ELECTRIC DRIVES LAB MANUAL

SUBJECT CODE: EE 791

JIS COLLEGE OF ENGINEERING
ELECTRICAL DEPARTMENT

LIST OF EXPERIMENT

1. Study of thyristors controlled DC Drive.
2. Study of Chopper fed DC Drive.
3. Study of AC Single phase motor-speed control using TRIAC.
4. PWM Inverter fed 3 phase Induction Motor control using PSPICE / MATLAB / PSIM Software.
5. VSI / CSI fed Induction motor Drive analysis using MATLAB / SPICE / PSIM Software.
6. Study of V/f control operation of 3phase induction motor drive.
7. Study of permanent magnet synchronous motor drive fed by PWM Inverter using Software.
8. Regenerative / Dynamic braking operation for DC Motor - Study uses software.
9. Regenerative / Dynamic braking operation of AC motor - study uses software.
10. PC/PLC based AC/DC motor control operation.

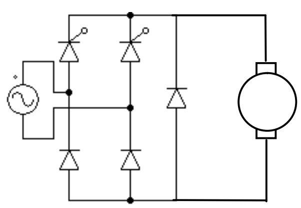
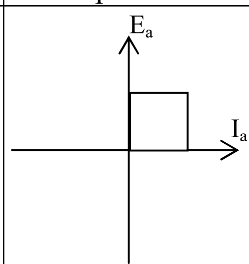
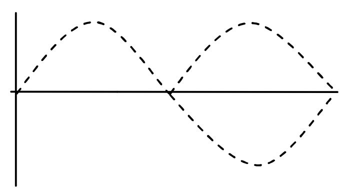
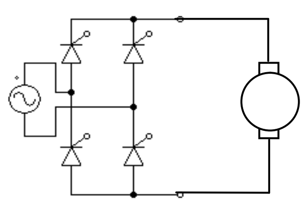
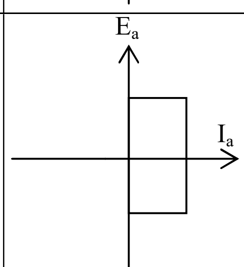
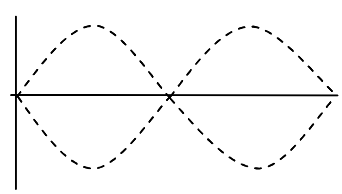
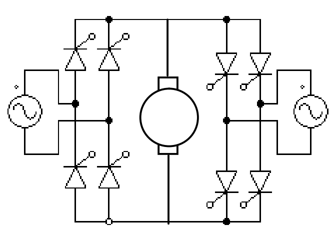
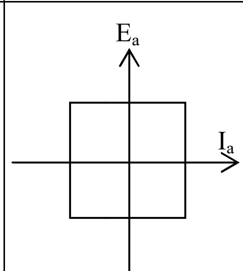
TITLE : Study of thyristor controlled DC Drive.

OBJECTIVE : To study the operation of speed control of DC motor by thyrister control using PSIM.

THEORY :

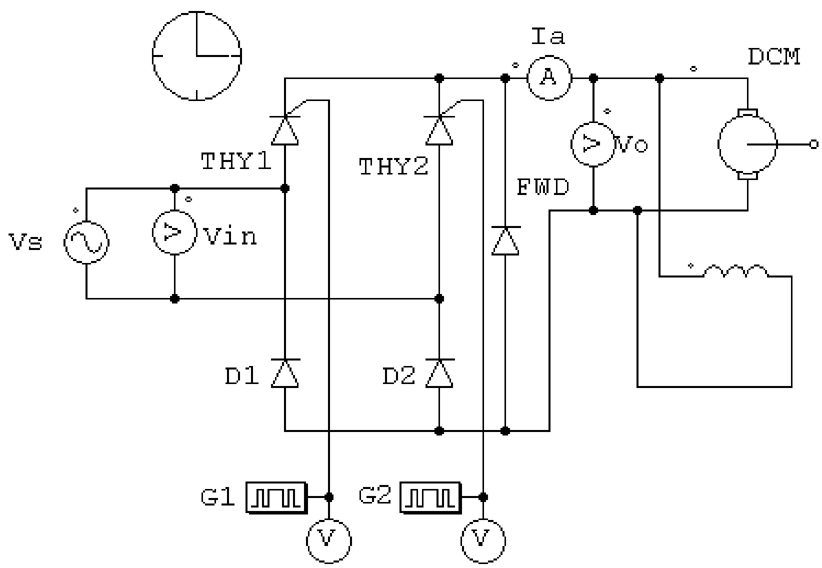
The phase controlled converter or thyristor controlled rectifier are used for speed control of dc shunt motor or separately excited dc motor and the chopper fed dc supply are used for speed control of dc series motor. The various type of single phase thyristor controlled converter fed dc drive are shown in below

Single Phase DC Drive Circuits

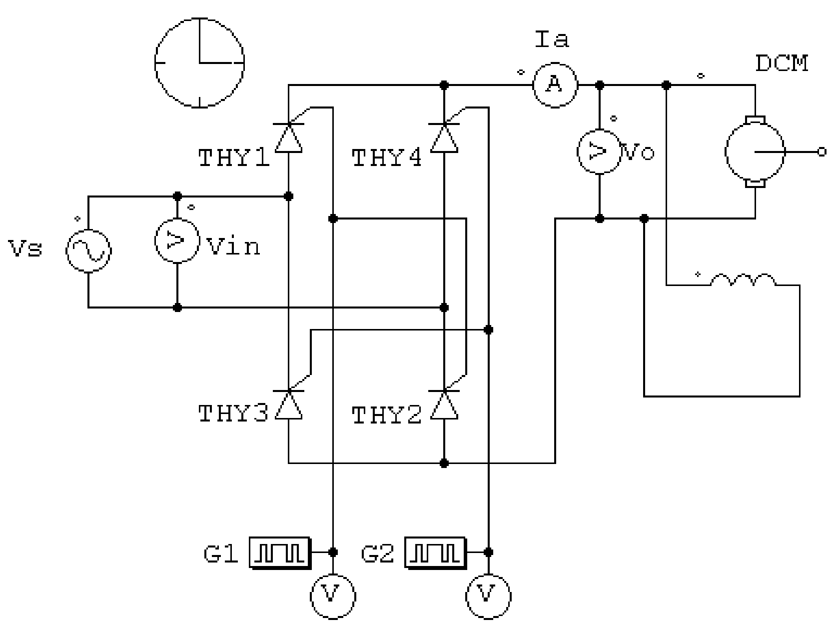
Armature Circuit	Quadrature Operation	Output Voltage	Voltage Waveform
		$E_a = \frac{\sqrt{2}V_m}{\pi}(1+\cos\alpha)$	
		$E_a = \frac{2\sqrt{2}}{\pi}V_m \cos\alpha$	
		$E_a = \frac{2\sqrt{2}}{\pi}V_m \cos\alpha_A$ $0 < \alpha_A < \pi$ $E_a = \frac{2\sqrt{2}}{\pi}V_m \cos\alpha_B$ $0 < \alpha_B < \pi$ $\alpha_B = \pi - \alpha_A$	

CIRCUIT DIAGRAM FOR PSIM :

1. Half-controlled rectifier:



2. Full-controlled rectifier:



PROCEDURE :

1) Open the PSIM software and construct the circuit of half-controlled single phase rectifier.
2) Use the “element” icon to get all the relevant components or devices.
3) Reset the parameters of different devices by double clicking over them as specified below :

Device	*Description*	*Parameters*
DCM	DC Shunt Motor	R_a = 0.5, L_a = 0.01, R_f = 75, L_f = 0.02, MI = 0.4, V_t = 120, I_a = 10, N = 1200, All Flags = 1.
THY(1-6)	Thyristor	Voltage drop = 0, Initial Position = 0, Current Flag = 0.
D(1-2)	Diode	Diode voltage drop = 0, Initial Position = 0, Current Flag = 0.
FWD	Free Wheeling Diode	Diode voltage drop = 0, Initial Position = 0, Current Flag = 0.
G1-G2	Gating Blocks for switch	Frequency = 50, No of points = 2 Switching points: G1: 20 35, G2: 200 215 (For α = 20°).
Vs	Supply Voltage	Peak amplitude = 170, Frequency = 50, Phase angle = 0, DC offset = 0, Tstart = 0.

4) Connect ammeters, voltmeter as shown in the fig.
5) Now click ‘simulation control’ icon for transient analysis. Set the parameters with suitable values like Time Step = 1E-005, Total Time = 4, Print Time = 0, Print Step = 10, All Flags = 0.
6) Then click “run simulation” for simulation process. Graphical window will appear.
7) Observe the waveforms of the following: Input voltage (V_{in}), Output Voltage (V_{out}), Armature Current (I_a), Gate Pulse.
8) Also observe the waveforms of the same for α = 50°, 75°, 200°, 290°).
9) Now simulate same for full-controlled single phase rectifier.
10) Record the all above waveform in graph paper.

DISCUSSION :

TITLE : Study of Chopper fed DC Drive.

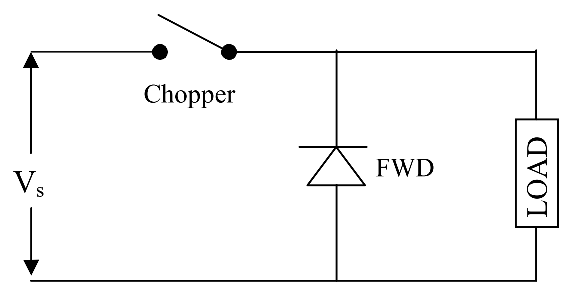
OBJECTIVE : To study the operation of speed control of DC motor by chopper circuit

APPRATUS :
- i) Chopper controlled DC drive kit.
- ii) DC Motor
- iii) Tachometer
- iv) Oscilloscope

THEORY :

In chopper controlled DC drive, the variable dc voltage which is fed to DC motor is controlled by chopping the constant or fixed input dc voltage by varying the ON and OFF times of a converter which is known as chopper. A chopper may be a Thyristor or MOSFET or IGBT act as a ON/OFF switch which connect the load and disconnect it from the supply and produced chopped load voltage.

