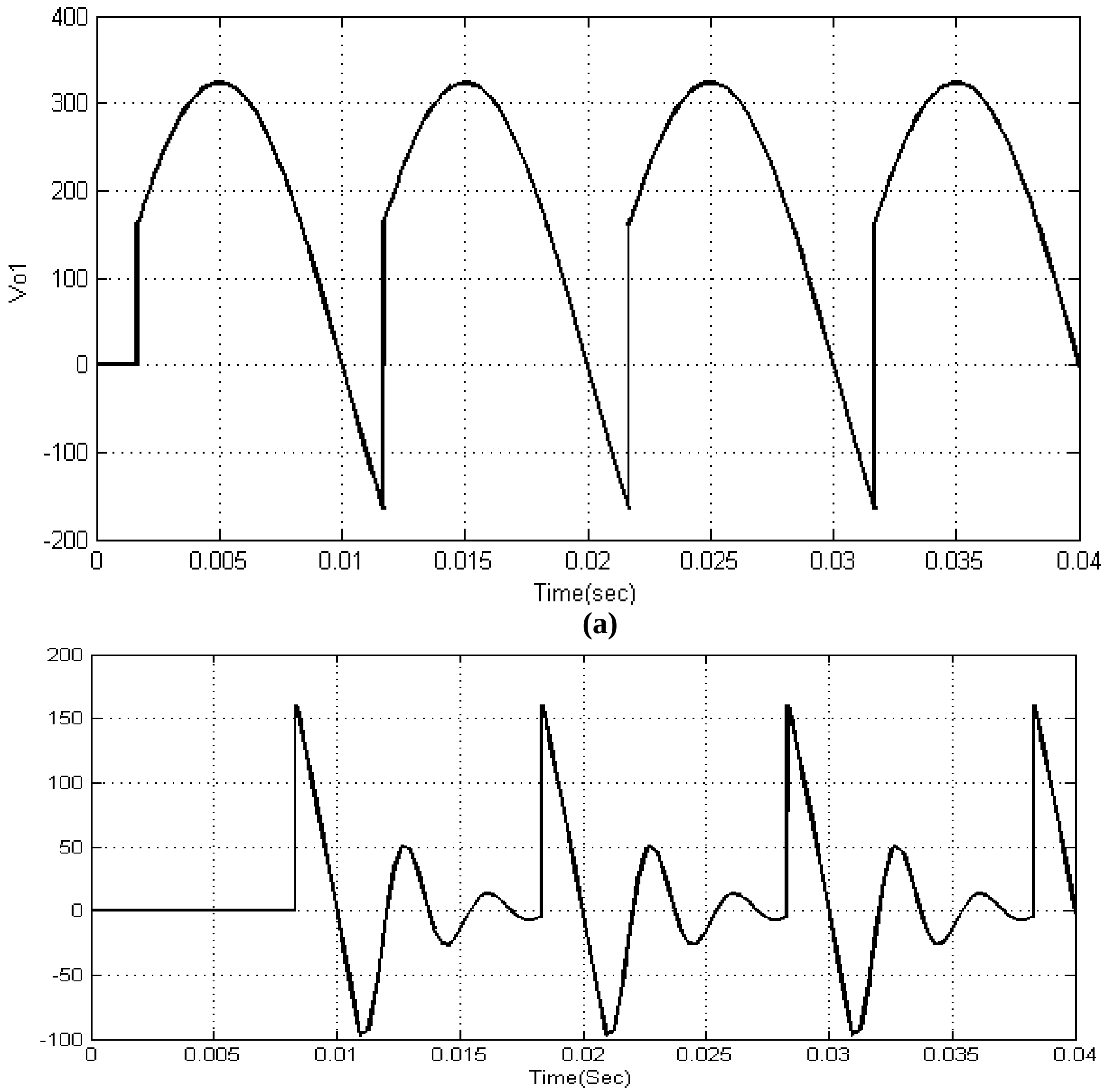
For NON-circulating mode:

1. Switch ON the single phase dual converter firing circuit. Make sure that all the pulses are proper before connecting to the power circuit.
2. Check all the SCR's in the power circuit.
3. Make the connections in the power circuit as shown in circuit diagram for non circulating mode.
4. Connect the firing pulse from the firing circuit to the respective SCR's gate/ cathode terminals in the power circuit.
5. Connect input AC supply to the power circuit through isolation transformer. Initially adjust the input voltage to 30V.
6. Switch ON the firing circuit. Select NCC mode. Select the P converter. Switch ON the MCB.
7. Vary the firing angle by Dec key and press ON/OFF key to ON and observe the voltage wave forms across the load.
8. Switch OFF the supply and connect input to 115V tapping of isolation transformer.
9. Note down the volt meter and ammeter reading for different values of firing angles.
10. With P-converter ON the dual converter will be operated in first quadrant operation.
11. In order to change the quadrant of operation from first to third. Select the N converter in the firing unit by pressing P/N key.
12. Repeat the above procedure for N-converter.

For circulating mode:

1. Switch ON the single phase dual converter firing circuit. Make sure that all the pulses are proper before connecting to the power circuit.
2. Check all the SCR's in the power circuit.
3. Make the connections in the power circuit as shown in circuit diagram for non circulating mode.
4. Connect the firing pulse from the firing circuit to the respective SCR's gate/ cathode terminals in the power circuit.
5. Connect input AC supply to the power circuit through isolation transformer. Initially adjust the input voltage to 30V.
6. Switch ON the firing circuit. Select CC mode. Switch ON MCB. Default firing angle is 90^0 for both the converters.
7. Press ON/OFF key to ON. Vary the firing angle by Inc/Dec key. Observe the wave forms across the load.
8. Switch OFF the supply and connect input to 115V tapping of isolation transformer.
9. Note down the volt meter and ammeter reading for different values of firing angles.

MODEL GRAPH:



(a)

(b)

Fig.4 Wave forms of converter-1 in 1- Φ Dual converter when operated with Non-circulating mode of operation at firing angles (a) $\alpha_1=30^0$ (b) $\alpha_1=150^0$

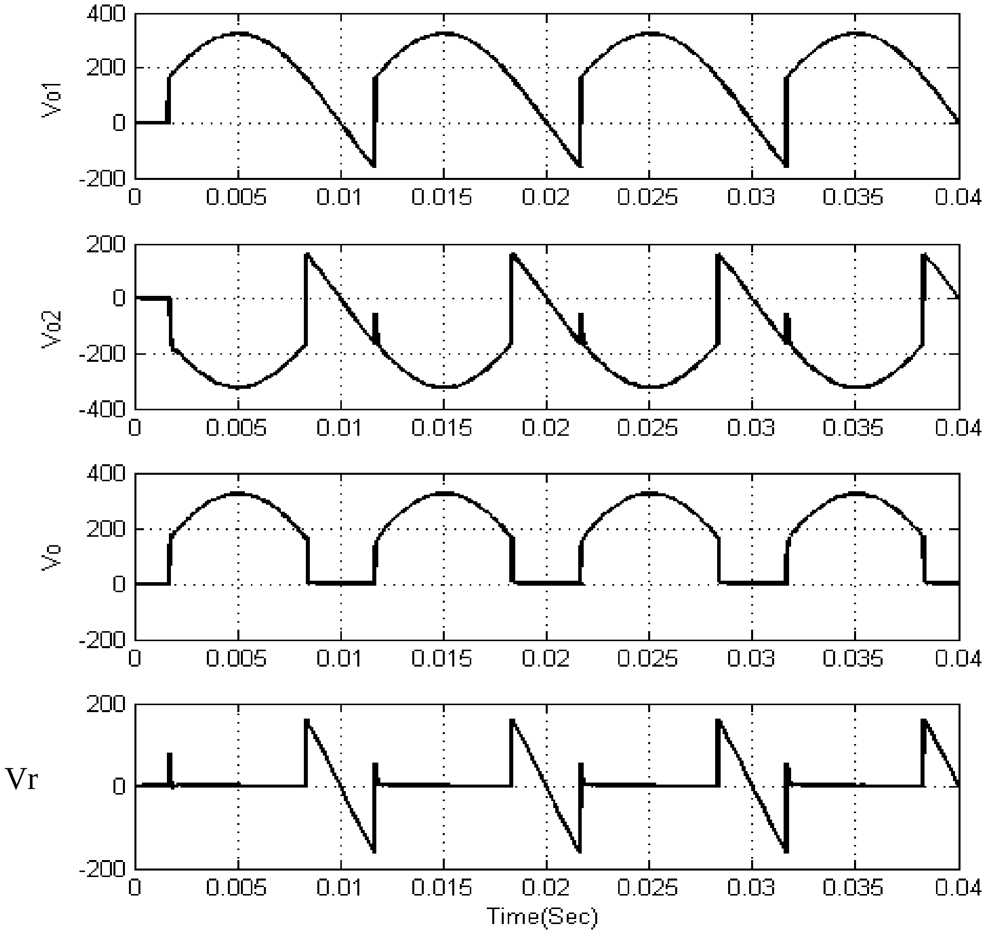


Fig.5 Wave forms of 1- Φ Dual converter when operated with circulating mode of operation

OBSERVATIONS:

Non-Circulating mode of operation:

S.No	P-Converter			N-Converter		
	Firing angle	Average Output Voltage		Firing angle	Average output Voltage	
		Theoretical	Practical		Theoretical	Practical

Circulating mode of operation:

S.No	**Firing angle**	**Average output Voltage**	
		Theoretical	**Practical**

FORMULAE USED:

For non-circulating mode of operation:

The average dc output voltage of P-Converter is

$V_{01} = \frac{2V_m}{\pi}\cos\alpha_1$ for continuous mode of operation

$V_{01} = \frac{V_m}{\pi}(\cos\alpha_1 - \cos\beta)$ for discontinuous mode of operation

The average dc output voltage of N-Converter is

$V_{02} = \frac{2V_m}{\pi}\cos\alpha_2$ for continuous mode of operation

$V_{02} = \frac{V_m}{\pi}(\cos\alpha_2 - \cos\beta)$ for discontinuous mode of operation

For non-circulating mode of operation:

$$V_o = \frac{V_{01} - V_{02}}{2}$$

$V_{01} = \frac{2V_m}{\pi}\cos\alpha_1$ for continuous mode of operation

$V_{01} = \frac{V_m}{\pi}(\cos\alpha_1 - \cos\beta)$ for discontinuous mode of operation

$V_{02} = \frac{2V_m}{\pi}\cos\alpha_2$ for continuous mode of operation

$V_{02} = \frac{V_m}{\pi}(\cos\alpha_2 - \cos\beta)$ for discontinuous mode of operation

$$\alpha_1 + \alpha_2 = 180^0$$

$$V_r = V_{01} + V_{02}$$

Result: The theoretical and experimental output wave forms and values of average voltage and current of 1-ϕ dual converter are verified.

Viva questions

1. What is a dual converter?
2. What are the applications of dual converter?
3. What is the purpose of using an inductor in the circuit?
4. Write the necessary condition for operation of dual converter in circulating current mode of operation?
5. Write the expression for average output voltage of converter1?

TITLE: SINGLE PHASE CYCLO CONVERTER
. **GPREC/DEEE/EXPT-PEL (P)-5**
Date: 17/01/2023

OBJECTIVE:

To verify the voltage wave forms of 1-ϕ cycloconverter with R and RL loads at different output frequencies.

APPARATUS:

Cycloconverter module, Cycloconverter firing circuit,1:1 isolation Transformer, Rheostat, Inductor, Voltmeter, Ammeter, Connecting wires.

THEORY:

A circuit which converts input power at one frequency to output power at a different frequency with one stage conversion is called a cycloconverter. There are two types of cycloconverters namely step-up cycloconverter and step-down cycloconverter. In step up cyclo converter, output frequency (f_o) > supply frequency (f_s) and for step down cycloconverter, $f_o < f_s$. The step and step down operation can be achieved by using mid-point converter configuration and bridge type configuration. In this experiment focus is given to midpoint converter configuration. This mid-point converter configuration has two groups of thyristors namely positive group and negative group. P1 and P2 form positive group and N1 and N2 form negative group.

During positive half cycle of input supply voltage terminal ‘a’ is positive with respect to ‘b’. Hence P1 and N2 are forward biased (forward blocking). To get output positive half cycle P1 is triggered and toget output negative halfcycle N2 is triggered. Similarly during negative half cycle of input supply voltage terminal ‘a’ is negative with respect to ‘b’. Hence P2 and N1 are forward biased (forward blocking). To get output positive half cycle P2 is triggered and toget output negative halfcycle N1 is triggered. Depending on output frequency tyristors are triggerd.

To get output frequency as fs/2 the tyristors are triggered as

At α P1 is triggered and load current flows through A-P1-Load-O
π +α P2 is triggered and load current flows through B-P2-Load-O
2π+α N2 is triggered and load current flows through O-N2-Load-B
3π+α N1 is triggered and load current flows through O-N1-Load-A

To get output frequency as fs/2 the tyristors are triggered as

At α P1 is triggered and load current flows through A-P1-Load-O
π +α P2 is triggered and load current flows through B-P2-Load-O
2π+α P1 is triggered and load current flows through A-P1-Load-O
3π+α N1 is triggered and load current flows through O-N1-Load-A
4π+α N2 is triggered and load current flows through O-N2-Load-B
5π+α N1 is triggered and load current flows through O-N1-Load-A

TITLE: SINGLE PHASE CYCLO CONVERTER
. **GPREC/DEEE/EXPT-PEL (P)-5**
Date: 17/01/2023

CIRCUIT DIAGRAM:

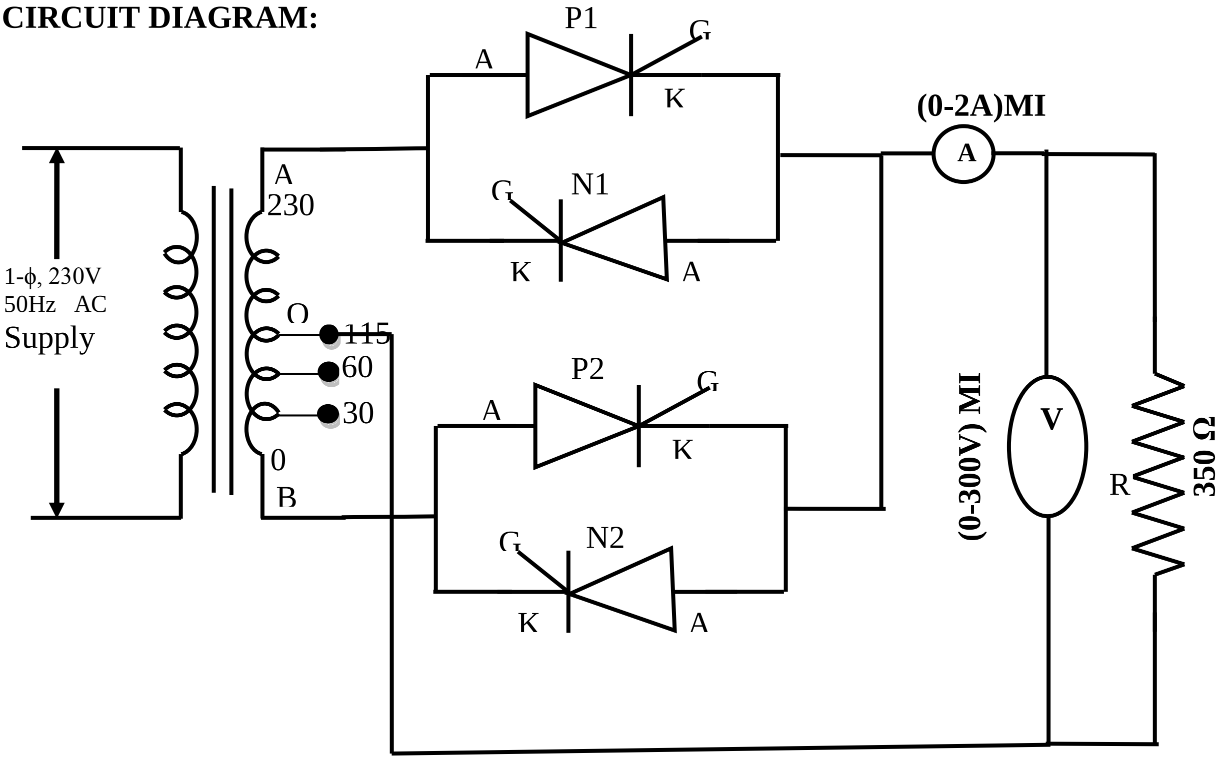


Fig.1 1-ϕ Cycloconverter with R-Load

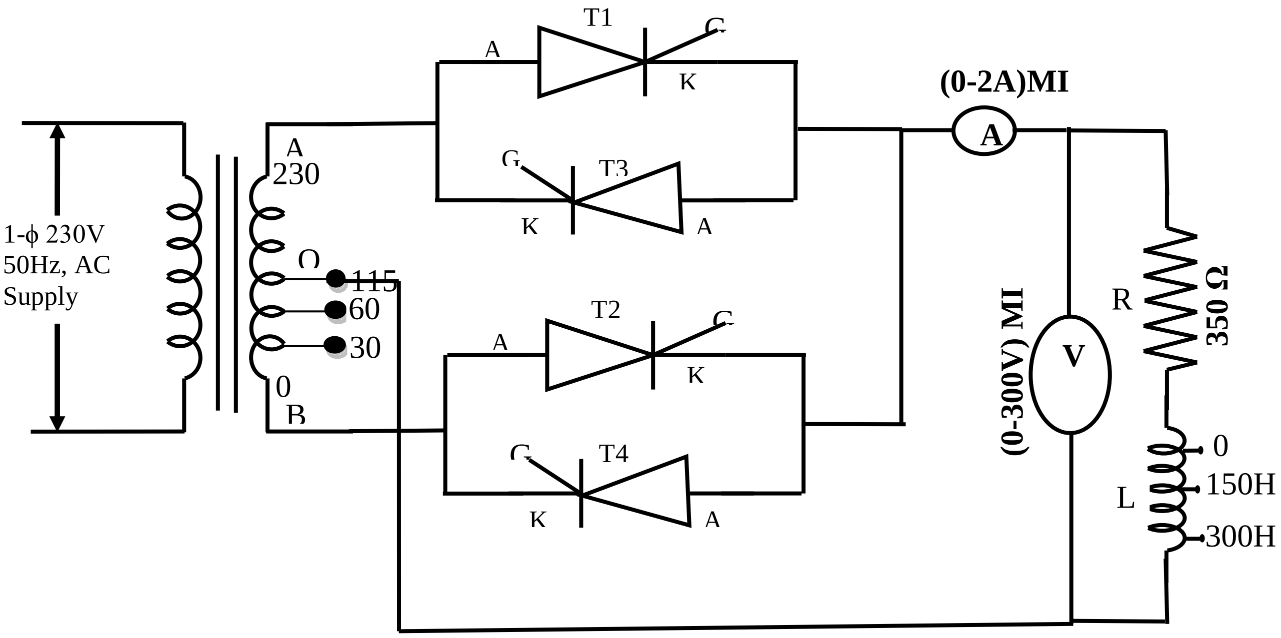


Fig.2 1-ϕ Cycloconverter with RL-Load

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Connect between 0V, 30V and 60V tapping of the isolation transformer secondary to the input terminals of the power module initially.
3. Connect the gate signal terminals of the firing circuit to the SCRs.
4. Connect one channel to the oscilloscope to the input terminals and another channel to the output terminals.
5. Switch ON the power supply and observe the wave forms.
6. Now switch OFF the supply and connect between 0V, 115V and 230V tapping of the isolation transformer to the input terminals of the power module.
7. Switch ON the power supply and note down average output voltage and current by changing the firing angle insteps.
8. Observe the frequency of output voltage by changing frequency in steps of f/2, f/3, f/4.
9. Draw the waveforms of input and output voltages at different frequencies on the graph sheet.