A schematic diagram of chopper is shown below.



The control voltage of chopper is V_c. When the chopper is ON for a time t_{on} the supply voltage V_s is connected to load and when chopper is OFF for a time t_{off} load current flows to the freewheeling diode D and load terminal is shorted. So, the frequency of operation is

$$f_c = \frac{1}{t_{on} + t_{off}} = \frac{1}{T}$$

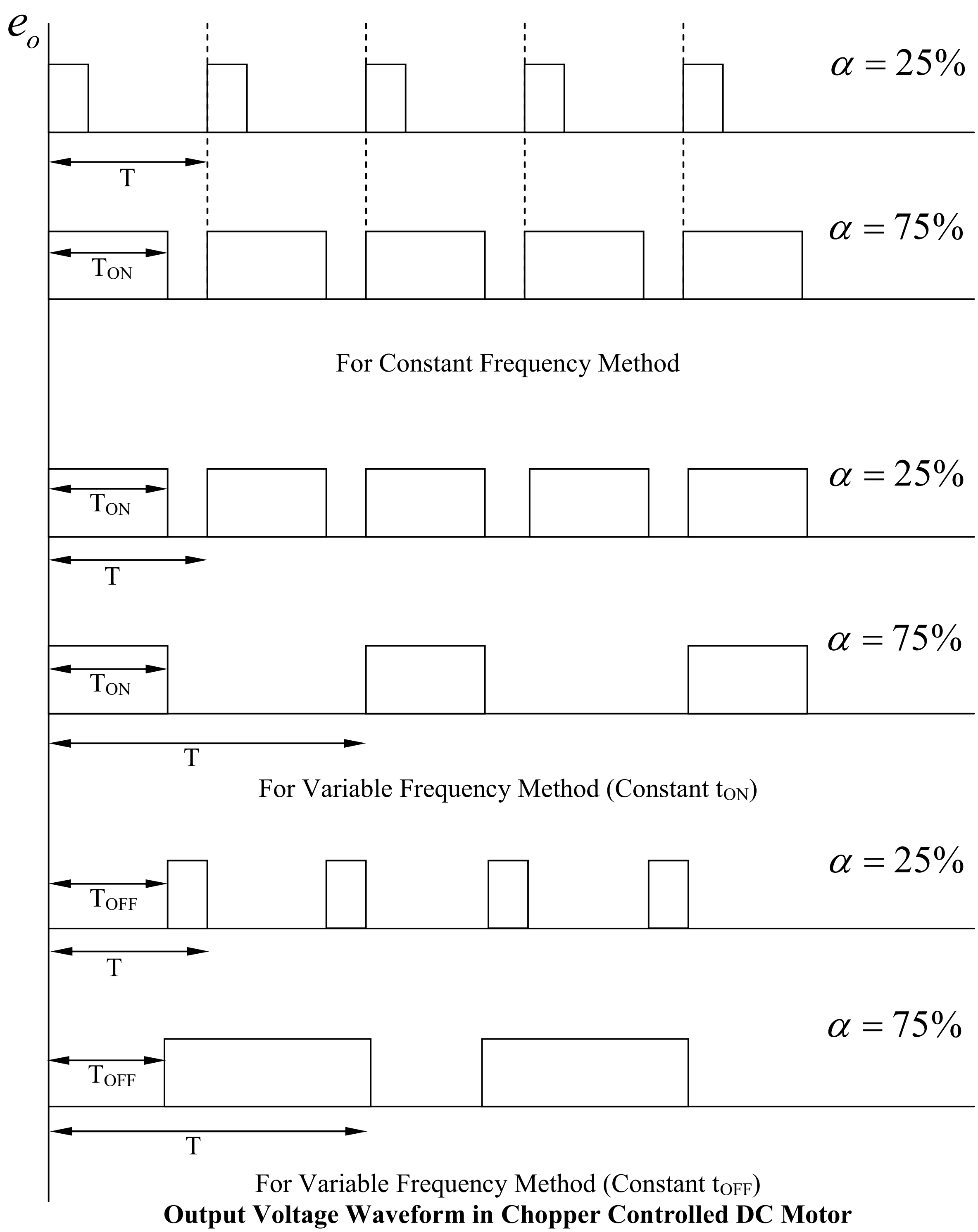
and its duty cycle is defined as $\alpha = {t_{on}}/{T}$. The output voltage across the load during the ON time is equal to difference between the source voltage V_s and voltage drop across power switch. Assuming that the switch is ideal, with zero voltage drop, the average output voltage V_{dc} is given as

$$V_{dc} = \frac{t_{on}}{T} V_s$$

Therefore the output voltage can be change by varying the duty cycle. The duty cycle can be changed in the following two ways

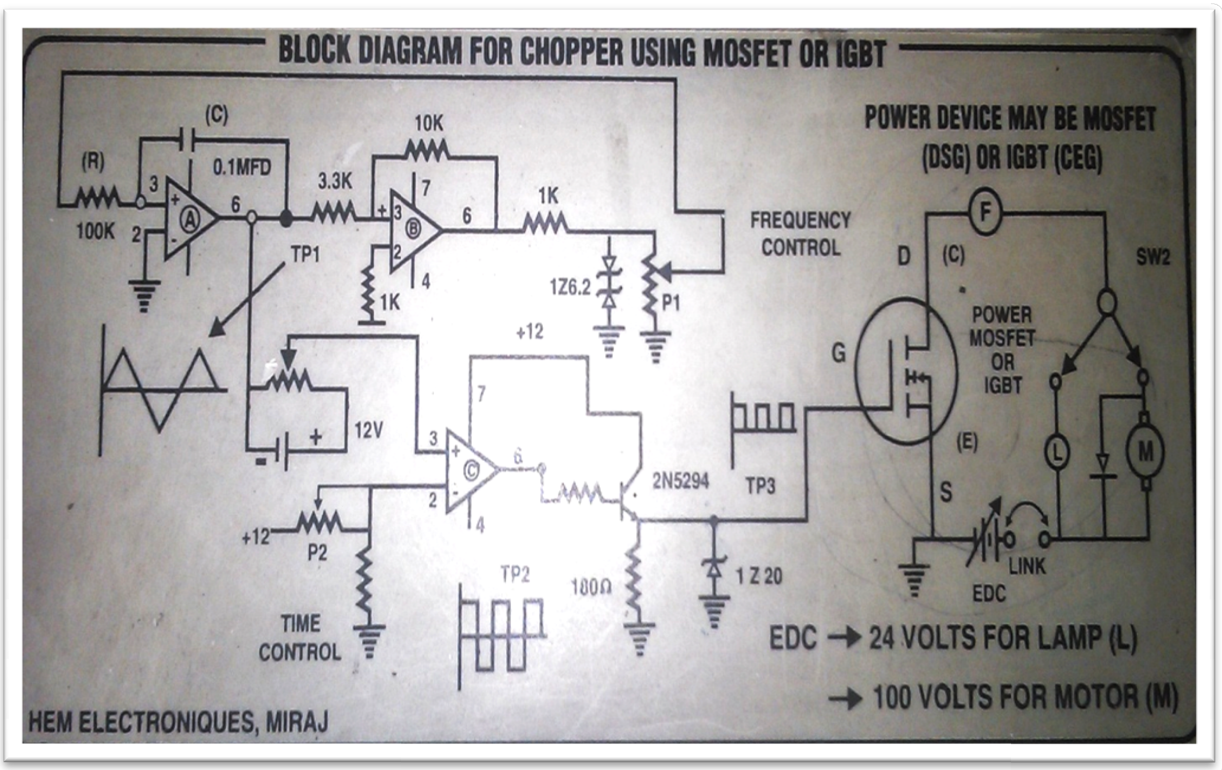
i. By keeping the switching or chopping frequency constant and varying the ON time.
ii. By keeping the ON time constant and varying the chopping frequency.

The constant frequency control method has the advantages of predetermined switching losses of chopper, enabling optimal design of cooling for power circuit, and predetermined harmonic components, leading to an optimal input filter.