WAVEFORMS:

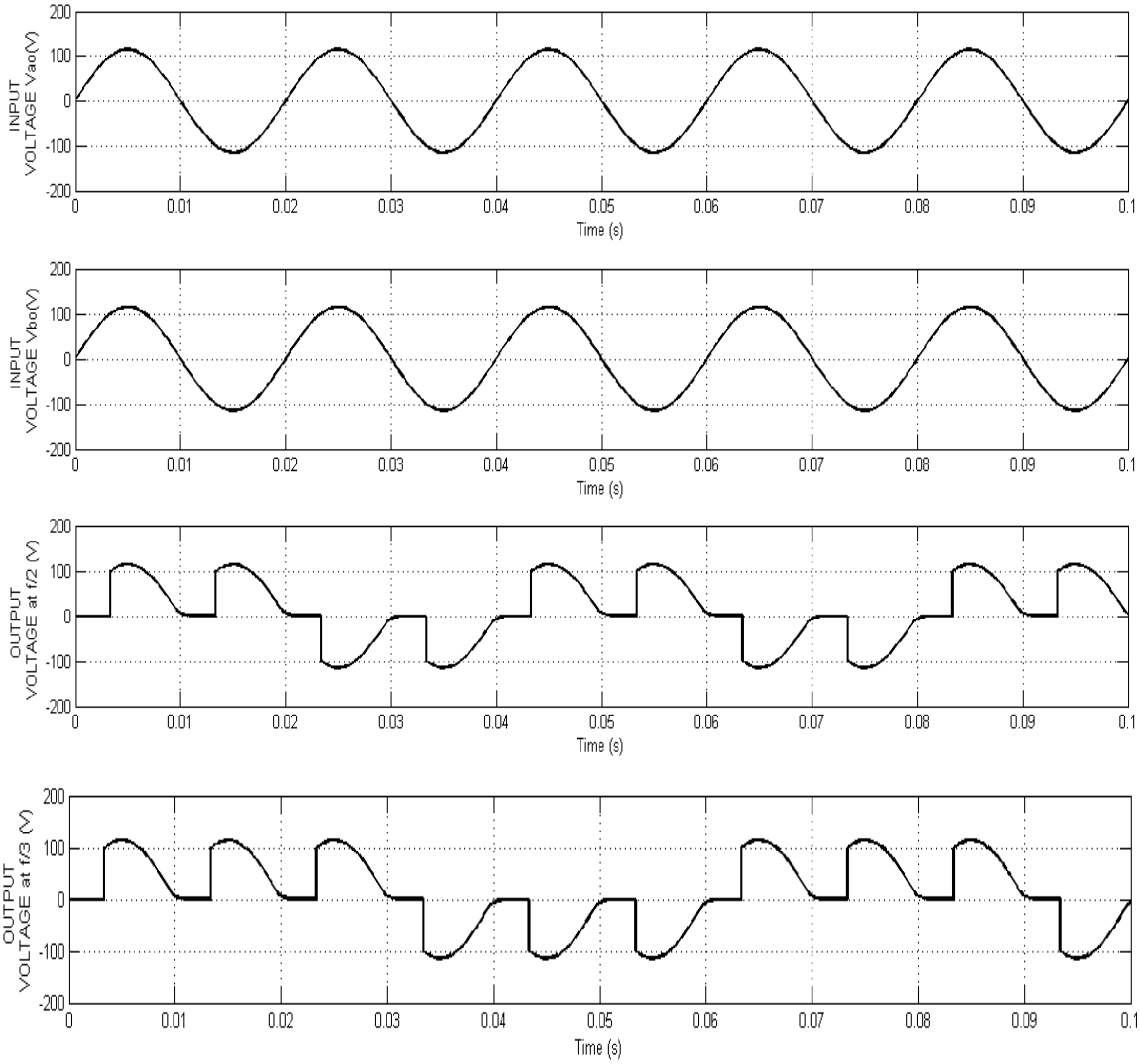


Fig.3:Wave forms 1-ϕ cycloconverter with R-Load at different frequencies

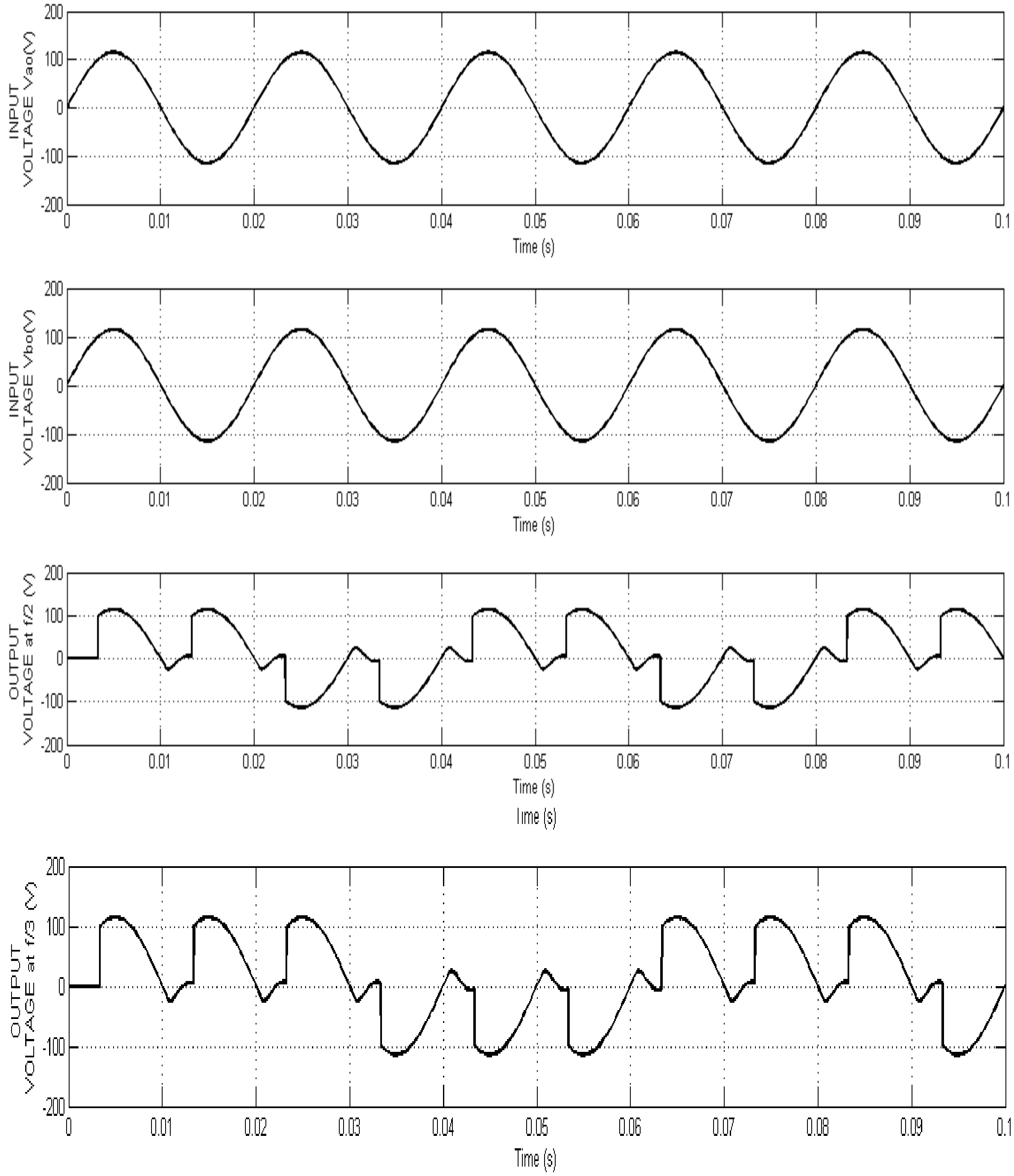


Fig.4: Wave forms 1-ϕ cycloconverter with RL-Load at different frequencies

TITLE: SINGLE PHASE CYCLO CONVERTER
. **GPREC/DEEE/EXPT-PEL (P)-5**
Date: 17/01/2023

OBSERVATIONS:

Firing Angle (α)	RMS output voltage (Vo) in volts		RMS output current (Io) in Amperes	
	At $f_O=f_s/2$	At $f_O=f_s/3$	At $f_O=f_s/2$	At $f_O=f_s/3$

RESULT:

The wave forms of 1-ϕ cycloconverter with R and RL loads at different frequencies are verified.

Viva questions:

1. Give the applications of cyclo converter?
   a) cyclo converters are used in speed control of high power drives, induction heating, static VAR compensation etc…
2. What are the types of cyclo converters?
   a) Step up cyclo converter and step down cyclo converter
3. Give the expression for rms voltage across the load in cyclo converter?
4. Which type of commutation takes place in cyclo converter?
   a) Natural commutation
5. Define cyclo converter?
   a) A circuit which converts input power at one frequency to output power at a different frequency with one stage conversion is called a cyclo converter

G. Pulla Reddy Engineering College (Autonomous): Kurnool
Department of Electrical & Electronics Engineering
B.Tech EEE – VI Semester (Scheme: 2020)
Power Electronics & Drives Laboratory (PEL (P))

TITLE: SINGLE PHASE AC VOLTAGE CONTROLLER

GPREC/DEEE/EXPT-PEL (P)-6

Date: 17/01/2023

OBJECTIVE:

To verify and compare theoretical and experimental results of 1-ϕ AC voltage controller using unidirectional and bidirectional switches with R & RL loads.

APPARATUS:

SCRs, SCR firing circuit, TRIAC module, UJT firing circuit ,1:1 isolation Transformer, Rheostat, Inductor, Voltmeter, Ammeter, Connecting wires.

THEORY:

If pair of unidirectional semiconductor switches (thyristors in anti-parallel connection) or a bidirectional switch (TRIAC) is connected between ac supply and load, the power flow can be controlled by varying the RMS value of AC voltage applied to the load and this type of power circuit is known as an AC voltage controller. In AC voltages controllers RMS voltage applied to load is varied but frequency is maintained constant(i.e same as input frequency). Because of AC input voltage, the thyristors or TRIAC are line commutated and hence no need of any extra commutation circuit. The circuit diagram of 1-ϕ AC Voltage Controller with unidirectional semiconductor switches (thyristors in Anti-parallel connection) is shown in Fig.1 and with bidirectional switch (TRIAC) is shown in Fig. 4. In single phase AC voltage controllers, controlled AC output voltage can be achieved by phase angle control and integral cycle control. The experiment focuses on phase angle control.

For R-Load: During positive half cycle Thyristor T1 (or TRIAC) is forward biased and is triggered at wt=α. Hence T1 (or TRIAC) starts conducting and source voltage is applied to the load from α to π. During this period output voltage and output current are positive. At wt= π both output voltage and output current falls to zero. After wt= π, T1 (or TRIAC) is reverse biased and it is turned off due to natural or line commutation. During negative half cycle T2 (or TRIAC) is forward biased and triggered is at wt= π + α. Hence T2 (or TRIAC) starts conducting and source voltage is applied to the load from wt= π + α to 2π. During this period load (output) voltage and output current are negative. At wt= 2π both output voltage and output current falls to zero. After wt= 2π, T2 (or TRIAC) is reverse biased and it is turned off due to natural or line commutation.

For RL-Load: During positive half cycle Thyristor T1 (or TRIAC) is forward biased and is triggered at wt=α. Hence T1 (or TRIAC) starts conducting and source voltage is applied to the load from α to π. During this period output voltage and output current are positive. At wt= π, output (load) voltage and source voltage are zero but output current is not zero because of presence of the inductance in the load circuit. At wt=β load current reduces to zero. From wt= α to β output voltage follows source voltage. After wt= β, T1 (or TRIAC) is line commutated and hence both output voltage and current becomes zero. During negative half cycle T2 (or TRIAC) is forward biased and triggered at wt= π + α. Hence T2 (or TRIAC) starts conducting and source voltage is applied to the load. At wt= 2π, output (load) voltage and source voltage are zero but output current is not zero because of presence of the inductance in the load circuit. Hence source voltage is applied to the load from wt= $\pi + \alpha$ to $\pi + \alpha + \gamma$ (γ is the conduction angle).

From the analysis of single phase AC voltage controller with RL-Load, it is observed that AC output voltage can only be controlled for $\alpha > \emptyset$. For $\alpha \leq \emptyset$ output voltage cannot be controlled and output voltage will be equal to source voltage.

CIRCUIT DIAGRAM: (UNIDIRECTIONAL SWITCH)

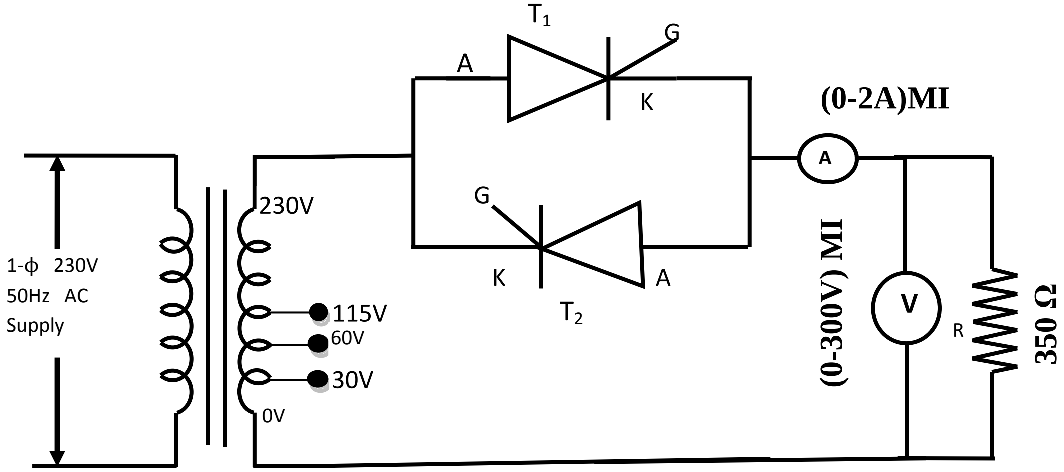


Fig.1 1-ϕ AC Voltage Controller using anti- parallel with R-Load

CIRCUIT DIAGRAM: (BIDIRECTIONAL SWITCH)

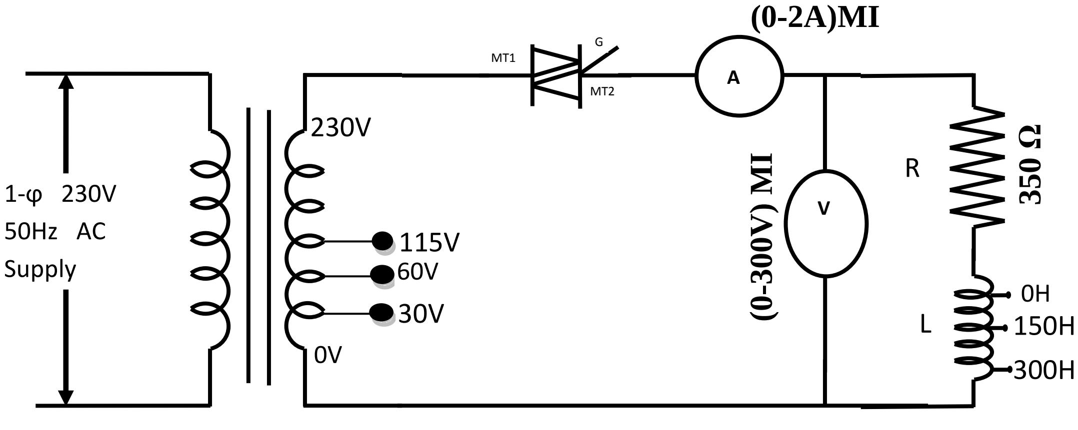


Fig. 3 1-Φ AC Voltage Controller using TRIAC with RL-Load

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Connect 30V tapping of the isolation transformer secondary to the input terminals of the power module initially.
3. Connect the gate signal terminals from the UJT firing circuit to the SCRs Modules. (For TRIAC circuit: Connect the gate signal terminals from the digital firing circuit to the TRIAC module.)
4. Connect one channel to the oscilloscope to the input terminals and another channel to the output terminals.
5. Switch ON the power supply and observe the wave forms.
6. Now switch OFF the supply and connect 230V tapping of the isolation transformer to the input terminals of the power module.
7. Switch ON the power supply and note down rms value of output voltage and current by changing the firing angle insteps.
8. Draw the waveforms of input and output voltages along with the gate pulses of the SCRs on the graph sheet.

WAVE FORMS:

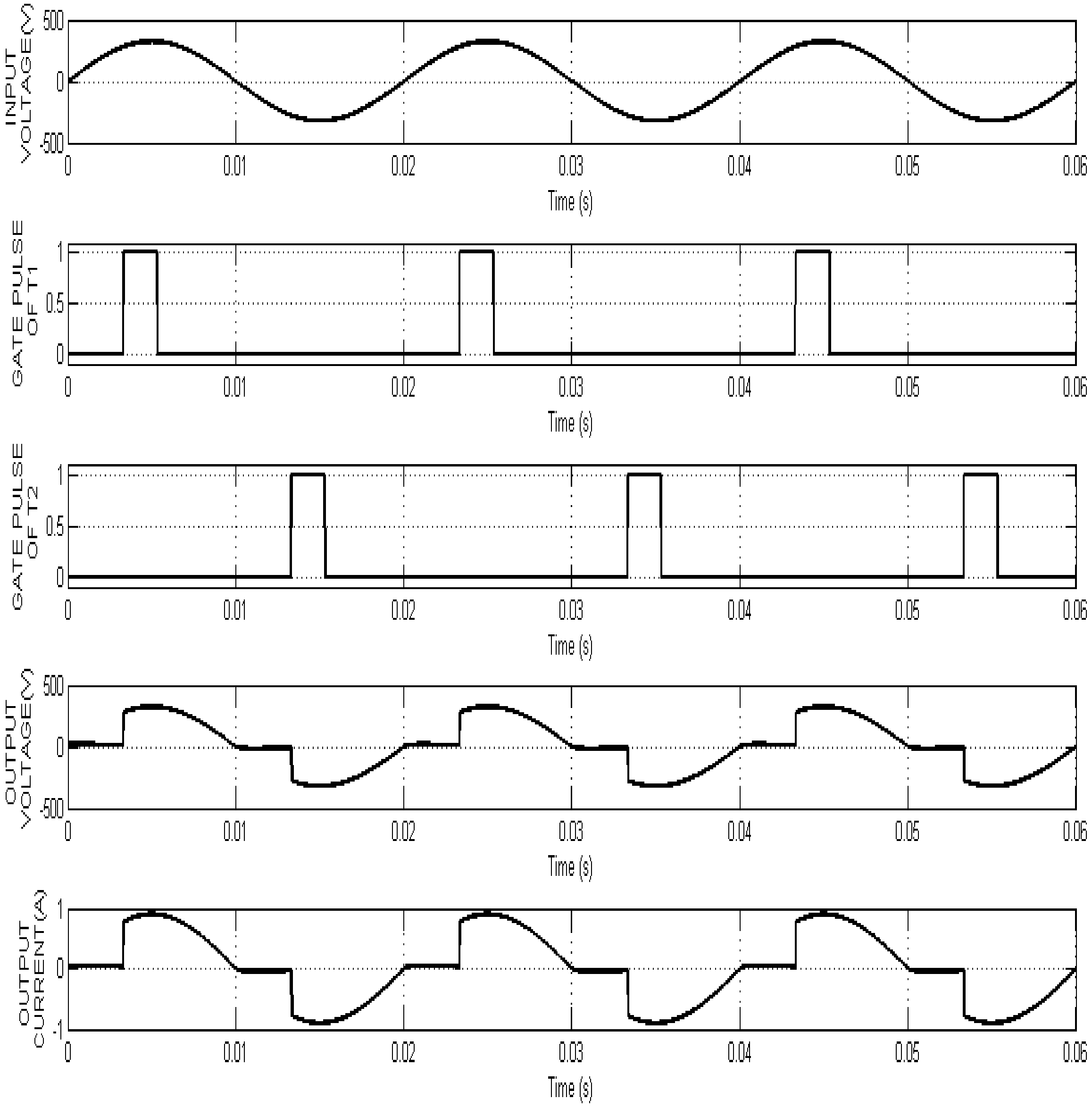


Fig. 8 Wave forms 1-ϕ AC Voltage Controller using unidirectional switches (Thyristors) with R-Load

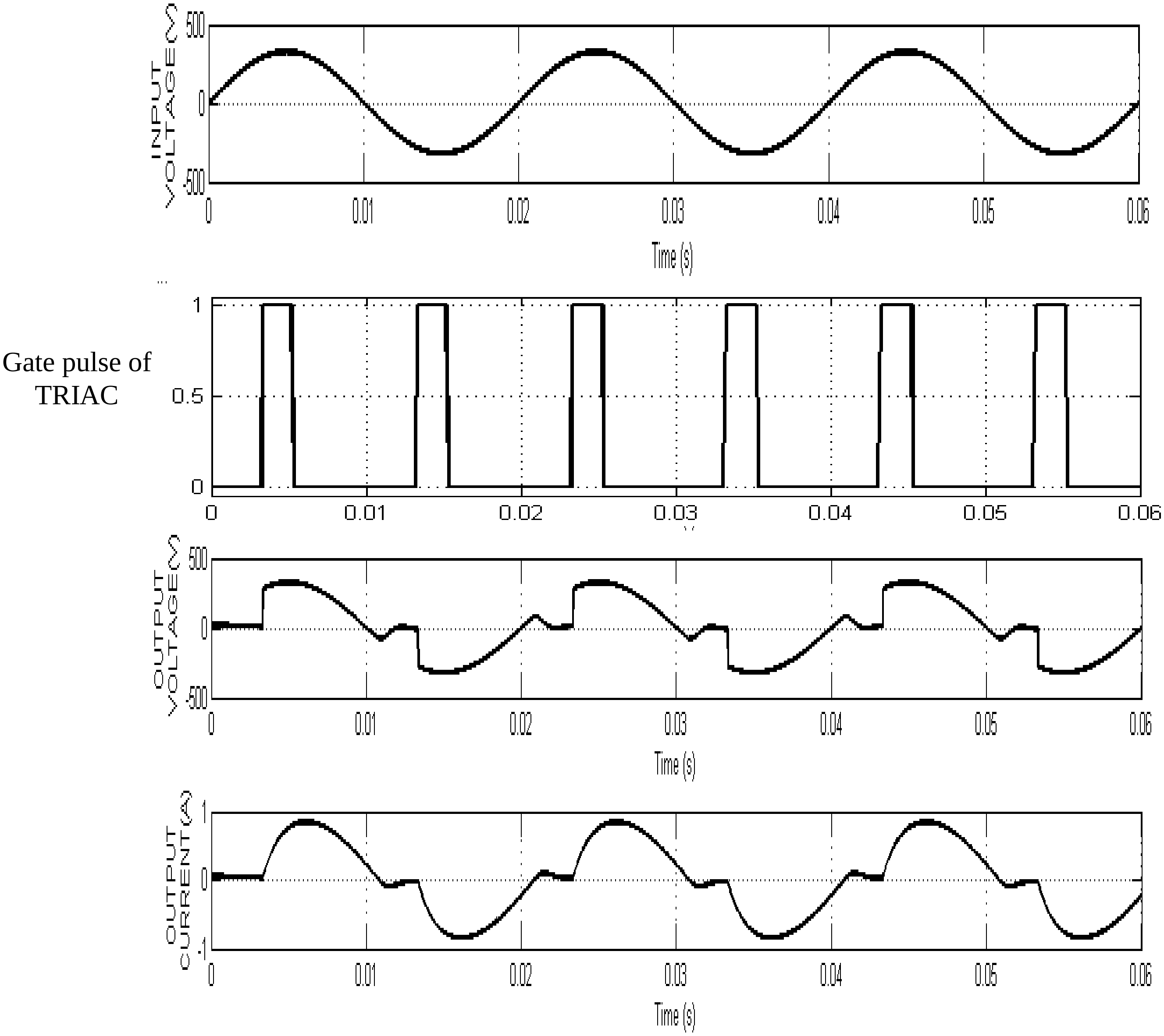


Fig. 11 Wave forms 1-ϕ AC Voltage Controller using bidirectional switch (TRIAC) with RL-Load

OBSERVATIONS:

Firing Angle (α)	RMS output voltage (Vo) in volts		RMS output current (Io) in Amperes	
	Theoretical values	Practical values	Theoretical values	Practical values

FORMULAE USED:

For R-Load

$$V_{O\,rms} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi} \left(V_m sin(wt)\right)^2 d(wt)} = \frac{V_m}{\sqrt{2\pi}}\left[(\pi-\alpha)+0.5sin(2\alpha)\right]^{1/2}$$

$$I_{o\,rms} = \frac{V_{o\,rms}}{R}$$

For RL-Load

$$V_{O\,rms} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\beta} \left(V_m sin(wt)\right)^2 d(wt)} = \frac{V_m}{\sqrt{2\pi}}\left[(\beta-\alpha)+0.5sin(2\alpha)-0.5sin(2\beta)\right]^{1/2}$$

$$I_{o\,rms} = \frac{V_{o\,rms}}{\sqrt{R^2+(\omega L)^2}}$$

$\sin(\beta-\phi) = \sin(\alpha-\phi)e^{\frac{-R}{\omega L}(\beta-\alpha)}$ (or) $\beta=\pi+\phi$

$$\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$$

RESULT:

The wave forms of 1-Φ AC voltage controller using Anti parallel connection of thyristors and TRIAC with R and RL-Load are observed and rms output voltage and current are measured and compared with theoretical values.

Viva questions

1. What is an ac voltage controller?
2. What are the applications of ac voltage controller?
3. What are the two types of control?
4. Give the classification of ac voltage controllers?
5. What is the difference between cyclo converter and ac voltage controller?

G. Pulla Reddy Engineering College (Autonomous): Kurnool
Department of Electrical & Electronics Engineering
B.Tech EEE – VI Semester (Scheme: 2020)
Power Electronics & Drives Laboratory (PEL (P))

TITLE: THREE PHASE AC VOLTAGE CONTROLLER
.
GPREC/DEEE/EXPT-PEL (P)-7
Date: 17/01/2023

OBJECTIVE:

To verify and compare theoretical, simulation and experimental results of 3-ϕ AC voltage controller with R load.

APPARATUS:

SCRs, SCR firing circuit,1:1 isolation Transformer, Rheostat, Inductor, Voltmeter, Ammeter, Connecting wires.

CIRCUIT DIAGRAM:

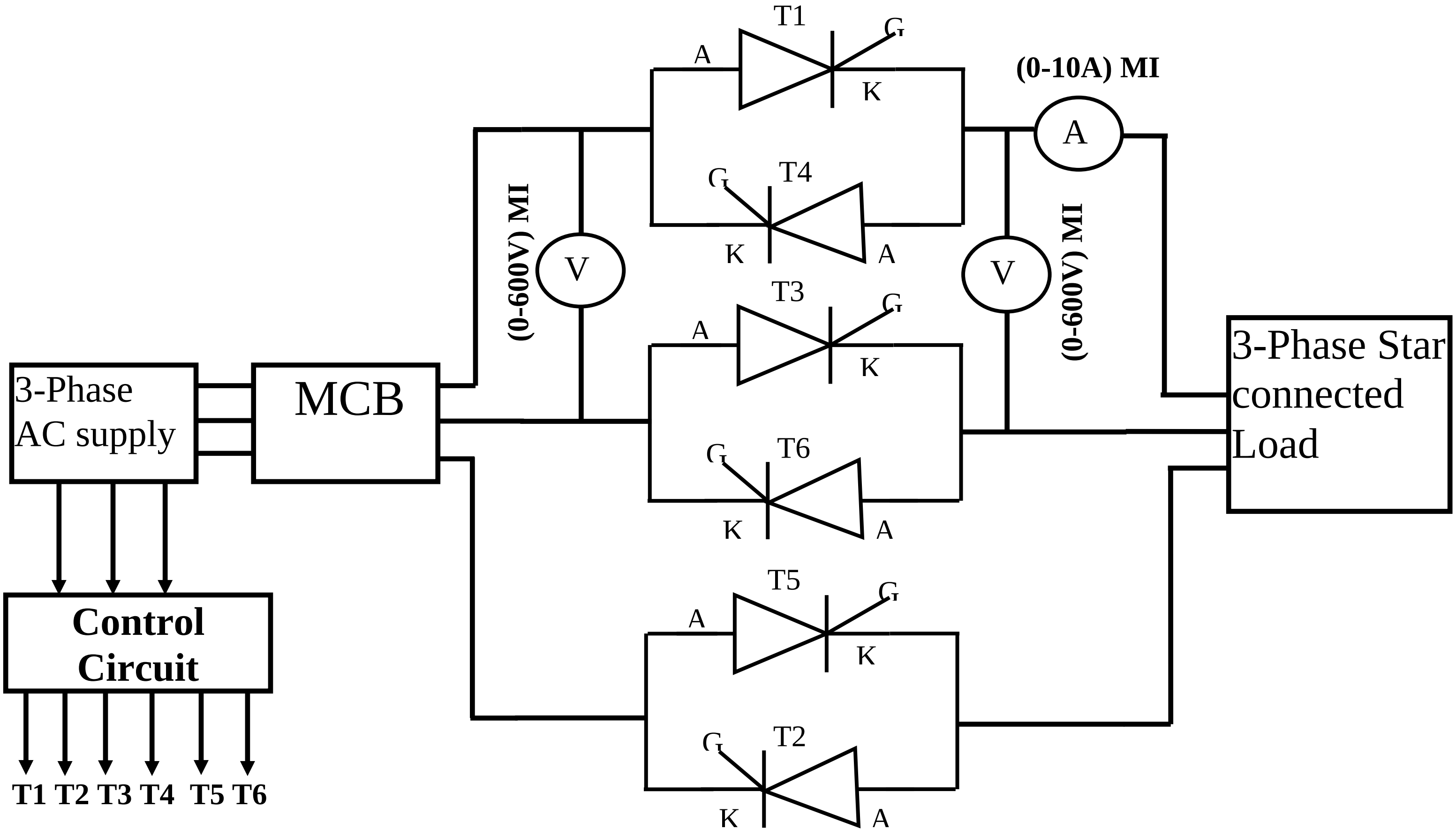


Fig.1 3-ϕ AC Voltage Controller with R-Load

THEORY:

If pair of thyristor switches are connected back to back between ac supply and load, the power flow can be controlled by varying the RMS value of AC voltage applied to the load and this type of power circuit is known as an AC voltage controller. The AC voltage controllers can be classified into two types (a) single phase controllers and (b) three-phase controllers. There are various configurations of three phase controllers depending on the connection of thyristors switches and load (star or delta). For star connected loads the connection of thyristors switches in AC voltage controller can be classified as three-phase three wire system and three-phase four wire system. In this experiment three-phase three wire system is considered.

The circuit diagram of three-phase three wire AC voltage controller is shown in Fig.1 with star connected resistive load. The firing sequence of thyristor are considered as

$$\mathbf{T1}=\alpha;\ \mathbf{T4}=180^0+\alpha$$
$$\mathbf{T3}=120^0+\alpha;\ \mathbf{T6}=120^0+180^0+\alpha$$
$$\mathbf{T5}=240^0+\alpha;\ \mathbf{T2}=240^0+180^0+\alpha \text{ (or) } 60^0+\alpha$$

Based on the firing angle conduction time (ON time) of each switch will change. Based on conduction interval and firing angle operation of three phase AC voltage controller is divided in to four modes.

$0^0\leq\alpha<60^0$ ---- Mode 1
$60^0\leq\alpha<90^0$ ---- Mode 2
$90^0\leq\alpha<150^0$ ---- Mode 3
$150^0\leq\alpha<180^0$ ---- Mode 4

In mode 1 at any time either three or two thyristors will be in conduction. So output phase voltage wave form follows input phase voltage when three thyristors are in conduction and follows line voltage when two thyristors are in conduction. The resulting output phase voltage plot for $\alpha = 30^0$ is shown in Fig. 4(a).

In mode 2 at each instant of time two thyristors will be in conduction. Hence the output phase voltage waveform follows input line voltage waveform only. The resulting output phase voltage plot for $\alpha = 60^0$ is shown in Fig. 4(b).

In mode 3 at each instant of time either two or one thyristor will be in conduction. So output phase voltage wave form follows input line voltage when two thyristors are in conduction and follows zero voltage waveform when one thyristor is in conduction. The resulting output phase voltage plot for $\alpha = 120^0$ is shown in Fig. 4(c).

In mode 4 at each instant of time only one thyristor will be in conduction. Hence the output phase voltage waveform will follow zero voltage wave form.

Hence it is observed that in a three phase three wire AC voltage controller output voltage can be controlled from $0^0\leq\alpha<150^0$ only and for firing angle greater that 150^0 output voltage is zero.