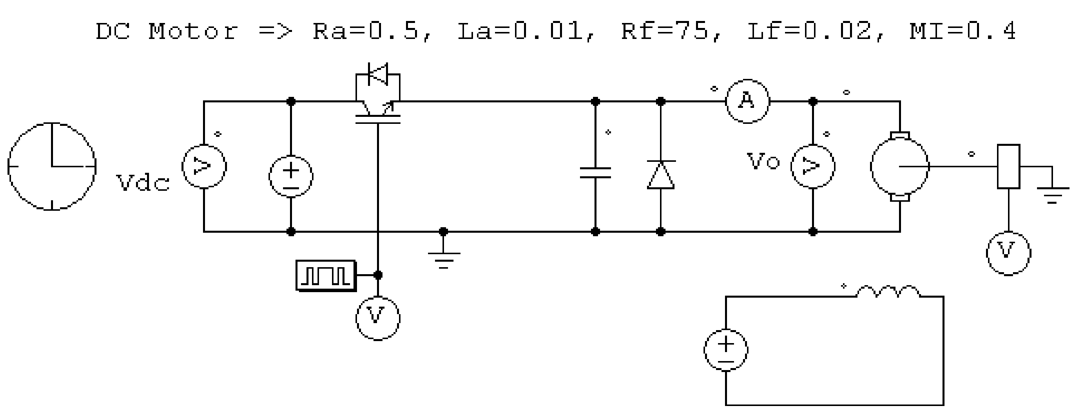


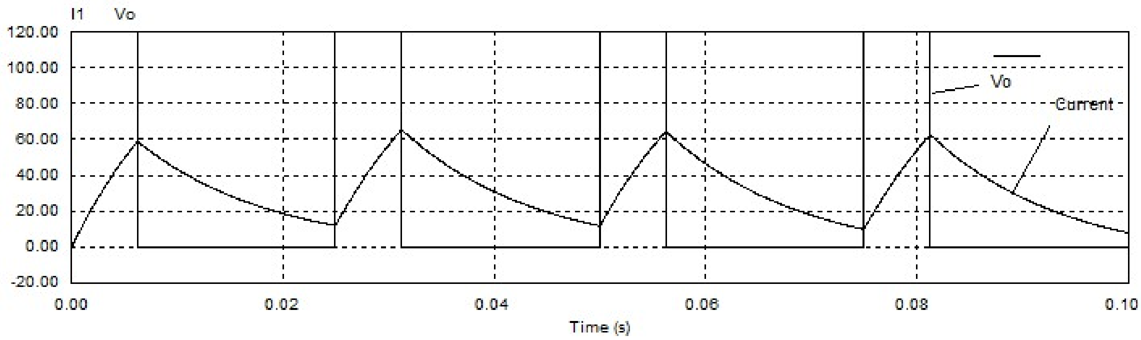
Output Voltage Waveform in Chopper Controlled DC Motor

CIRCUIT DIAGRAM OF THE KIT USED FOR THE EXPERIMENT:

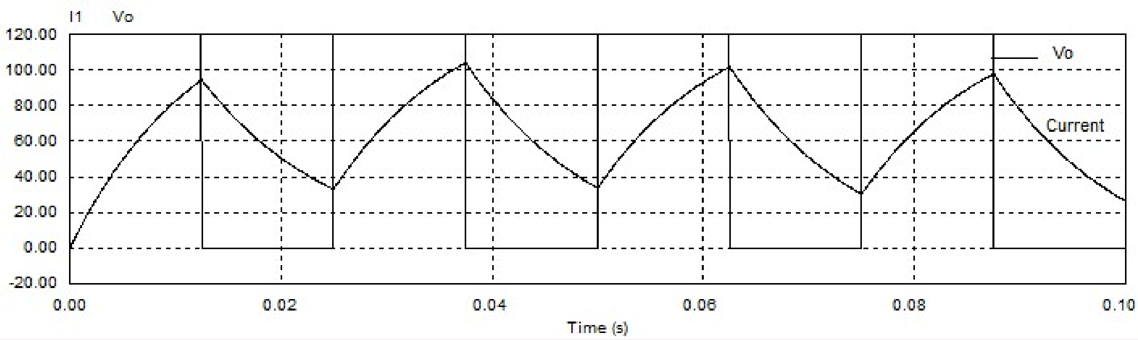


CIRCUIT DIAGRAM FOR PSIM :

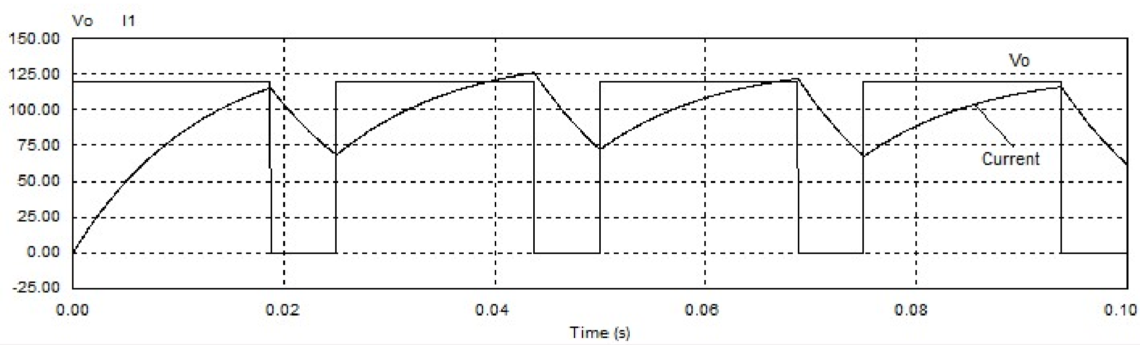




For $\alpha = 35°$



For $\alpha = 90°$



For $\alpha = 135°$

PROCEDURE :

1) Ensure that the link between the binding posts marked (LINK or AMMETER) is open. This link provides main dc power as I/P to chopper.
2) Keep the switch SW2 in lower position (low voltage position). Connect the CRO between TP1 and ground. Ensure that both P1 and P2 posts are in most anticlockwise position.
3) Now switch on the mains supply and observe the waveform for triangular waveforms at TP1 and other waveforms at TP2 and TP3.
4) Now you may place link across the binding post marked link and make available the dc voltage for the power circuit. Then by controlling the post P2 i.e. on time control you can observe that a variable dc voltage appears across the lamp, thereby changing its intensity.

5) Ensure that the link is removed and now you may change the switch SW2 to high voltage position. But you must ensure that a dc series motor connected as load by 8 pin socket.
6) By controlling the ON time pot P2 you can control the speed of dc series motor. The waveform can be observed across point B and C by CRO.
7) By controlling P1 chopping frequency can be controlled.
8) The motor terminal voltage is measured by voltmeter across A and C.
9) Disconnect the circuit from the supplies.

OBSERVATION TABLE :

Sl. No.	T_{ON}	$T_{OFF} = T - T_{ON}$	Duty Cycle T_{ON}/T	Motor Speed (r.p.m.)	Motor Current (Amp)	Output Voltage (Volts)		Error (%)
						Measured	Calculated	

DISCUSSION :

TITLE : Study of AC Single phase motor-speed control using TRIAC

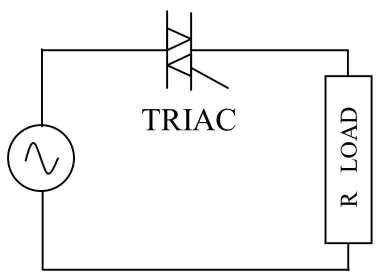
OBJECTIVE : To study the operation of ac regulation of R and R-L load and speed control of single phase ac motor using TRIAC.

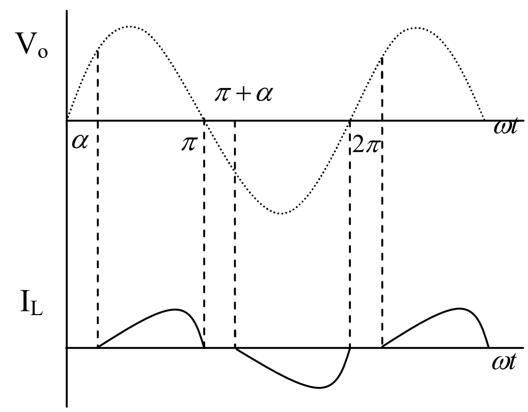
APPRATUS :
- i) Chopper controlled DC drive kit.
- ii) DC Motor
- iv) Tachometer
- iv) Oscilloscope

THEORY :

1. AC REGULATION OF R LOAD

The simplest form of ac regulator or controlled circuits consist of a single thyristor or TRIAC feeding dc power to a resistive load R as shown in below. The voltage and current waveform of R load is also shown below.





The source voltage is $V_s = V_m \sin\omega t$. A TRIAC can conduct only when anode voltage is positive and a gating signal is applied. Let, at some delay angle α , a positive gate signal is applied between gate and cathode. As a result TRIAC is turn on and immediately, full supply voltage is applied to load as V_0. At the instant of delay angle α , V_0 rises from zero to $V_m \sin\alpha$ as shown below.

The average voltage V_{av} across load R is given by

$$V_{av} = \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin\omega t \; d\left(\omega t\right)$$

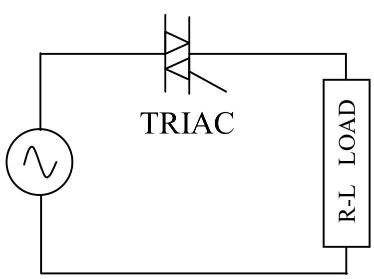
$$= \frac{V_m}{\pi}\left(1+\cos\alpha\right)$$

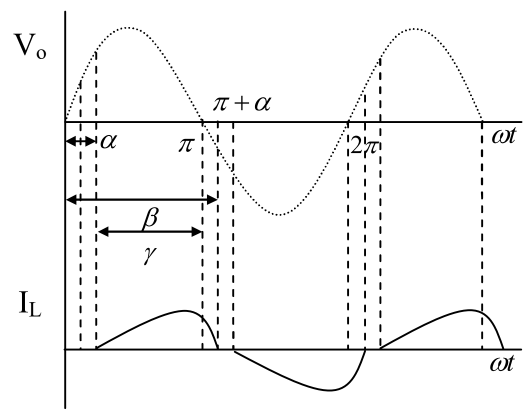
The rms value of load voltage is given by

$$V_{rms} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi} V_m^2 \sin^2 \omega t \; d(\omega t)}$$
$$= \frac{V_m}{\sqrt{2\pi}}\sqrt{2(\pi-\alpha)+\sin 2\alpha}$$

2. AC REGULATION OF R-L LOAD

The circuit of single phase full wave ac voltage regulator using TRIAC feeding R-L load is shown in fig. The load current is continuous to conduct even after $\omega t = \pi$ due to inductance in the circuit. Let us assume that TRIAC conduct until $\omega t = \beta$. Thus conduction angle is $\gamma = \beta - \alpha$. The voltage and current waveform of R-L load is also shown below.