PROCEDURE:

1. Check all the SCRs for performance before making the connections.
2. Connect 3-phase, 400 V ac supply to the R Y B (3-phase terminals) provided in the front panel of firing circuit for phase synchronization. Connect 3-phase neutral point to the green terminal provided in the back panel.
3. Switch ON the 3-phase supply to the firing unit and observe the R Y B test signals with respect to the ground. If the proper neutral point is connected to the back panel we can observe clear R Y B signals with 15 V amplitude.
4. Connect firing pulses from the firing circuit to the respective SCR's gate and cathode.
5. Connect the 3-phase AC input to the power circuit preferably through 3-phase isolation transformer/ 3-phase autotransformer.
6. Initially set the input AC voltage to 60 V, switch ON the firing circuit. Vary the firing angle potentiometer and observe the voltage waveforms across the load.
7. If the bridge output is coming properly, switch OFF the supply and connect 440V tapping of the isolation transformer to the input terminals of the power module.
8. Switch ON the power supply and note down RMS output voltage and current by changing the firing angle insteps.
9. Draw the waveforms of input and output voltages along with the gate pulses of the SCRs on the graph sheet.

WAVE FORMS:

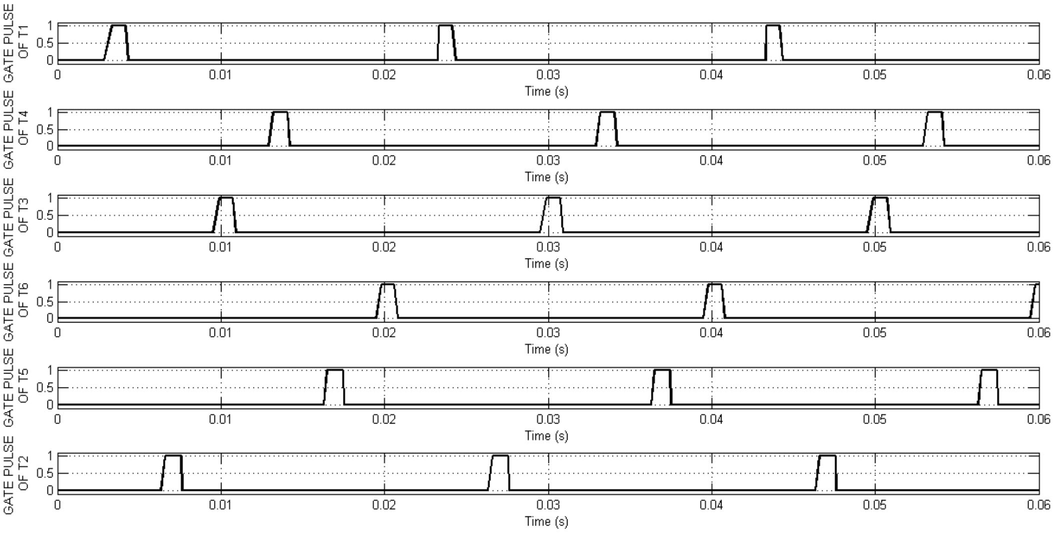
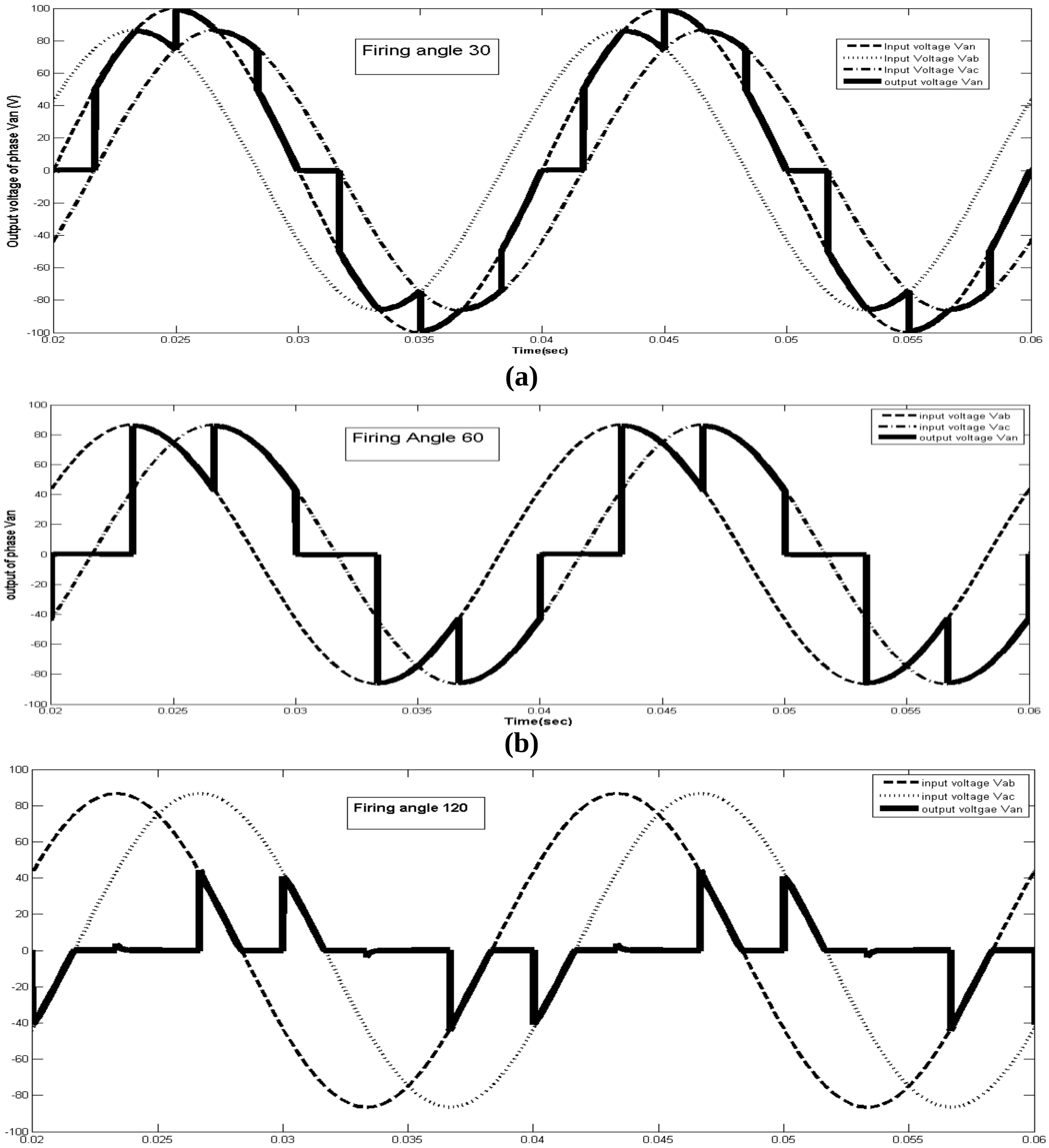


Fig.3 Wave forms of gating pulse 3-ϕ AC Voltage Controller



(a)

(b)

(c)

Fig.4 Wave forms 3-ϕ AC Voltage Controller R-Load at different firing angles (phase voltage)

OBSERVATIONS:

Firing Angle (α)	RMS output voltage (Vo) in volts		RMS output current (Io) in Amperes	
	Theoretical values	Practical values	Theoretical values	Practical values

FORMULAE USED:

For $0^0 \le \alpha \le 60^0$

$$V_0 = \sqrt{6}V_s\left[\frac{1}{\pi}\left(\frac{\pi}{6} - \frac{\alpha}{4} + \frac{\sin 2\alpha}{8}\right)\right]^{\frac{1}{2}}$$

For $60^0 \le \alpha \le 90^0$

$$V_0 = \sqrt{6}V_s\left[\frac{1}{\pi}\left(\frac{\pi}{12} + \frac{3\sin 2\alpha}{16} + \frac{\sqrt{6}\cos 2\alpha}{16}\right)\right]^{\frac{1}{2}}$$

For $90^0 \le \alpha \le 150^0$

$$\mathrm{V}_0 = \sqrt{6}V_s\left[\frac{1}{\pi}\left(\frac{5\pi}{24} - \frac{\alpha}{4} + \frac{\sin 2\alpha}{16} + \frac{\sqrt{3}\cos 2\alpha}{16}\right)\right]^{\frac{1}{2}}$$

RESULT:

The theoretical, simulation and experimental output wave forms and values of voltage and current of 3-ϕ AC voltage controller with R Load are verified.

Viva questions

1. What are the applications of three phase ac voltage controllers?
2. Give the expression for the output voltage across load in a three phase ac voltage controllers?
3. What is phase angle control?
4. What are the modes of operation of three phase ac voltage controllers?
5. What happens when only one switch conducts in a three phase AC voltage controller

G. Pulla Reddy Engineering College (Autonomous): Kurnool
Department of Electrical & Electronics Engineering
B.Tech EEE – VI Semester (Scheme: 2020)
Power Electronics & Drives Laboratory (PEL (P))

TITLE: SINGLE PHASE FULL BRIDGE PWM INVERTER
. **GPREC/DEEE/EXPT-PEL (P)-8**
Date: 17/01/2023

OBJECTIVE:

To verify and compare theoretical and experimental results of 1-ø full bridge PWM inverter with R load.

APPARATUS:

IGBT Based PWM inverter module, Rheostat, Connecting wires

THEORY:

A circuit that converts DC power into AC power at desired output voltage and frequency is called an inverter. Based on the type of commutation technique employed inverters are classified into three types

a) Line commutated inverters
b) Load commutated inverters
c) Forced commutated Inverters

In this experiment focus is given on forced commutated inverters. Based on the type of sources used forced commutated inverters are classified into two types

- Voltage source inverters
- Current source inverters

The circuit diagram of single phase full bride voltage source inverter is shown In Fig.1. The circuit utilizes IGBT's. For full bridge inverter when H1, L2 conduct output voltage is V_{dc} and when H2, L1 conduct output voltage is $-V_{dc}$. The frequency of output voltage can be varied by varying the time period (T) of control signals employed to IGBT's. There are various methods for the control of output voltage in voltage source inverters.

- External control of AC output voltage
- External control of DC input voltage
- Internal control of inverter

Among these methods first two methods require external peripheral components and third method does not require any peripheral components. Because of higher number of advantages (low cost, less complex and higher efficiency) internal control is employed in all industrial applications.

In internal control, fixed input voltage is given to the inverter and controlled ac output voltage is obtained by adjusting the ON and OFF periods of the IGBT's. Because of ON and OFF times variation this method is called as pulse width modulation (PWM). In PWM techniques width of the pulses is modulated to get output voltage control.

Based on number of pulses in the half cycle PWM techniques are classified as

- Single pulse width modulation
- Multiple pulse width modulation

The implementation of PWM techniques is carried out based on carrier comparison approach. In this approach desired output frequency reference signal is compared with high frequency carrier signal. The intersection point of reference signals with carrier signals gives the switching times or ON and OFF times of switching devices. Based on type of reference signal used for the generation of control signals multiple pulse width modulation technique is divided into several types as

- Constant pulse width modulation
- Sinusoidal pulse width modulation
- Trapezoidal pulse width modulation, etc.

From these PWM techniques it is observed that along with the voltage and frequency control, harmonic content present in the output voltage can also be controlled by employing different modulation techniques.

CIRCUIT DIAGRAM:

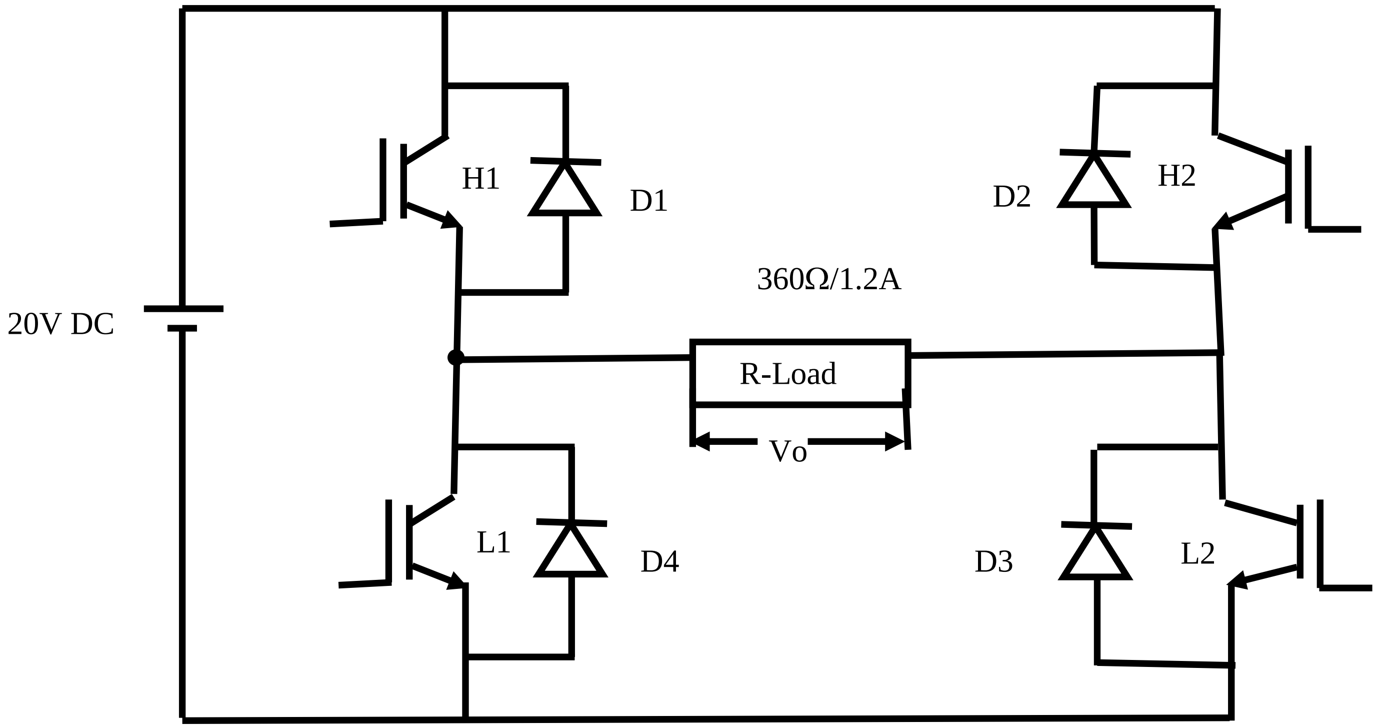


Fig.1:1- ø Full Bridge PWM inverter

PROCEDURE:

1. Switch ON 20 Volts DC supply to the IGBT power module.
2. Now M-00 blinks. Press INC key to set the duty cycle from 00-100%. Now press FRQ/DTY key. Now F-100 blinks. Now use INC and DEC key to increase or decrease the frequency from 20 Hz to 100 Hz.
3. After setting the duty cycle and frequency, press RUN/STOP key. Now the driver output pulses are available at outputs H_1, L_1, H_2 and L_2.
4. The duty cycle starts from 1 degree and slowly comes to the set duty cycle.
5. Press RUN/STOP key again, the driver outputs are come to OFF. Now set the modulation type to other type and check the outputs.
6. Now make the connections as given in the circuit diagram.
7. Connect DC supply from 30V/2A regulated power supply unit.
8. Connect a resistive load at load terminals.
9. Connect the driver output signals to the gate and emitter of corresponding IGBTs.
10. Switch ON the dc supply. Switch ON the driver outputs and observe the output voltage across the load for different modulation algorithms.

WAVE FORMS:

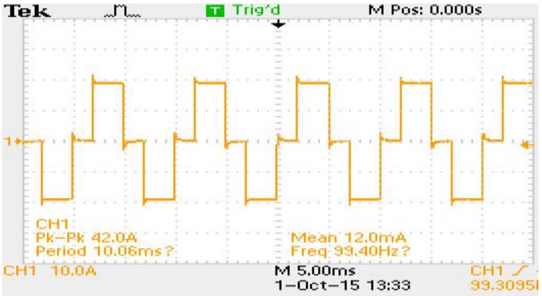


Fig. 3(a) Wave forms of Single PWM

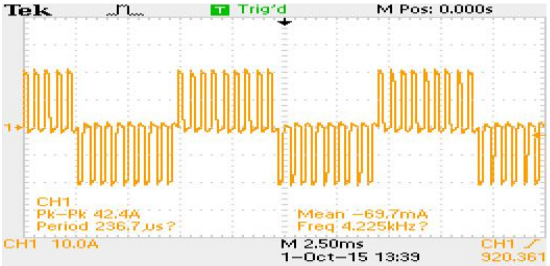


Fig. 3(b) Wave forms of Multiple PWM

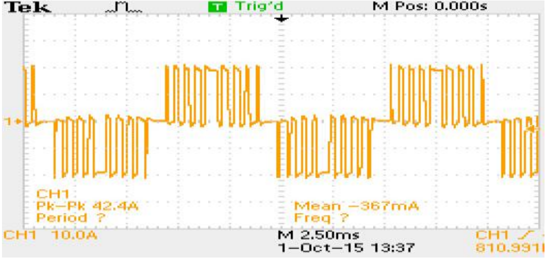


Fig.3 (c) Wave forms of Sinusoidal PWM WM

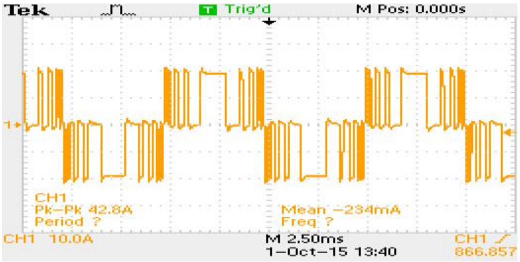


Fig. 3(d) Wave forms of Trapezoidal PWM

TITLE: SINGLE PHASE FULL BRIDGE PWM INVERTER
. **GPREC/DEEE/EXPT-PEL (P)-8**
Date: 17/01/2023

TABULAR COLUMN:

S.No	Type of PWM	Output Frequency	Modulation index	Output Voltage

RESULT: Output wave forms of voltage and current of 1-ϕ full bridge PWM inverter of with R Load are verified.