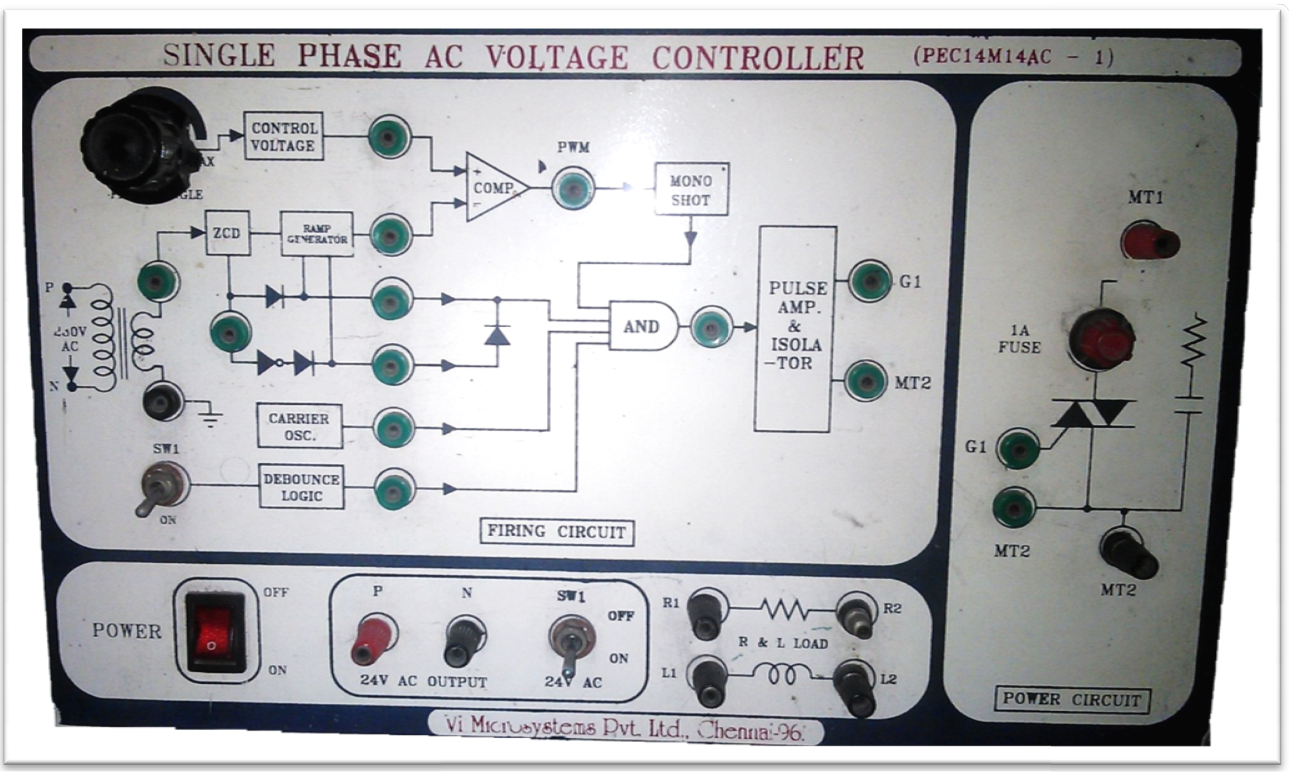
The average voltage V_{av} across load R is given by

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

The rms value of load voltage is given by

$$V_{rms} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\beta} V_m^2 \sin^2 \omega t \; d(\omega t)}$$
$$= \frac{V_m}{\sqrt{2\pi}}\sqrt{(\sin 2\alpha - \sin 2\beta)+2(\beta-\alpha)}$$

CIRCUIT DIAGRAM OF THE KIT USED FOR THE EXPERIMENT:



PROCEDURE:

A. For R load

1) Connect pulse amplifier and isolator output G1 and MT2 with TRIAC terminal G1 and MT2 respectively.
2) Connect 24 V AC output terminal P with TRIAC terminal MT1.
3) Connect TRIAC terminal MT2 with load resistance terminal R2.
4) Connect 24 V AC output terminal N with load resistance terminal R1.
5) Connect the CRO probe across load terminal R1 and R2.
6) Connect voltmeter across load resistor.
7) Switch ON trainer Power ON/OFF switch and 24 V AC ON/OFF switch.
8) Switch ON the Debounce Logic switch.
9) Vary the control voltage knob (triggering angle) minimum to maximum step by step.
10) For each step note down the output voltage and firing or triggering angle α.
11) Calculate the output voltage and also the error.

B. For R-L load

1) Connect pulse amplifier and isolator output G1 and MT2 with TRIAC terminal G1 and MT2 respectively.
2) Connect 24 V AC output terminal P with TRIAC terminal MT1.
3) Connect TRIAC terminal MT2 with load resistance terminal R2.
4) Connect load resistor terminal R1 with load inductor terminal L2
5) Connect 24 V AC output terminal N with load inductor terminal L1.
6) Connect the CRO probe across load terminal R1 and R2.
7) Connect voltmeter across load resistor.
8) Follow the step 7-11 as for R load.

C. For AC Motor load

1) Connect pulse amplifier and isolator output G1 and MT2 with TRIAC terminal G1 and MT2 respectively.
2) Connect 230 V, 50 Hz AC supply line terminal with TRIAC terminal MT1.
3) Connect TRIAC terminal MT2 with one of the terminal of 1Φ ac motor terminal and other terminal of motor is connected with AC supply neutral terminal.
4) Now by varying the firing angle observe the speed of the motor by tachometer.
5) Also measure the motor input voltage by voltmeter.

OBSERVATION TABLE :

A. For R load

Sl. No.	Firing Angle (α) (Degree)	Output Voltage (Volts)		Error (%)
		Measured	Calculated	

B. For R-L load

Sl. No.	Firing Angle (α) (Degree)	Excitation Angle (β) (Degree)	Output Voltage (Volts)		Error (%)
			Measured	Calculated	

C. For AC Motor load

Sl. No.	Firing Angle α	Output Voltage (Volts)	Speed (rpm)	Motor Current (Amps)

DISCUSSION :

TITLE : Study of V/f control operation of 3phase induction motor drive

OBJECTIVE : To study the speed control of induction motor by varying supply frequency.

THEORY :

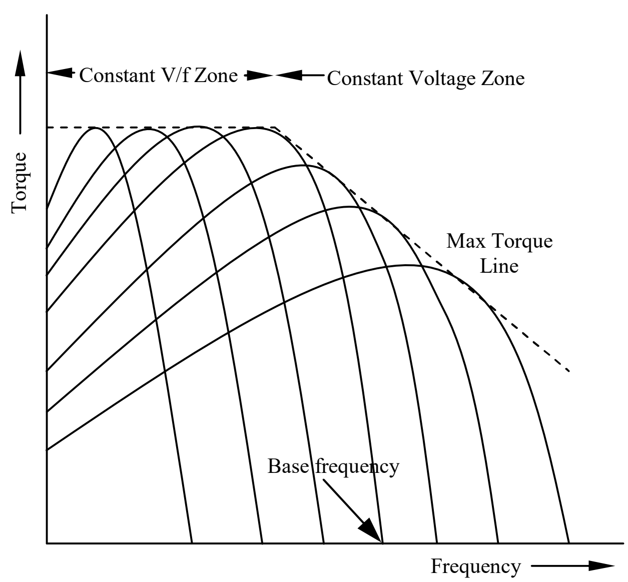
The air-gap induced emf in an ac machine is given by

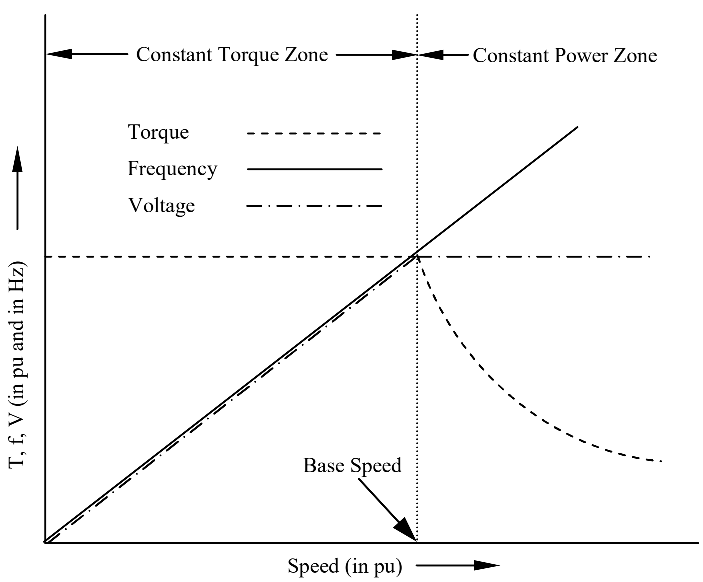
$$E = 4.44 K_w \phi_m f T$$

Where K_w is stator winding factor, ϕ_m maximum air-gap flux, f is supply frequency and T is no of turns per phase in stator. Any reduction in supply frequency, without a change in terminal voltage, causes an increase in air-gap flux. Induction motors are designed to operate at knee point of magnetization characteristic to make full use of magnetic material. Therefore increase in flux will saturate the motor. This will increase magnetizing current, distort line current and voltage, increase core loss and stator copper loss.

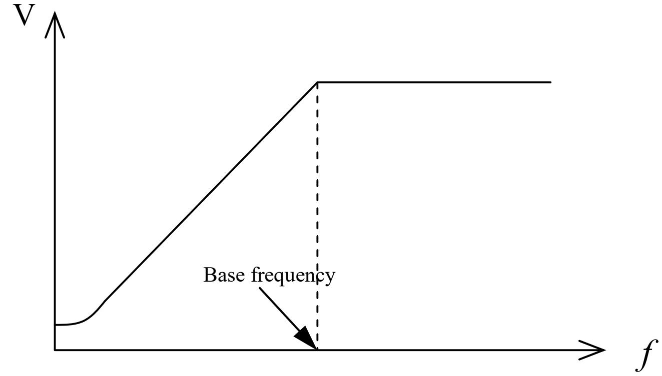
Since voltage induced in stator is proportional to product of supply frequency and air-gap flux, hence the air-gap flux can be maintained constant for optimum flux level in a machine by keeping the ratio of (applied voltage to stator impedance drop) and stator frequency constant. At high voltage level, stator impedance $(R_s + jX_{ls})$ drops is very small, so constant torque operation is maintained by just V/f constant. On the other hand, for low speed operation stator drop increased and thus ratio V/f is to be slightly boosted.

So, with constant torque operation speed can be varied from very low to near synchronous value with both voltage and frequency attaining their rated value at synchronous speed. Any speed above the synchronous speed can be obtained by increasing the above rated value. The applied voltage cannot be increased anymore because this results in weakening the air-gap flux and reduction in torque. The motor now operates in constant power zone. With increase in frequency, air-gap flux also weakens.

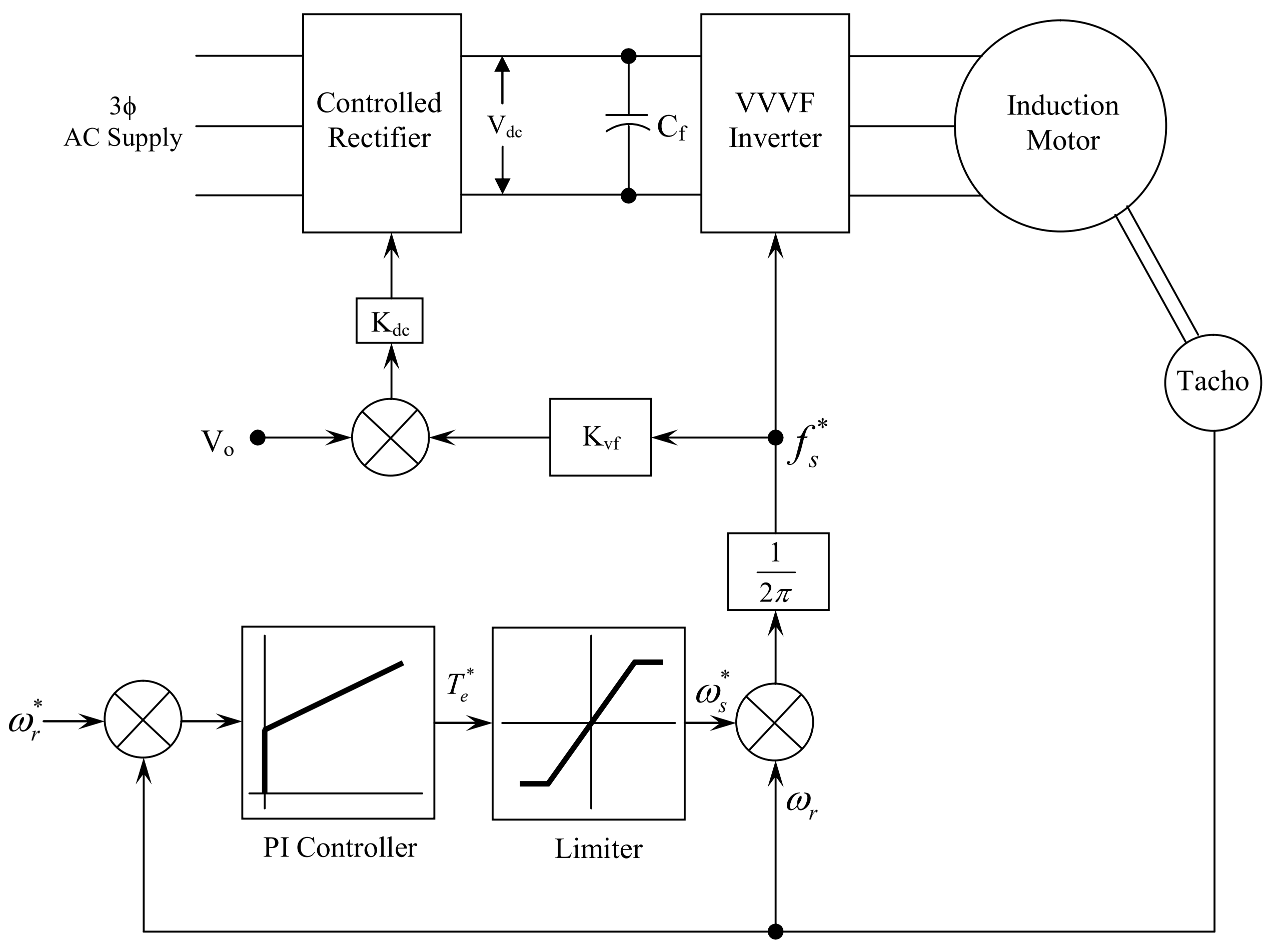




Therefore, whenever stator frequency is changed to obtain speed control, stator input voltage has to be changed accordingly to maintain air-gap flux constant. So, usually a preprogrammed volts-to-frequency relationship is used as shown below.



The block diagram of closed-loop induction motor drive with constant volts/Hz control strategy is shown below.



The actual rotor speed is compared with its commanded value, ω_r^* and the error is processed through a controller, usually PI controller and a limiter to obtain the slip-speed command, ω_s^*. The limiter ensured ensures that the slip-speed command is within the maximum allowable slip speed of the induction motor. The slip-speed command is then added to electrical rotor speed to obtain the stator frequency command. Thereafter, the stator frequency command is processed as in an open-loop drive. K_{dc} is the proportionality constant between dc load voltage and stator frequency.

PROCEDURE:

1) Switch ON power supply and change the frequency set point from minimum value to maximum value step by step.
2) For each step note down the output voltage armature current and speed.
3) Plot the applied voltage vs supply frequency curve.

OBSERVATION TABLE :

Sl. No.	Supply Frequency (Hz)	Applied Voltage (Volts)	V/f Ratio	Armature Current (Amps)	Speed (rpm)

DISCUSSION :

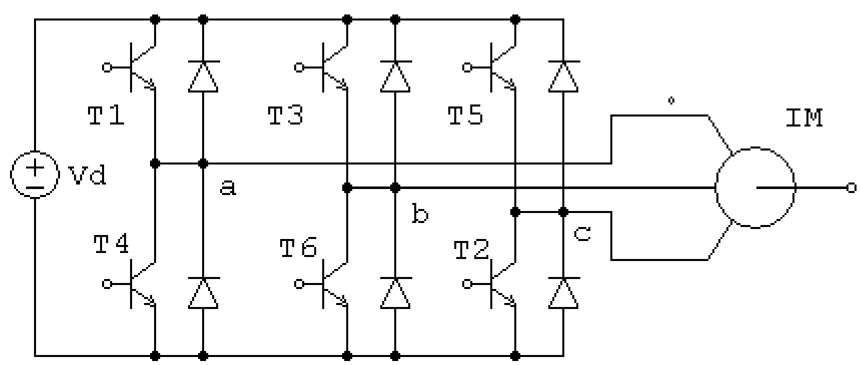
TITLE : VSI fed Induction motor Drive analysis.

OBJECTIVE : To study VSI fed Induction motor Drive analysis using PSIM Software.

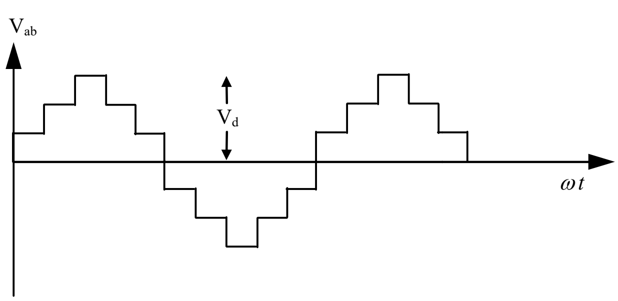
THEORY :

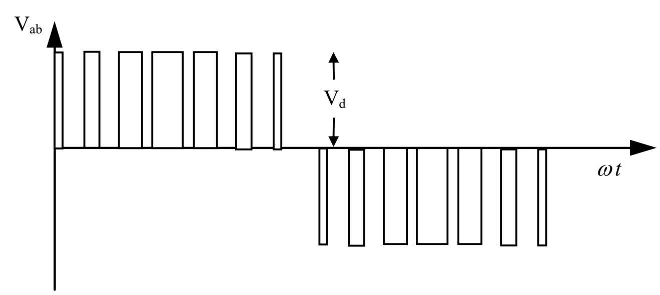
Voltage source inverter gives a variable frequency supply from a constant dc supply. The schematic diagram of a VSI fed induction motor drive using transistor is shown in below. Any other self-commutated device can be used instead of transistor. Generally MOSFET is used in low voltage and low power inverters, IGBT and power transistors are used up to medium power levels and GTO and IGCT are used for high power levels.

VSI can be operated as a stepped wave inverter or a pulse width modulated (PWM) inverter. When operated as a stepped wave inverter, transistor are switched in the sequence of their numbers with a time difference of T/6 and each transistor is kept on for the duration of T/2, where T is the time period of one cycle. Resultant line voltage waveform is shown in fig. Frequency of the inverter operation is varied by varying T and the output voltage of inverter is varied by varying dc input voltage.