Viva questions

1. Define modulation index?
2. What is mean by PWM? Why PWM techniques are employed to inverters
3. What are the applications of inverters?
4. What are different PWM techniques?
5. Which type of power switches are used in inverters?

TITLE: FORCED COMMUTATED STEP DOWN CHOPPER

. **GPREC/DEEE/EXPT-PEL (P)-9**
Date: 17/01/2023

OBJECTIVE:

To verify the voltage wave forms of DC chopper or voltage commutated chopper with resistive load and compare the theoretical and practical values of output voltage and current.

APPARATUS:

DC chopper module, chopper firing circuit, rheostat, Ammeter, Voltmeter, DC supply, CRO, Connecting Wires.

THEORY:

A chopper is a static circuit that converts fixed DC voltage to a variable DC voltage. Chopper circuit involves one stage conversion, hence efficiency is high. Moreover the chopper circuit also offers smooth control and gives fast response. In choppers output voltage can be controlled by opening (OFF) and closing (ON) the semiconductor switch periodically. This turn ON and turn OFF is realized in two different strategies called constant switching frequency system and variable switching frequency system.

In constant switching frequency system ON-time (T_{on}) is varied but chopping frequency is constant (T). In variable switching frequency scheme chopping frequency is varied and either ON time (T_{on}) is kept constant or OFF time (T_{off}) is kept constant. In this experiment constant switching frequency system is employed for the control of output voltage.

The power semiconductor devices used for chopper circuit can be forced commutated thyristor, power BJT, Power MOSFET, IGBT. In this experiment thyristor is used as a switch and it is employed with commutation components. The thyristor commutation techniques uses resonant LC or under damped RLC circuits to force the anode current to zero. Primarily the classification of commutation techniques is based on the manner in which anode current is reduced to zero.

- Load commutation or class A commutation
- Resonant pulse commutation or class B commutation or current commutation
- Complementary commutation or class C commutation or voltage commutation
- Impulse commutation or class D commutation or voltage commutation
- External pulse commutation or class E commutation
- Line commutation or class F commutation

TITLE: FORCED COMMUTATED STEP DOWN CHOPPER

GPREC/DEEE/EXPT-PEL (P)-9
Date: 17/01/2023

In this experiment Class D or voltage commutation is discussed. The circuit diagram of step down chopper with thyristor employed with voltage commutation is shown In Fig.1. In the figure Thyristor T1 is commutated with the help of auxiliary thyristor (T2) and LC elements.

Initially Main thyristor T_1 and auxillary thyristor T_2 are off and capacitor is assumed charged to voltage V_s with upper plate positive. When T_1 is turned on, source voltage V_s is applied across load and load current Io begins to flow which is assumed to remain constant. With T_1 ON another oscillatory circuit consisting of C,T_1,D and L is formed. With the firing of T_2, a reverse voltage V_s is suddenly applied across T_1 forcing the anode current of T_1 to zero, thus commutating T1. Hence this method of commutation is called voltage commutation.

CIRCUIT DIAGRAM:

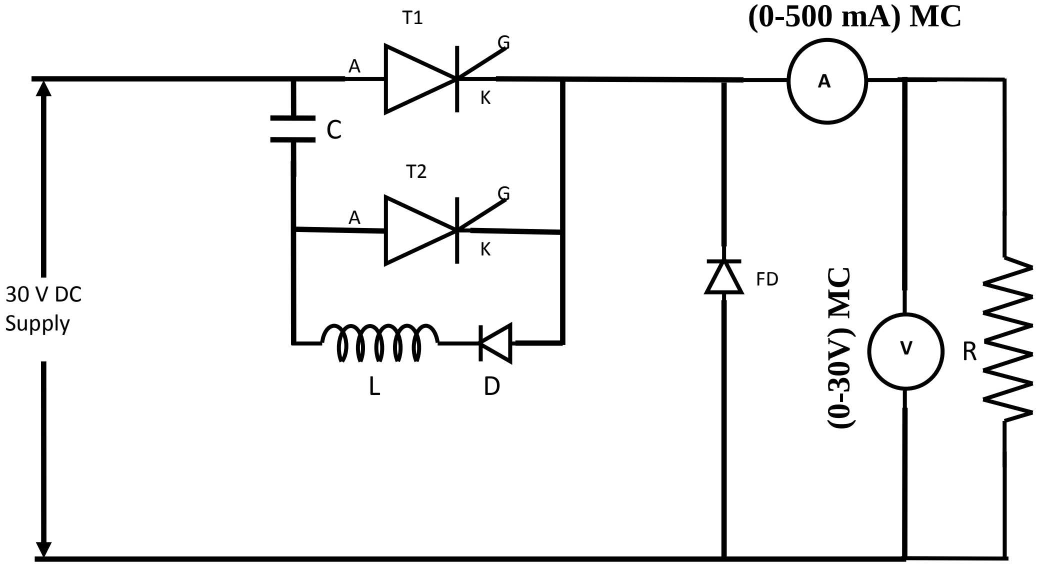


Fig.1 Voltage Commutated chopper with R-Load

TITLE: FORCED COMMUTATED STEP DOWN CHOPPER
. **GPREC/DEEE/EXPT-PEL (P)-9**
Date: 17/01/2023

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Connect the signals terminals of the chopper firing circuit to the SCRs in the chopper module.
3. Connect one channel of the oscilloscope to the input terminals and another channel to the output terminals.
4. Switch ON the power supply and note down output voltage and current by increasing the duty cycle in steps.
5. Draw the waveforms of input and output voltage on the graph sheet.

WAVE FORMS:

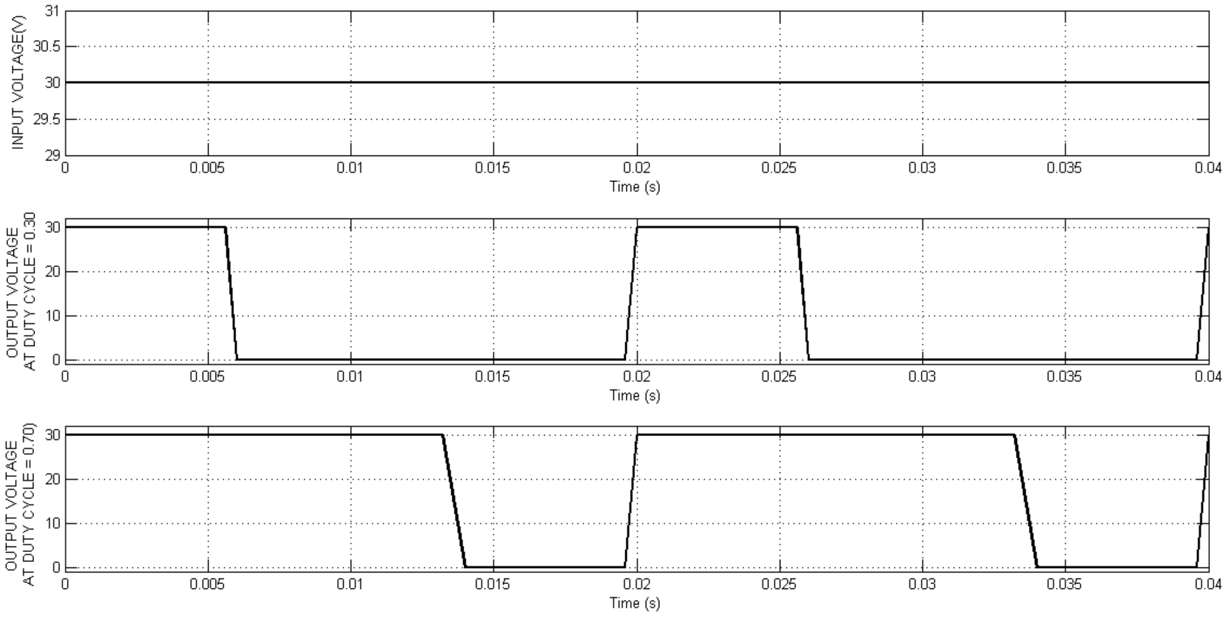


Fig.2 Wave forms voltage commutated chopper at different duty ratios

TITLE: FORCED COMMUTATED STEP DOWN CHOPPER

. **GPREC/DEEE/EXPT-PEL (P)-9**
Date: 17/01/2023

OBSERVATIONS:

Duty Cycle (α)	**Average output voltage (Vo) in volts**		**Average output current (Io) in Amperes**	
	Theoretical values	**Practical values**	**Theoretical values**	**Practical values**

FORMULAE USED:

$$V_o = \alpha V_s$$
$$\alpha = \frac{T_{on}}{T}$$
$$I_0 = \frac{V_0}{R}$$

RESULT:

The wave forms of DC chopper with Resistive load are observed and output voltage and average output current are measured and compared with theoretical values.

Viva questions

1. Define duty cycle?
2. What are different control strategies that are used choppers for the control of output voltage?
3. What are the applications of dc choppers?
4. What is mean by commutation? Why commutation need to be employed in choppers.
5. What is the relation between input voltage and output voltage in a step down chopper?

G. Pulla Reddy Engineering College (Autonomous): Kurnool
Department of Electrical & Electronics Engineering
B.Tech EEE – VI Semester (Scheme: 2020)
Power Electronics & Drives Laboratory (PEL (P))

TITLE: STEP UP CHOPPER

GPREC/DEEE/EXPT-PEL (P)-10
Date: 17/01/2023

OBJECTIVE:

To verify and compare theoretical and experimental results of Step up choppers.

APPARATUS:

SCR,SCR firing circuit,1:1 isolation Transformer, Rheostat, Inductor, Voltmeter, Ammeter, Connecting wires.

THEORY: Chopper is a basically static power electronics device which converts fixed dc voltage / power to variable dc voltage or power.

STEP UP CHOPPER:

Step up chopper or boost converter is used to increase the input voltage level of its output side. When switch is ON it short circuits the load. Hence output voltage during T_{ON} is zero or capacitor voltage. During this period inductor gets energized. So, $V_S = V_L$. When switch is OFF, inductor L discharges through the load. So, the output voltage is the sum of both source voltage V_S and inductor Voltage V_L**.** Hence output voltage is greater than $V_{S.}$

STEP DOWN CHOPPER:

Step down chopper or Buck converter is used to reduce the input voltage level at the output side. When switch is ON, $V_O = V_{S.}$ When switch is OFF, $V_O = 0$.but I_0 continues to flow in the same direction through freewheeling diode. Hence the average value of the output voltage is always less than the input voltage.

TITLE: STEP UP CHOPPER

GPREC/DEEE/EXPT-PEL (P)-10
Date: 17/01/2023

CIRCUIT DIAGRAM:

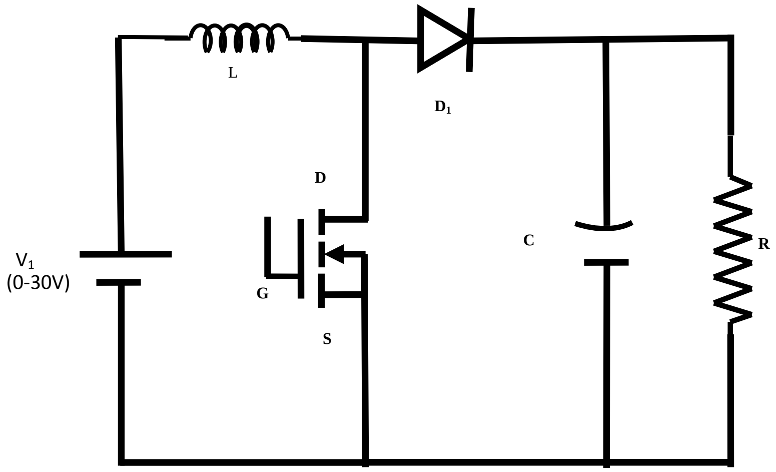


Fig.1 Step up chopper with R-Load

PROCEDURE:

1. Initially keep all the switches in the OFF position
2. Initially keep duty cycle POT in minimum position
3. Connect banana connector 24V DC source to 24V DC input.
4. Connect the driver pulse [output to MOSFET input
5. Switch on the main supply
6. Check the test point waveforms with respect to ground.
7. Vary the duty cyle POT and tabulate the Ton, Toff & output voltage
8. Trace the waveforms of Vo Vs & Io
9. Draw the graph for Vo Vs Duty cycle, K

TITLE: STEP UP CHOPPER

GPREC/DEEE/EXPT-PEL (P)-10
Date: 17/01/2023

FORMULAE USED:

$$V_0 = \frac{V_s}{1-k}$$

Where K is duty ratio. Ranges between 0 and 1.

TABULAR COLUMN

Vs = ____________ V

S.NO	T ON (sec)	TOFF (sec)	T (sec)	Duty Ratio, $k=T_{ON} / T$	Vo

RESULT:

Thus the output response of Step up MOSFET based chopper is analyzed.

Viva questions

1. Define duty cycle?
2. What are the applications of step up choppers?
3. What is the relation between input voltage and output voltage in a step up chopper?
4. What are semi conductor devices that can be used in choppers
5. Classification of choppers

G. Pulla Reddy Engineering College (Autonomous): Kurnool
Department of Electrical & Electronics Engineering
B.Tech EEE – VI Semester (Scheme: 2020)
Power Electronics & Drives Laboratory (PEL (P))

TITLE: R, RC and DIGITAL FIRING METHODS FOR SCR (1-Φ Half Wave Rectifier)
GPREC/DEEE/EXPT-PEL (P)-11
Date: 17/01/2023

3215OBJECTIVE:

To test the performance of R, RC and digital firing methods for SCR.

APPARATUS:

SCR,SCR firing circuit, R & RC module ,1:1 isolation Transformer, Rheostat, Inductor, Voltmeter, Ammeter, Connecting wires

THEORY:

Firing methods (or) triggering methods are nothing but the turn ON methods of SCR. When anode is positive with respect to cathode a thyristor can be turned ON (can be changed from forward blocking to forward conduction) by following methods

I. Forward voltage triggering
II. Gate triggering
III. dv/dt triggering
IV. temperature triggering
V. light triggering

Turning ON the thyristor by gate triggering is simple, reliable and efficient; it is therefore the mostly usual method of firing the thyristor. In gate triggering method thyristor is turned ON by applying a positive gate voltage between gate and cathode. This positive gate voltage can be generated by using Analog and digital circuits. Such circuits are called as analog and digital firing circuits.

Analog firing methods:

- **R-Triggering:**

  Resistance firing circuits are simplest and most economical firing circuits for SCR's. The Fig. 1 shows most basic resistance triggering or firing circuit. Here the resistance (R1) is the variable resistance. In case R1 is zero gate current should not exceed maximum permissible gate current (I_{gm}). Hence R2 is therefore connected in series with R1 and it can be found from relation

  $$R2 \geq \frac{V_m}{I_{gm}}$$

  Where V_m is maximum value of source voltage
  I_{gm} is the maximum permissible gate current.

  R3 is the stabilizing resistance and should have such a value that maximum voltage drop across it does not exceed maximum possible gate voltage (V_{gm}). This can happen only when R1 is zero. Under this condition R3 can be found from the relation

$$R3 \leq \frac{R2\,V_{gm}}{V_m - V_{gm}}.$$

As the resistance R1 and R2 are large gate triggering circuit draws a small current. Diode D allows the flow of current during positive half cycle only. Though the circuit is simple and economical it suffers from limited range of firing angle control (0^0 to 90^0).

- **RC-Triggering:**

The limited range of firing angle control can be overcome by RC firing circuit. Fig.2 illustrates RC half wave triggering circuit. The circuit uses variable resistance, capacitance and pair of diodes. The variable resistance is used to vary the firing angle (charging time of capacitor voltage. i.e gate cathode voltage). Diode D1 is used to prevent break down of gate cathode junction through D2 during negative half cycle. Diode D2 is used to discharge capacitor at a faster rate during negative half cycle.

The SCR will be triggered when $V_c = V_{gt} + V_{d1}$

Where V_{gt} is gate triggering voltage

V_{d1} is voltage drop across diode D1.

For triggering the current I_{gt} must be supplied by the voltage source through R, D1 and gate to cathode circuit. Hence the maximum value of R is found from the relation

$$R \leq \frac{V_s - V_{gt} - V_d}{I_{gt}}$$

With this RC triggering the firing angle can be controlled from 0^0 to 180^0 but can never be zero and 180^0.

- **Digital firing circuit:**
  - Firing angle can be varied smoothly from 0^0 to 180^0 by using SCR firing circuit.
  - SCR firing circuit is protected by snubber circuit inside the SCR firing circuit box.

TITLE: R, RC and DIGITAL FIRING METHODS FOR SCR (1-Φ Half Wave Rectifier)

GPREC/DEEE/EXPT-PEL (P)-11
Date: 17/01/2023

CIRCUIT DIAGRAM:

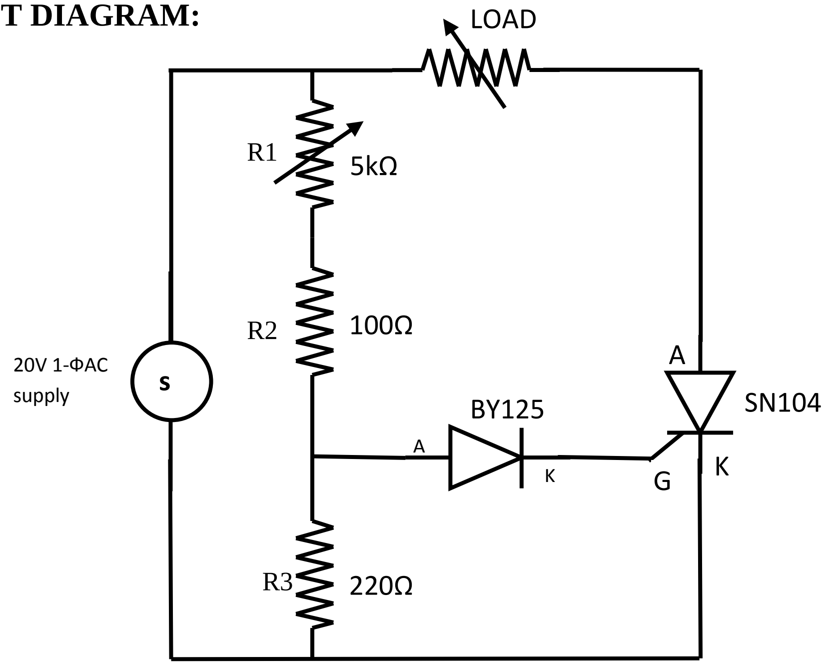


Fig.1 R-triggering circuit (analog) employed SCR (1-ϕ half wave rectifier)

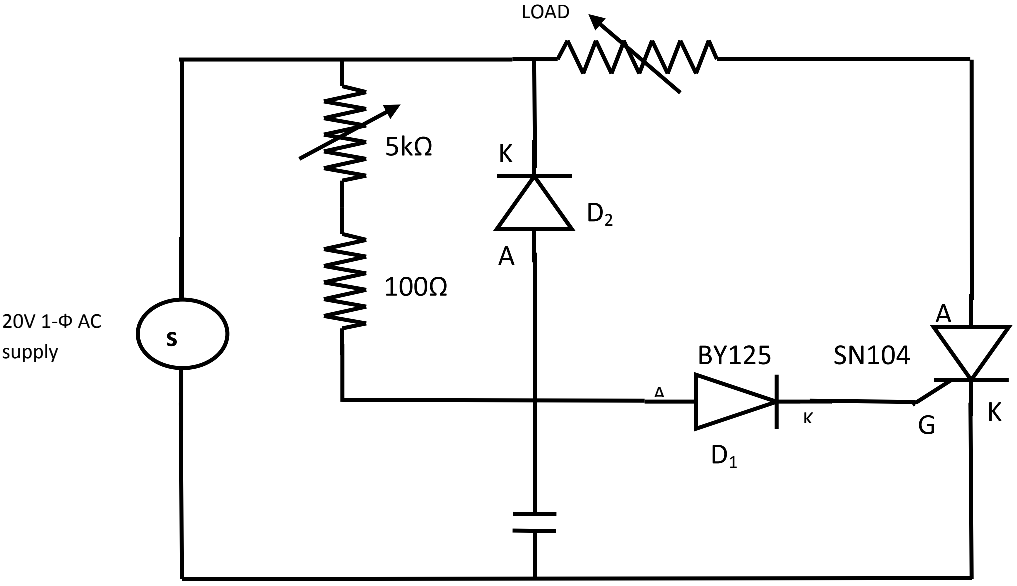


Fig.2 RC-triggering circuit (analog) employed SCR (1-ϕ half wave rectifier)

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Keep the load resistance in maximum position.
3. Vary the variable resistance (R1) in steps from minimum position to maximum position and note down the output voltage and current.
4. Draw the waveforms of input and output voltages on the graph sheet.

WAVE FORMS:

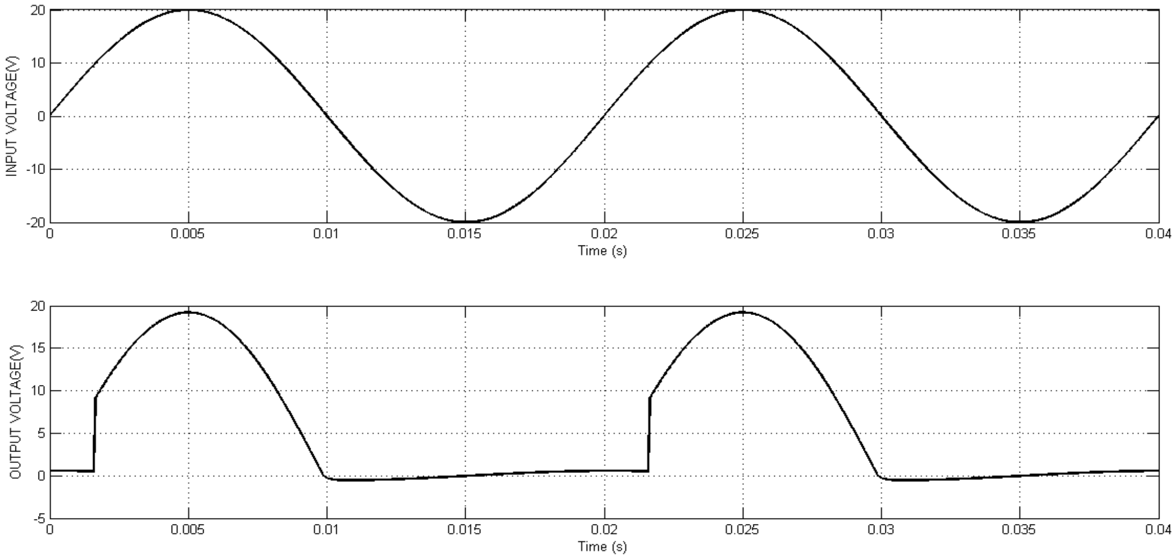


Fig.3 Wave forms R-triggering circuit employed SCR (1-ϕ half wave rectifier)

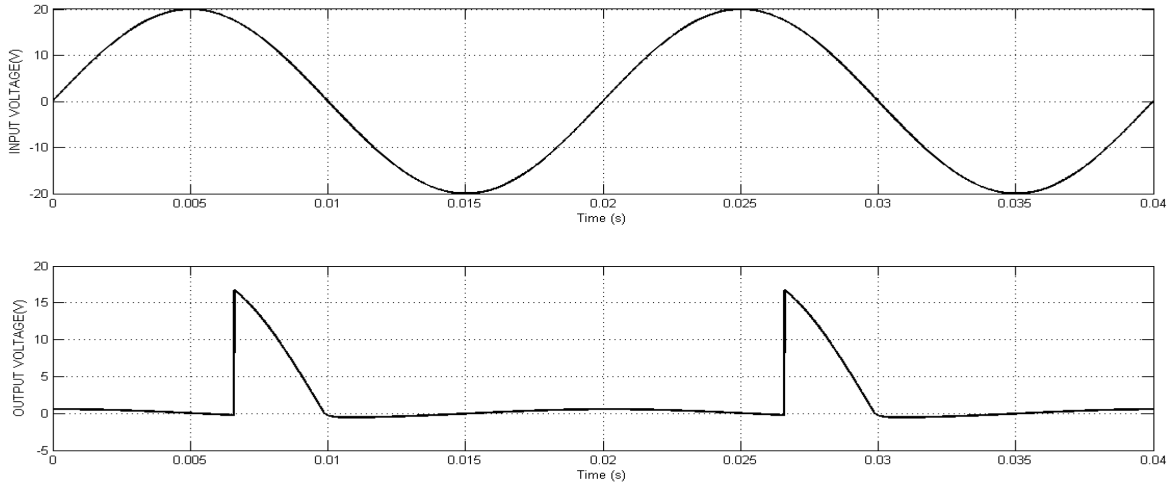


Fig.4 Wave forms 1-Φ RC-triggering circuit employed SCR (1-ϕ half wave rectifier)

CIRCUIT DIAGRAM:

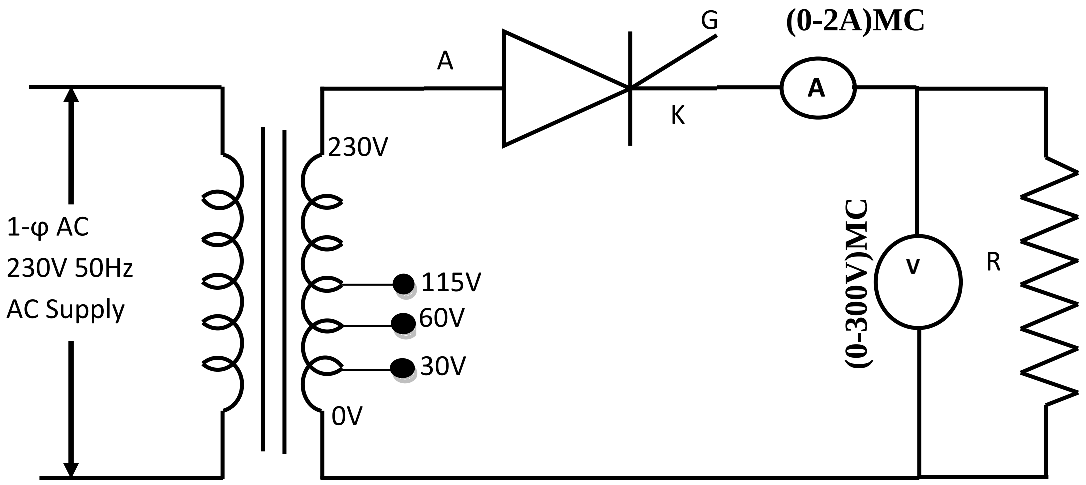


Fig.5 Digital firing circuit for SCR (1-Φ Half wave rectifier R-Load)

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Connect 30V tapping of the isolation transformer secondary to the input terminals of the power module initially.
3. Connect the gate signal terminals of the digital firing circuit to the gate and cathode of SCR.
4. Connect one channel to the oscilloscope to the input terminals and another channel to the output terminals.
5. Switch ON the power supply and observe the wave forms.
6. Now switch OFF the supply and connect 230V tapping of the isolation transformer to the input terminals of the power module.
7. Switch ON the power supply and note down average output voltage and current by changing the firing angle insteps.
8. Draw the waveforms of input and output voltages along with the gate pulse of the SCR on the graph sheet.

WAVE FORMS:

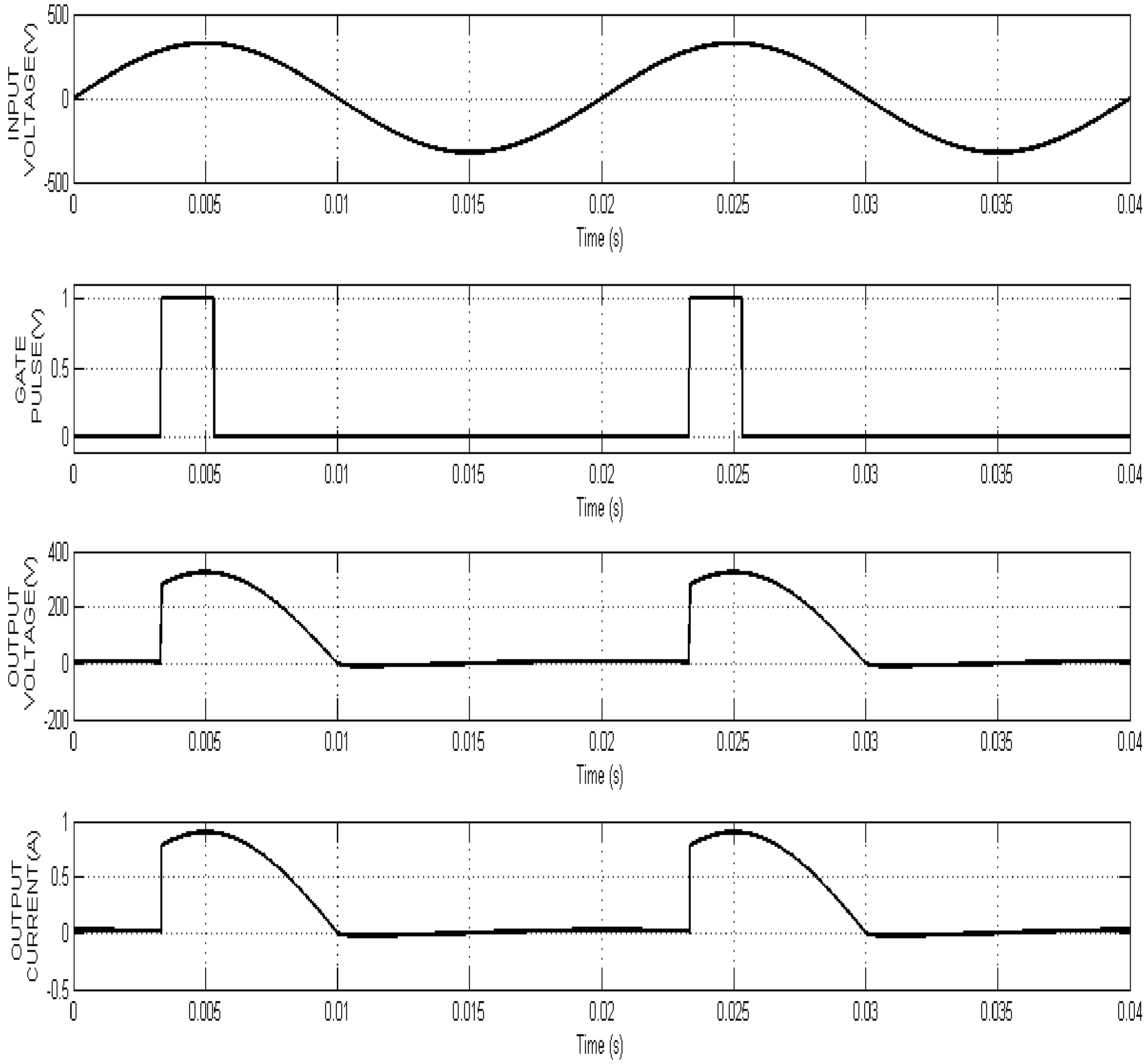


Fig.6 Wave forms for digital firing circuit of SCR (1-Φ Half wave rectifier R-Load)

TITLE: R, RC and DIGITAL FIRING METHODS FOR SCR (1-Φ Half Wave Rectifier) **GPREC/DEEE/EXPT-PEL (P)-11**
Date: 17/01/2023

OBSERVATIONS:

Input voltage	Firing Angle (α)	Average output voltage (Vo) in volts		Average output current (Io) in Amperes	
		Theoretical values	Practical values	Theoretical values	Practical values

FORMULAE USED:

For R-Load

$$V_{o\ avg} = \frac{1}{2\pi}\int_{\alpha}^{\pi} V_m \sin(\omega t)\, d(\omega t) = \frac{V_m}{2\pi}(1 + cos\alpha) \qquad I_{O\ avg} = \frac{Vo_{\ avg}}{R}$$

RESULT:

The theoretical and experimental output wave forms and values of voltage and current of 1-ϕ half wave rectifier using analog and digital firing methods with R Load are verified.

Viva questions:

1. What is the maximum firing angle of R-triggering circuit and why?
2. What is the maximum firing angle of RC-triggering and why?
3. In R-triggering circuit why is R_{min} is connected in series with variable resistor?
4. What are different firing circuits used for turning on of SCR?
5. What are the advantages of digital firing circuit over analog firing circuit?

G. Pulla Reddy Engineering College (Autonomous): Kurnool
Electrical & Electronics Engineering Department
B.Tech EEE – VI Semester (Scheme: 2020)
Power Electronics & Drives Laboratory (PEL (P))

Title: Static Kramer Drive (Speed Control of Induction Motor Using EMF Injection Method)	**GPREC/DEEE/EXPT-PEL (P)-12** **Date: 17-01-2023**

Objective: To control the speed of the three-phase slip ring induction motor using EMF injection method.