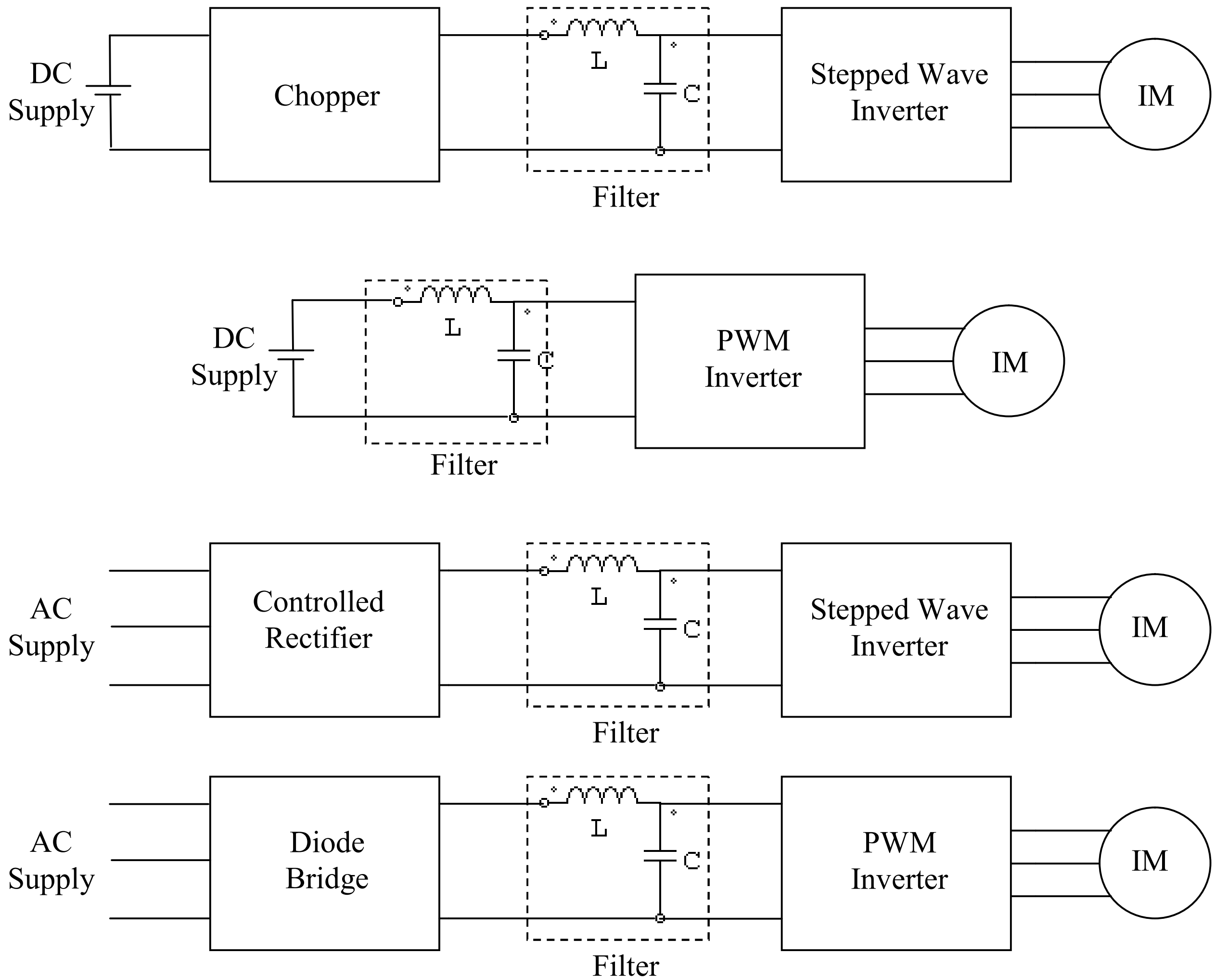
Transistor Inverter-fed Induction Motor Drive





The various VSI controlled IM drive is shown below.

i. When supply is dc, variable dc input voltage is obtained by connecting chopper between dc supply and inverter.
ii. When supply is fixed dc, PWM inverter is used.
iii. When supply is ac, variable dc input voltage is obtained by connecting a controlled rectifier or diode bridge rectifier between ac supply and inverter.



Various Type of VSI Controlled Induction Motor Drive

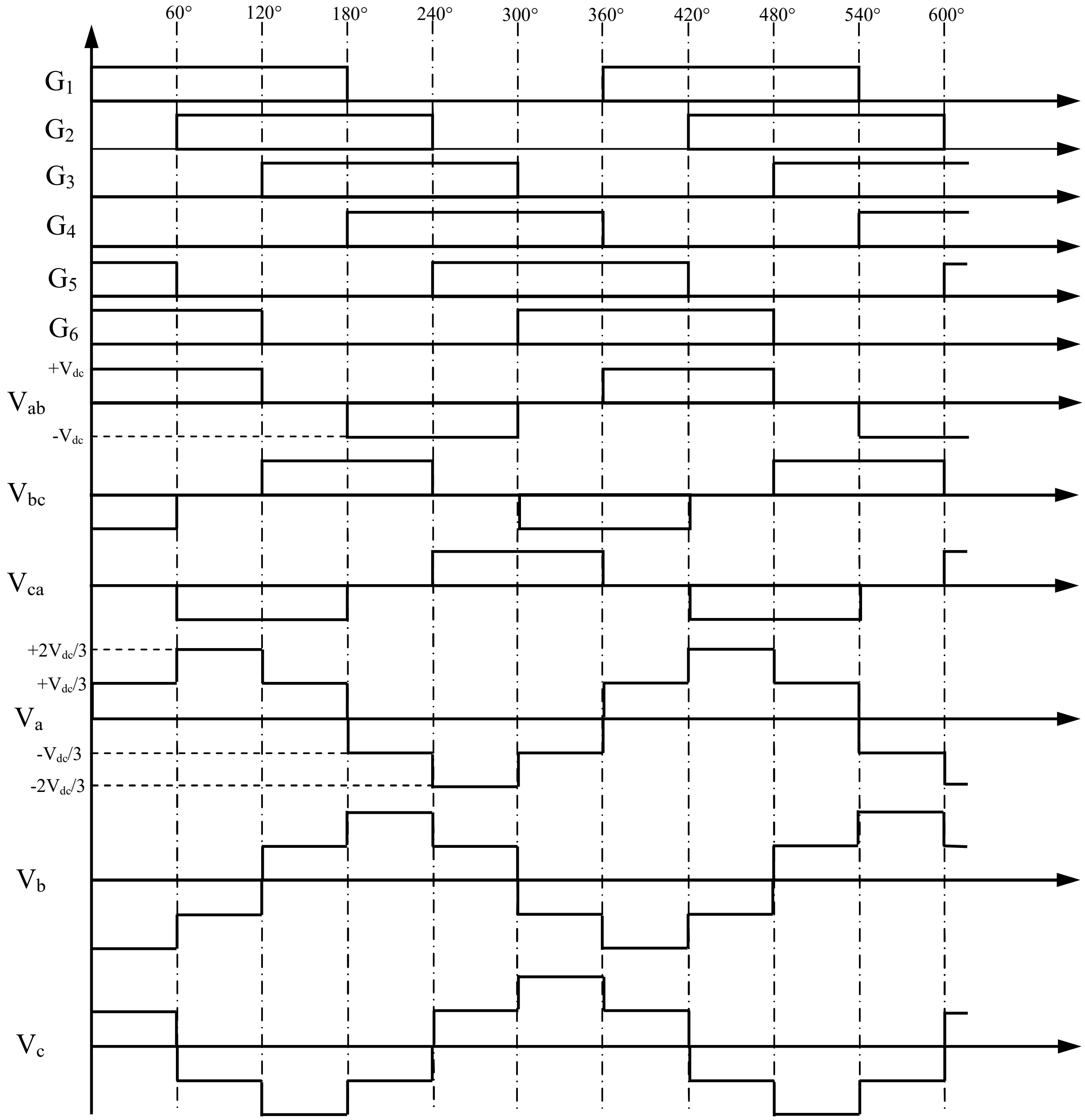
The line voltages in terms of phase voltages in a three phase system with phase sequence *abc* are

$$V_{ab} = V_a - V_b$$
$$V_{bc} = V_b - V_c$$
$$V_{ca} = V_c - V_a$$

Where V_{ab}, V_{bc} and V_{ca} are line voltages and V_a, V_b and V_c are phase voltages. The phase voltages in terms of line voltages in a three phase system can be written as

$$V_a = \frac{V_{ab} - V_{ca}}{3} \qquad V_b = \frac{V_{bc} - V_{ab}}{3} \qquad V_c = \frac{V_{ca} - V_{bc}}{3}$$

Although the line-to-line voltages are 120° electrical in duration, and the phase voltages are six-stepped and of quasi-sine waveforms. The gating signals and resulting line voltages and phase voltages waveform are shown below.



These periodic voltage waveforms, when resolved into Fourier components, have the following form

$$V_{ab}\left(t\right)=\frac{2\sqrt{3}}{\pi}V_{dc}\left(\sin\omega_s t-\frac{1}{5}\sin 5\omega_s t+\frac{1}{7}\sin 7\omega_s t-\ldots\ldots\right)$$

$$V_{bc}\left(t\right)=\frac{2\sqrt{3}}{\pi}V_{dc}\left(\sin\left(\omega_s t-120°\right)-\frac{1}{5}\sin 5\left(\omega_s t-120°\right)+\frac{1}{7}\sin 7\left(\omega_s t-120°\right)-\ldots\ldots\right)$$

$$V_{ca}\left(t\right)=\frac{2\sqrt{3}}{\pi}V_{dc}\left(\sin\left(\omega_s t+120°\right)-\frac{1}{5}\sin 5\left(\omega_s t+120°\right)+\frac{1}{7}\sin 7\left(\omega_s t+120°\right)-\ldots\ldots\right)$$

The phase voltages are shifted from the line voltages by 30° and their magnitude are $\frac{2V_{dc}}{\pi}$. Only the fundamental produce the useful torque and hence only it needs to be considered for the steady state performance evaluation of inverter-fed ac motor drive. In this regard, the fundamental rms phase voltage for the six-stepped waveform is

$$V_{ph} = \frac{V_a}{\sqrt{2}} = \frac{2}{\pi} \times \frac{V_{dc}}{\sqrt{2}} = 0.45V_{dc}$$

The main drawback of stepped wave inverter-fed induction motor drive is

i. Because of low frequency harmonics, motor losses are increased at all speeds causing derating of motor.
ii. Motor develop pulsating torque due to fifth, seventh, eleventh and thirteenth harmonics which cause jerky motion of rotor at low speed.
iii. Harmonic content in motor current increases at low speeds. The machine saturates at light load at low speed due to high (V/f) ratio. These two effects overheat the machine at low speeds, thus limiting lowest speed to around 40% of base speed.