Circuit Diagram:

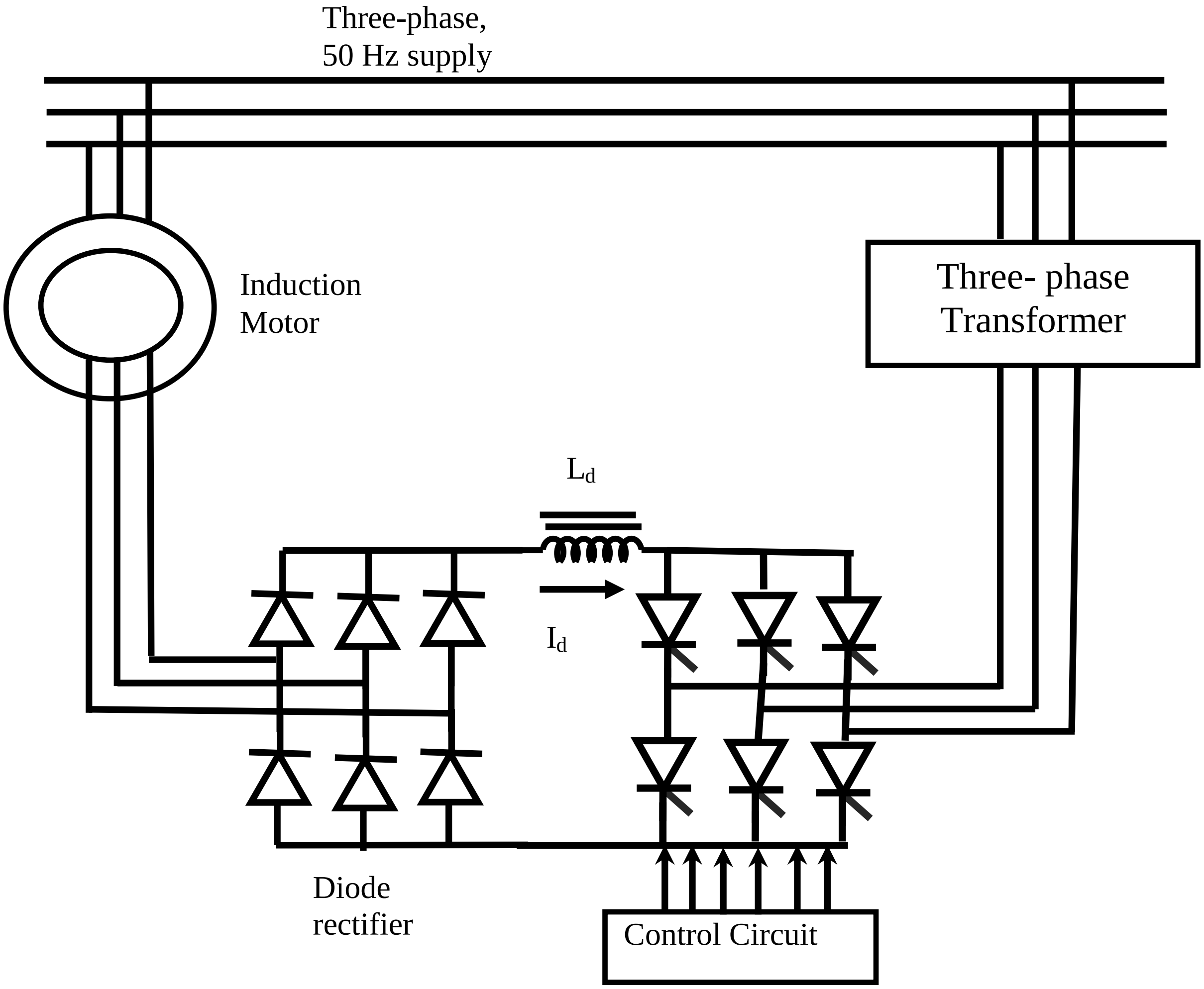


Fig 1. Static Kramer Drive

Apparatus:

Name	**Type**	**Numbers Required**
3-phase slip-ring induction motor		1
PEC16HV10B module		1
3-phase autotransformer		1
3-phase isolation transformer		1
Rheostat (150 ohm/5A)		1
Inductor (150 mH)		1
Tachometer	Digital	1
Multimeter	Digital	1
Connecting wires		required
Patch cards		required

Theory:

Compared to squirrel cage induction motor, the slip ring induction motor has number of disadvantages, such as high cost, weight, volume and inertia and frequent maintenance due to the presence of brushes and slip rings. However, the control of a slip ring induction motor from rotor allow cheaper drives suitable for few applications. Rotor side control methods vary the slip power for the speed control. The portion of air gap power which is not converted in to mechanical power is called slip power. Slip power control methods regulate the amount of slip power. Hence for a given air gap power, the power converted in to mechanical power is altered. Consequently the speed for a given torque is changed.

As discussed power delivered to the rotor across the air gap (P_{ag}) is equal to sum of the mechanical power (P_m) delivered to the load and the rotor copper loss (P_{cu}).

$$P_{ag} = P_m + P_{cu} \qquad (1)$$

The air gap flux of the machine is established by the stator supply and it remains practically constant. The speed of induction motor can be controlled by varying the amount of mechanical power delivered. This can be achieved by increasing the rotor copper losses. This method of speed control is called rotor resistance control. The main drawback of the rotor resistance control system is large slip power is dissipated in the external resistance connected to the rotor and this reduces the efficiency of the motor at low speeds.

Without connecting any external resistance to rotor, when compared to total air gap power rotor copper losses will be very small. In such situations if rotor copper losses are neglected then equation (1) can be written as

$$P_{ag} = P_m \qquad (2)$$

At this condition mechanical power is equal to air gap power. Now to vary the speed, mechanical power need to be varied. This can be achieved by injecting voltage into the rotor circuit. Such method is called emf injection method. This emf injection or voltage injection can be achieved by Static Kramer system and scherbius system. When a voltage is injected to the rotor circuit the equation (2) can changed as.

$$P_m = P_{ag} - P_r \qquad (3)$$

Where P_r is the power absorbed or dissipated by the voltage source connected to the rotor circuit. The magnitude and sign of P_r can be controlled by controlling magnitude and phase of voltage source connected to the rotor. When P_r is zero motor runs at natural speed. A positive P_r (voltage source connected to rotor act as sink) will reduce P_m and therefore motor will run at reduced speed. Thus by varying P_r from 0 to P_{ag} will allow speed control from synchronous speed to zero speed. When P_r is negative (Voltage source connected to rotor act as source of power) P_m will be larger than P_{ag} and the motor will run at a speed higher than synchronous speed.

In the static Kramer system power P_r can be controlled by controlling the inverter firing angle. The relation between slip and firing angle in Static Kramer system may be derived as

$$s = \left| -\cos\alpha \right|$$

Procedure:

1. Connect the 3-phase input supply to the AC input terminals of the module through an isolation transformer or autotransformer.
2. Connect the motor stator terminals to the R, Y, B terminals of the module.
3. Connect the slip-ring induction motor rotor terminals to the u, v, w terminals of the module.
4. Connect the secondary R, Y, B terminals to the transformer secondary terminals.
5. Connect the primary R, Y, B terminals to the transformer primary terminals.
6. Connect the PULSE OUTPUT from the pulse transformer to the PULSE INPUT of the power circuit through the cable.
7. Switch ON the 3-phase ac power supply to the power module.
8. Switch ON the MCB provided on the left side of the module.

9. Check for the waveforms at each test points. Now the motor starts to rotate.
10. Switch ON the MCB provided on the right side of the module.
11. Vary the firing angle of the inverter using the 90^o to 180^o varying pot provided on the front panel of the module.
12. Note down the motor speed values for every firing angle and plot it down on a graph.

Observations:

S.No	**Firing angle (degrees)**	**Speed (rpm)**

Result: Speed control of slip ring induction motor using emf injection is done.

Remarks in Any:

VIVA QUESTIONS

1. **What are different speed control methods for an induction motor and which type is used in this experiment.**

Ans.

Stator side control methods
- Stator voltage control
- Stator frequency control
- Stator v/f control

Rotor side control Methods
- **Slip Power recovery schemes**
  - Rotor resistance control
  - EMF injection method

EMF injection method is used in this experiment.

2. **Name the methods used for speed control of induction motor using emf injection method?**

Static scherbius drive scheme for above and below synchronous speed
Static Kramer drive scheme for below synchronous speed.

3. **What are advantages and disadvantages of rotor resistance control?**

Advantages: Wide range of speed can be controlled.
Low converter cost (converter power rating is low because of its connection to rotor side).

Disadvantages: Poor power factor.

4. **Write the relation between speed or slip and firing angle in slip power recovery scheme**

Ans. $S=|-\cos\alpha|$ α is varied from 90^0 to 180^0

5. **As compared to squirrel cage induction motor, a wound rotor induction motor is preferred when the major consideration is**

Ans: High starting torque, Low windage losses and slow speed operation.

6. **What is the maximum value of firing angle for safe commutation of thyristors?**

⊐165^0

G. Pulla Reddy Engineering College (Autonomous): Kurnool
Electrical & Electronics Engineering Department
B.Tech EEE –VII Semester (S-17)
Power Electronics & Drives Laboratory (PEL (P))

Title: Three Phase Fully controlled rectifier/ Chopper fed DC Motor Drive	**GPREC/DEEE/EXPT-PEL (P)-13** **Date: 17/01/2023**

Objective: To control the speed of the permanent magnet DC motor drive using 3-phase fully controlled bridge rectifier or DC chopper.

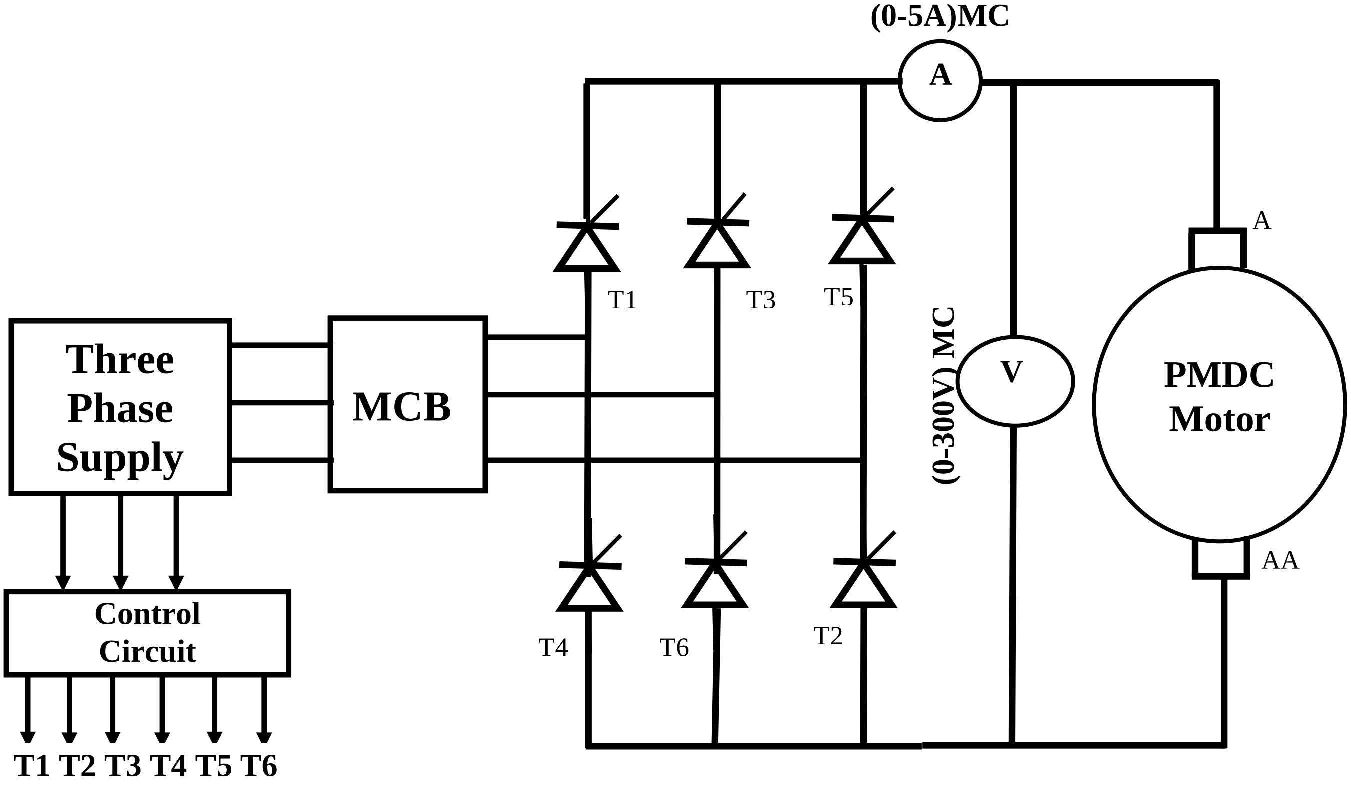


Fig 1. Three phase rectifier fed permanent magnet DC motor

Prepared by: Dr. M. Harsha Vardhan Reddy, Associate Professor

Approved by: Dr. K. Sri Gowri, HOD, EEE Dept

Revision No.: 0

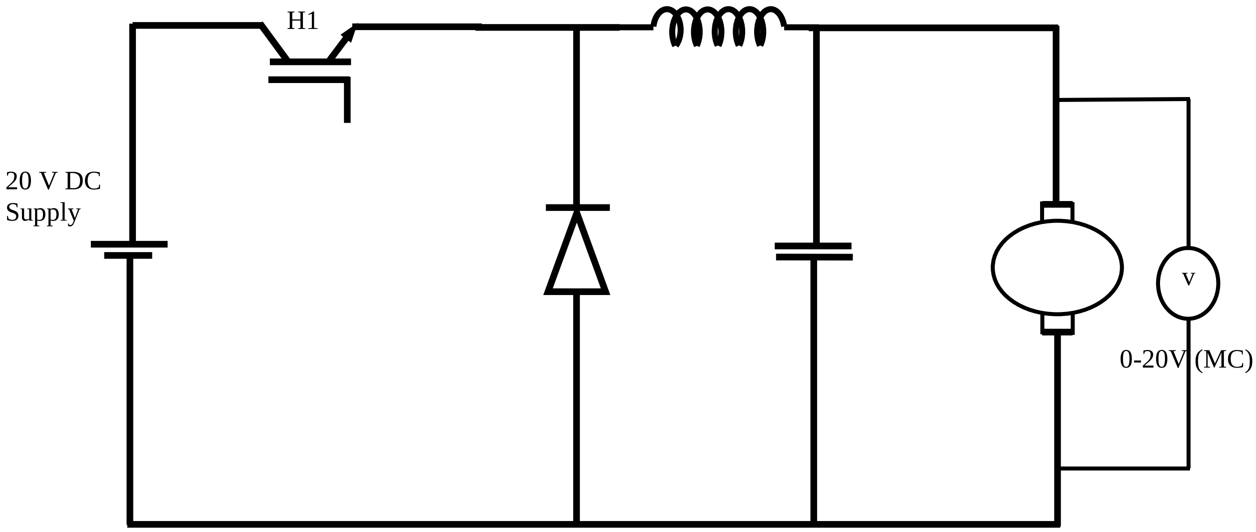


Fig 2. DC chopper fed permanent magnet DC motor

Apparatus:

Name	**Type**	**Numbers Required**
PMDC Motor		1
3-phase isolation transformer		1
IGBT based PWM module		1
Firing circuit		1
Patch cards		required
Tachometer		1
Multimeter		1
Connecting wires		required

Theory:

The torque speed relation in a DC motor can be written as

$$\omega_m = \frac{V_a}{K_a\phi} - \frac{T_e R_a}{(K_a\phi)^2} \qquad (1)$$

From equation (1) three methods of speed controls are possible by varying

- The applied armature voltage (V_a)
- The resistance in the armature circuit (R_a)

- The flux(ϕ)

In this experiment armature voltage control method is employed for the speed control of permanent magnet DC (PMDC) motor. As the considered motor is PMDC motor field flux remains constant ($K_a\phi = K$). Hence equation (1) can be modified as

$$\omega_m = \frac{V_a}{K} - \frac{T_e R_a}{(K)^2} \qquad (2)$$

For the equation (2) it is observed that speed of PMDC motor can be controlled by varying the armature voltage (V_a). This armature voltage can be varied by using a single phase or three phase controlled rectifier by connecting it between load (PMDC motor) and supply. The controlled rectifier converts fixed AC voltage to variable DC voltage. By varying the firing angle of the converter, variable DC voltage is obtained. Because of advantages like high DC output voltage, high ripple frequency three phase rectifiers are preferred over single phase rectifiers. Semi converter and full converter are the mostly preferred and commonly used converters for all practical applications. In this experiment full converter fed PMDC motor is considered. Assuming continuous conduction mode of operation the relation between output voltage (armature voltage) and firing angle is by (3).

$$Va = \frac{3V_{ml}}{\pi}\cos\alpha \qquad (3)$$

V_{ml} = Peak value of the input line voltage.

α= Firing angle.

From equation (3) it is observed that by varying the firing angle between 0^0 to 180^0 armature voltage is controlled. Hence the speed of PMDC motor is also controlled.

The three phase full converter is a two quadrant converter. Using this we can operate the PMDC motor in first (forward motoring) and fourth (reverse braking) quadrant operation. If sufficient and large inductance is connected in series with the load or any sufficient mechanical energy is provided the PMDC motor operates in first quadrant from 0^0 to 90^0 and fourth quadrant from 90^0 to 180^0.

With discontinuous mode of operation in 0^0 to 90^0 the PMDC motor operates in motoring mode of operation.

From the equation (2) it is also observed that speed of PMDC motor is controlled by varying the armature voltage (V_a). As the available voltage source is DC, choppr can be used for the variation of armature voltage. The chopper used in this experiment is four quadrant chopper. The appropriate control signals are programmed in a micro controller. By varying the duty cycle of the control signals output voltage of the chopper is controlled. The relation between input and output voltage of a chopper is given by (4)

$$V_a = \delta V_{dc}$$
$$where\ \delta = \frac{T_{on}}{T} = duty\ cycle \qquad (4)$$

Title: Three Phase Fully controlled rectifier/ Chopper fed DC Motor Drive **GPREC/DEEE/EXPT-PEL (P)-13**
Date: 17/01/2023

Procedure:

For three phase fully controlled bridge rectifier fed DC motor Drive

1. Check all the SCRs for performance before making the connections.
2. Connect 3-phase, 400 V ac supply to the R Y B (3-phase terminals) provided in the front panel of firing circuit for phase synchronization. Connect 3-phase neutral point to the green terminal provided in the back panel.
3. Switch ON the 3-phase supply to the firing unit and observe the R Y B test signals with respect to the ground. If the proper neutral point is connected to the back panel we can observe clear R Y B signals with 15 V amplitude.
4. Connect firing pulses from the firing circuit to the respective SCR's gate and cathode.
5. Connect the 3-phase AC input to the power circuit preferably through 3-phase isolation transformer (connect the primary in delta and secondary in star)
6. Initially set the input AC voltage to 60 V, switch ON the firing circuit. Vary the firing angle potentiometer and observe the voltage waveforms across the load.
7. If the bridge output is coming properly, switch OFF the MCB, connect the separately excited DC motor between load points and increase the input voltage to rated voltage.
8. Switch ON the MCB, switch ON the trigger outputs and note down the output voltage, output current and speed for different firing angles.

For DC chopper fed DC motor Drive

1. Using connecting wires connections are made as per the circuit diagram.
2. Using patch cards connect control signals to gate and emitter terminals of corresponding IGBT's.
3. Switch ON 20 volts DC supply to the power module.
4. Duty cycle is varied step by step from 0% to 100% in forward direction.
5. The corresponding speed of DC motor is measured using tachometer and the voltage is measured using multimeter and tabulated.

Observations:

S.No	Firing angle (α) / Duty cycle	Output voltage(V)	Output current(A)	Speed (rpm)

Result: Speed control of PMDC motor using three phase rectifier/ chopper is done.

Remarks in Any:

VIVA-QUESTIONS:

1. **What are different speed control methods for an DC motor which type is used in this experiment.**

Ans. The armature voltage control (V_a)

Filed voltage control or flux (ϕ)

For permanent magnet DC motor (PMDC motor) field flux is constant and hence field voltage cannot be controlled. Hence armature voltage control is used.

Armature voltage control method is used in this experiment.

2. **Give the relation between speed and torque in a three phase full controlled rectifier fed PMDC drive?**

$$\omega_m = \frac{V_a}{K_a\phi} - \frac{T_e R_a}{(K_a\phi)^2} \quad \text{and } Va = \frac{3V_{ml}}{\pi}\cos\alpha$$

3. **Draw the speed torque characteristics of DC motor with armature voltage control.**

4. **What are the advantages of three phase rectifier fed DC drives over single phase rectifier fed DC drives?**

High power rating of the drive system, size and cost of the filters are reduced, input power factor is improved and efficiency of the drive is improved.

5. **What are different types of braking methods for DC Motor?**

Ans: Regenerative braking, Dynamic braking and Plugging.

G. Pulla Reddy Engineering College (Autonomous): Kurnool
Electrical & Electronics Engineering Department
B.Tech EEE –VII Semester (S-17)
Power Electronics & Drives Laboratory (PEL (P))

Title: V/f controlled induction motor Using dSPACE 1104 kit	**GPREC/DEEE/EXPT-PEL (P)-14** **Date: 17/01/2023**

Objective: To implement the sinusoidal pulse width modulation algorithm using dSPACE kit for the V/f (scalar) control of DC-link converter fed induction motor drive.

Circuit diagram:

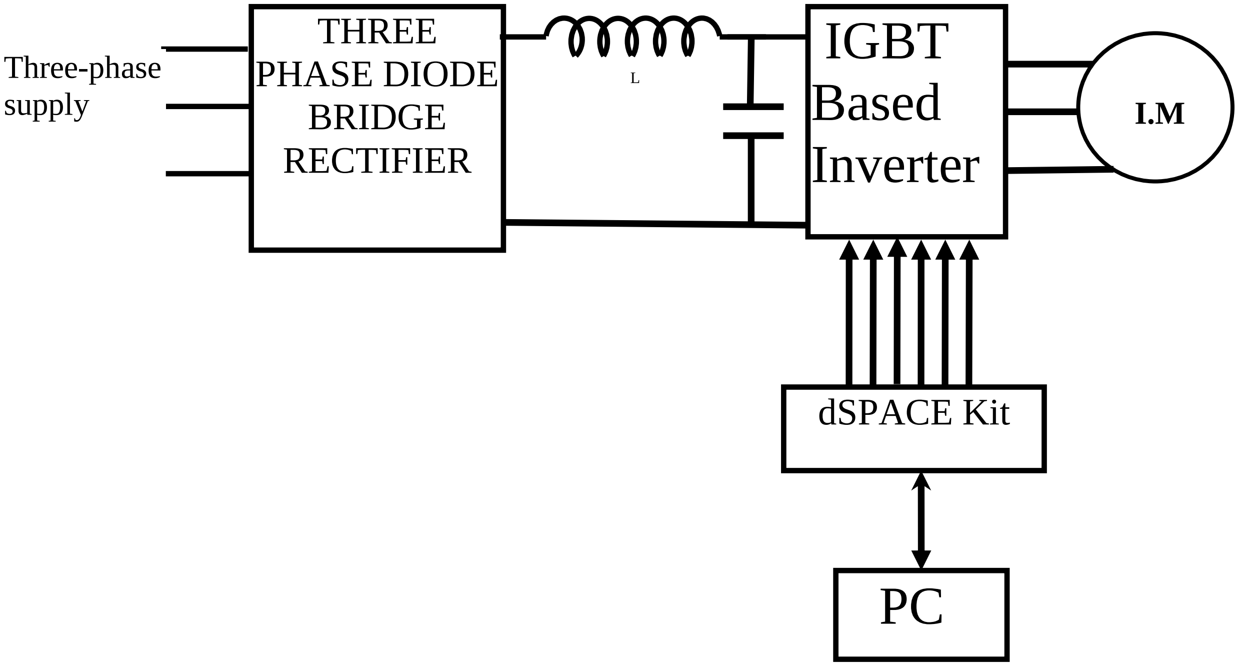


Fig. 1 DC link converter fed induction Motor drive controlled from dSPACE 1104 kit

Apparatus:

Name	**Type**	**Numbers Required**
DC-Link converter		1
Induction Motor		1
Patch cards		required
Multimeter		1
Connecting wires		required
dSPACE control board		1
current and voltage sensors		1
DSO		1

Theory:

The speed- torque relation in induction motor is given by equation (1)

$$Te = \frac{3}{2\pi f}\frac{V^2 R'_r / s}{(R_s + R'_r / s)^2 + (X_s + X'_r)^2} \quad (1)$$

From equation (1) it is observed that speed of squirrel cage induction motor can be controlled by controlling.

(a) Stator voltage (V)
(b) Stator frequency (f)
(c) Stator voltage and frequency control.

In this experiment focus is given on V/f control of induction motor drive. To convert fixed AC power to variable AC power, different converter configurations can be used.

(a)AC voltage controller
(b) Cycloconverter
(c) DC-link converter

AC voltage controller converts fixed AC voltage (power) to variable AC voltage (power) but frequency is maintained constant. So for V/f control AC voltage contoller cannot be used. Cycloconverter converts fixed AC voltage to variable AC voltage and variable frequency. With cycloconverter smooth variation in voltage is possible but smooth variation in frequency is not possible. Hence wide range of speed control with constant air gap flux is not possible. Moreover, as phase control principle is employed in both the converters (AC voltage controller and cycloconverter), for low output voltages the converters draws poor input power factor.

DC-link converter can overcome both these drawbacks. DC-link converter is employed with uncontrolled rectifier at its front end and a PWM inverter at its back end. Uncontrolled rectifier converts fixed AC voltage and frequency to fixed DC voltage. This constant DC voltage is converted to variable AC voltage with variable frequency using PWM inverter. As uncontrolled rectifier is employed, better input power factor is maintained. With PWM inverter smooth variation in voltage and frequency is possible.

The control signals for PWM inverter are generated using dSPACE 1104 control board. The pulse pattern or control signals are designed in MATLAB Simulink. MATLAB software is interfaced with dSPACE control board using PCI slots on mother board of CPU. The MATLAB code is converted in to suitable high level language code of the processor embedded in dSPACE control board. In the MATLAB code itself, we need to assign the appropriate port numbers to the control signals.

The sinusoidal pulse width modulated control signals are generated through MATLAB. In this modulation method several pulses for half cycle are present and pulse width of each pulse varies in a sinusoidal fashion. These control signals are generated by comparing three reference signals with common high frequency carrier signals. The intersection point of reference signals with carrier signals defines the switching instants. The output voltage of inverter is controlled varying the amplitude of reference signal and output frequency is controlled by changing the frequency of reference signals. Number of pulses per half cycle can be varied by changing the switching frequency or carrier signal frequency. As number of pulses per half cycle is increased lower order harmonics in the output voltage are reduced.

Procedure:

1. Connect the dspace kit to the personal computer.
2. Connect the 3-φ supply to the power module through 3-φ isolation transformer
3. Connect the 3-φ Induction motor to the UVW terminals of the power module.
4. Open the dspace control desk and open the MATLAB.
5. Write coding or design a Simulink model to generate control signals (Sinusoidal PWM). For simulation file give the approximate configuration parameters (start time =0 sec, stop time=inf, select the real time workshop system target file as rfil and build the program.
6. After the computation of build process, check the pulses in oscilloscope and connect the pulse outputs to the appropriate terminals in the power circuit.
7. Switch on the 3-φ main supply and MCB of power module.
8. Slowly increase the input voltage by using auto transformer to get a DC voltage of about 510V. Now it can be observed that the induction motor starts to rotate.
9. Observe the performance of induction motor drive at various modulation indicies.
10. Observe the line current and line voltage plots in DSO using current and voltage sensors.

Result: Sinusoidal Pulse Width Modulation algorithm is implemented using MATLAB based dSPACE control board for the speed control of DC link inverter fed induction motor drive.

REMARKS IF ANY:

VIVA QUESTIONS:

1. **What are different speed control methods for an induction motor and which type is used in this experiment.**

Ans.

Stator side control methods
- Stator voltage control
- Stator frequency control
- Stator v/f control

Rotor side control Methods
- **Slip Power recovery schemes**
  - Rotor resistance control
  - EMF injection method

Stator V/f control method is used in this experiment.

2. **Write the relation between speed and torque in an induction motor.**

$$T_e = \frac{3}{\omega_{ms}} \frac{V^2 R'_r / s}{(R_s + R'_r / s)^2 + (X_s + X'_r)^2}$$

3. **Draw the speed torque characteristics of induction motor with variation of V/f control.**

4. **What are different converters that are used for the V/f control?**

Cycloconverter and DC-link converter

Smooth variation in frequency is not possible with cycloconverter (Only step variation in frequency). Hence DC-link converter is used in this experiment for V/f control of induction motor.

5. **Write different operating methods in an inverter.**

180^0 Mode of operation
120^0 Mode of operation
PWM mode of operation

In this experiment PWM control of inverter is used for v/f control of induction motor.

G. Pulla Reddy Engineering College (Autonomous): Kurnool
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B.Tech EEE – VI Semester (Scheme: 2020)
Power Electronics & Drives Laboratory (PEL (P))

TITLE: SIMULATION OF POWER ELECTRONIC CONVERTER

.
GPREC/DEEE/EXPT-PEL (P)-15
Date: 17/01/2023

Objective: To simulate different power electronic converters like rectifier, inverter chopper using MATLAB simulink.

Simulation Circuit diagram:

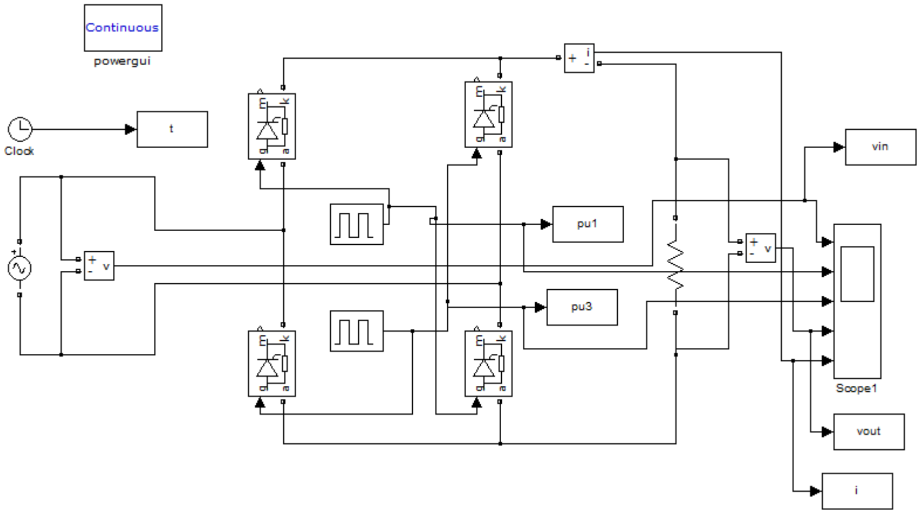


Fig.1 Single phase full bridge rectifier

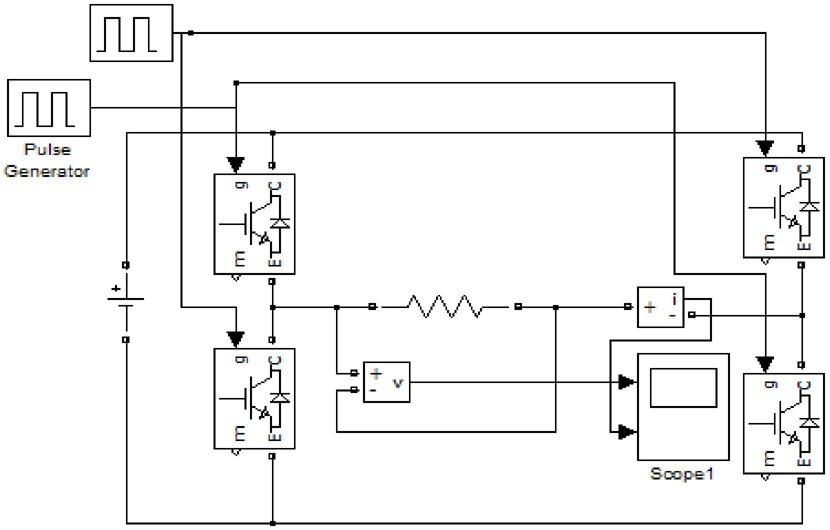


Fig.2 Single phase full bridge inverter

TITLE: SIMULATION OF POWER ELECTRONIC CONVERTER
. **GPREC/DEEE/EXPT-PEL (P)-15**
Date: 17/01/2023

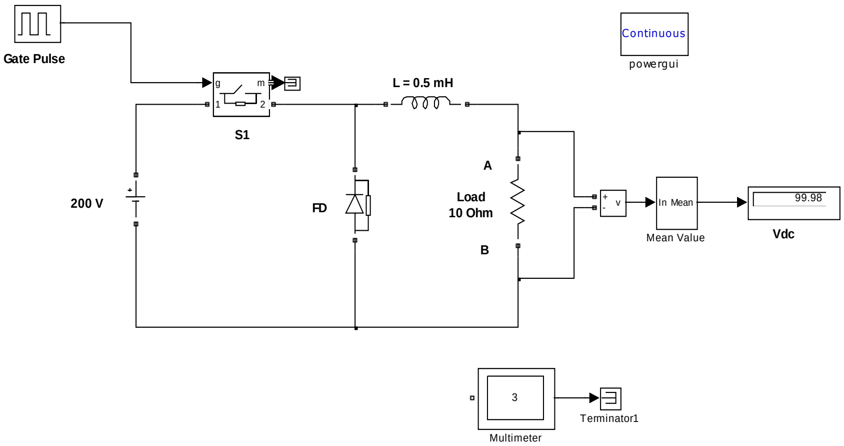


Fig.3 Step down chopper

Apparatus:

Name	Type	Numbers Required
MATLAB Software	2009A	1

Procedure:

1. Open the Model file from the MATLAB main window.
2. From the simulink library browser drag and place the required components on to the model window.
3. The required blocks needed for the experiment are available in the simpower systems and sumulink tool boxes.
4. Connect all the components to form the required circuit.
5. Set the model parameters and configuration parameters.
6. Save and execute the model file.
7. Observe the results.

Result: Simulation of different power electronic converters were performed and results were verified.

TITLE: SIMULATION OF POWER ELECTRONIC CONVERTER
. **GPREC/DEEE/EXPT-PEL (P)-15**
Date: 17/01/2023

SIMULATION PARAMETERS For Rectifier:

AC voltage source:

Peak Amplitude(V)	325
Phase (deg)	0
Frequency(Hz)	50

RLC series branch:

Branch Type	RLC
Resistance (ohms)	360
Inductance(H)	150mH
Capacitance(F)	inf

Simulation - configuration parameters

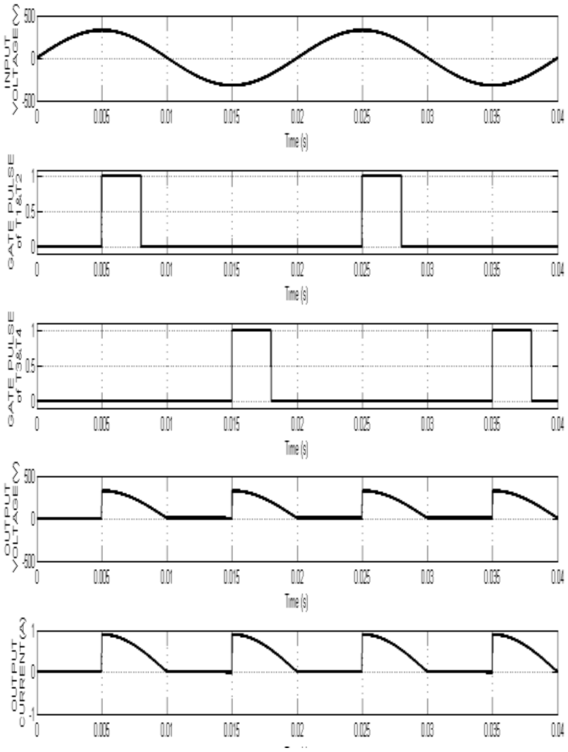
Start Time	0
Stop Time	0.04
Type	Variable step
Solver	0rder 3

Pulse generator: 1

Amplitude	1
Period(sec)	0.02
Pulse width(% of period)	30
Phase delay(Sec)	(60*0.01)/180

Pulse generator: 2

Amplitude	1
Period(sec)	0.02
Pulse width(% of period)	30
Phase delay(Sec)	(240*0.01)/180



Simulation resilts of full bridge rectifier