The fundamental component in the output phase voltage of PWM inverter operating with sinusoidal PWM is given by

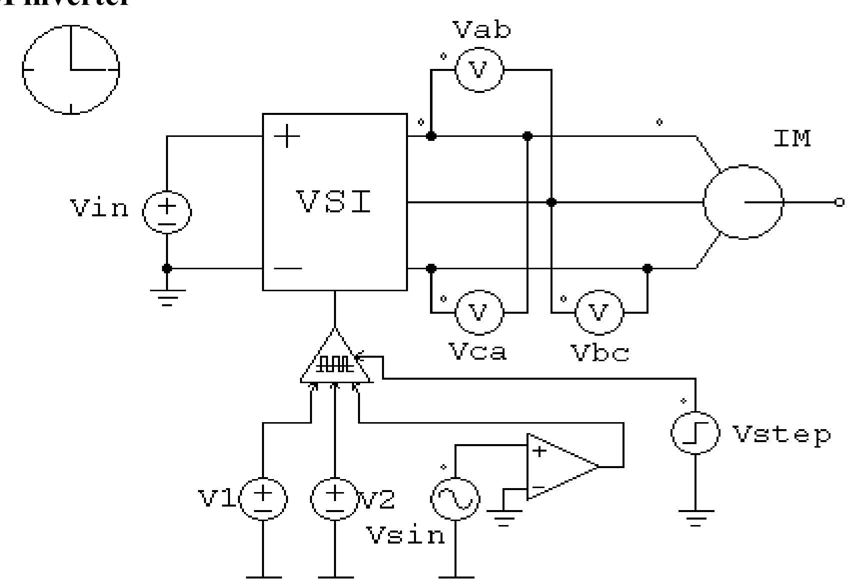
$$V_{ph} = m\frac{V_{dc}}{2\sqrt{2}}$$

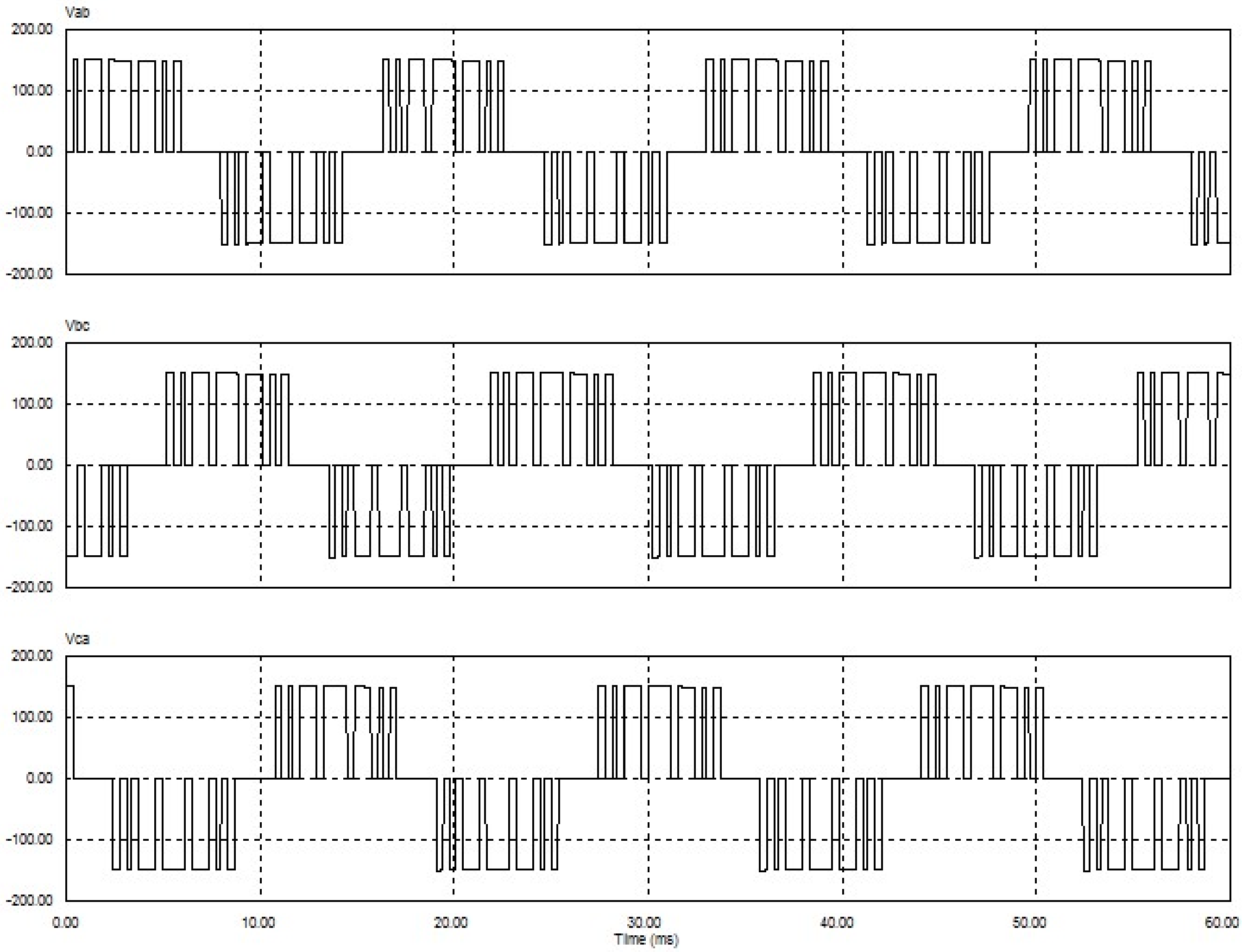
Where m is the modulation index. The advantage of PWM inverter-fed induction motor drive is

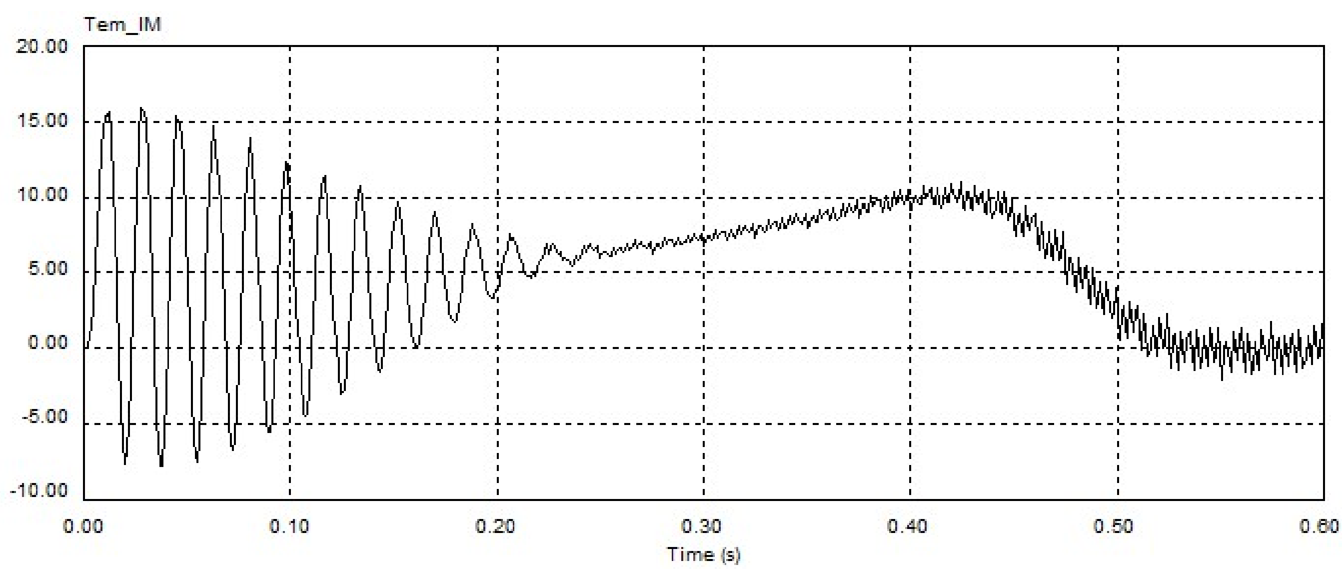
i. Harmonics are reduced
ii. Low frequency harmonics are eliminated
iii. Associated losses are reduced
iv. Smooth motion is obtained at low speeds

CIRCUIT DIAGRAM FOR PSIM :

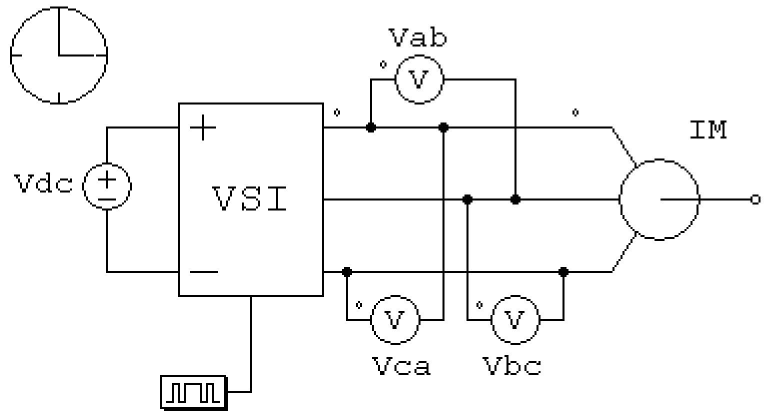
A. VSI with PWM inverter

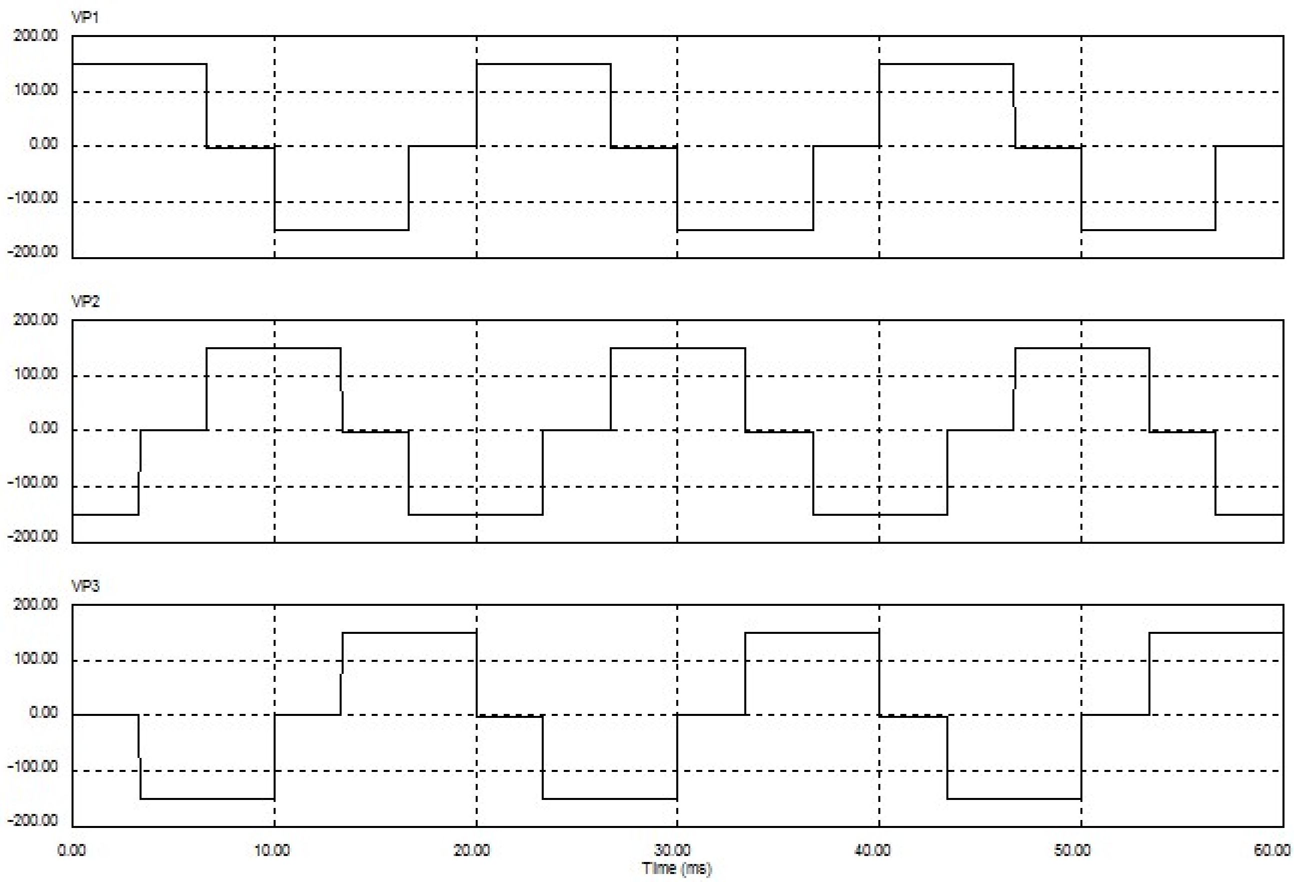


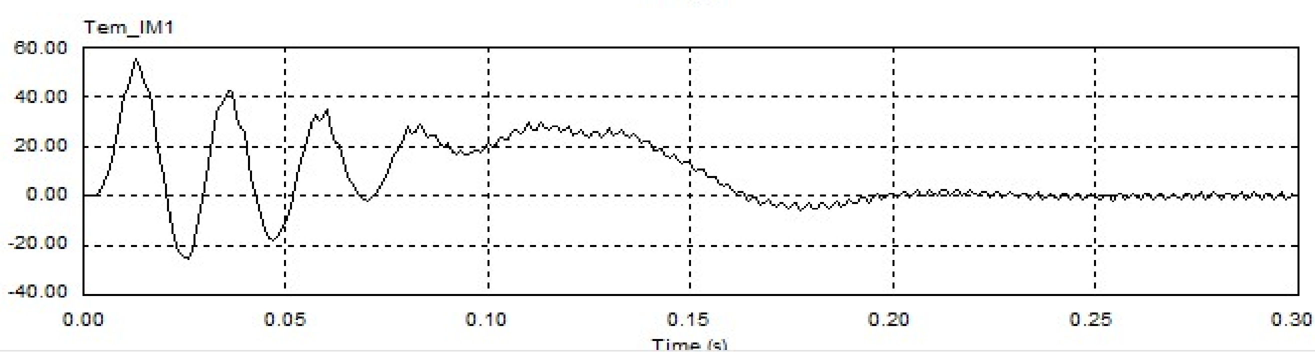

Vab
200.00
100.00
0.00
-100.00
-200.00
Vbc
200.00
100.00
0.00
-100.00
-200.00
Vca
200.00
100.00
0.00
-100.00
-200.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Time (ms)


Tem_IM
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Time (s)

B. VSI with Stepped Wave Inverter







PROCEDURE :

1) Open the PSIM software and construct the circuit of half-controlled single phase rectifier.
2) Use the "element" icon to get all the relevant components or devices.
3) Reset the parameters of different devices by double clicking over them as specified below :

Device	*Description*	*Parameters*
IM	Induction Motor	R_s = 0.183, L_s = 0.0015, R_r = 0.277, L_r = 0.0022, L_m = 0.0538, MI = 0.0165, P = 4, All Flags = 1.
VSI	Voltage Source Inverter	All = 0.
V_{in}	Supply Voltage	Amplitude = 150.
PATTCTRL	PWM Pattern Controller	Frequency = 50, Update Angle = 360, Current Flag = 0.
G	Gatting Block	Frequency = 50, No of point = 2, Switching point = 0 180.
V1	Voltage Source	Amplitude = 0.
V2	Voltage Source	Amplitude = 0.92.
V_{sin}	Voltage Source	Peak Amplitude = 110, Frequency = 50, Phase angle = 0, DC offset = 0, Tstart = 0.
V_{step}	Step Voltage	Vstep = 1, Tstep = 0.

4) Connect voltmeter as shown in the fig.
5) Now click 'simulation control' icon for transient analysis. Set the parameters with suitable values like Time Step = 1E-005, Total Time = 0.06, Print Time = 0, Print Step = 1, All Flags = 0.
6) Then click "run simulation" for simulation process. Graphical window will appear.
7) Observe the waveforms of the following: Input voltage (V_{in}), Output Voltage (V_{ab}, V_{bc} and V_{ca}).
8) Also observe the waveforms of electromagnetic torque (Tem_IM).
9) Record the all above waveform in graph paper.

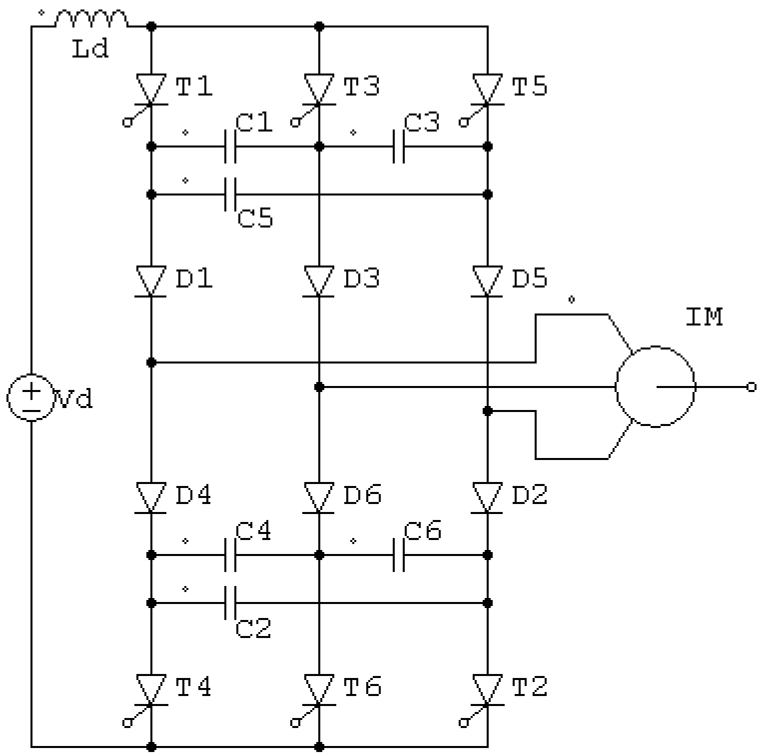
DISCUSSION :

TITLE : CSI fed Induction motor Drive analysis.

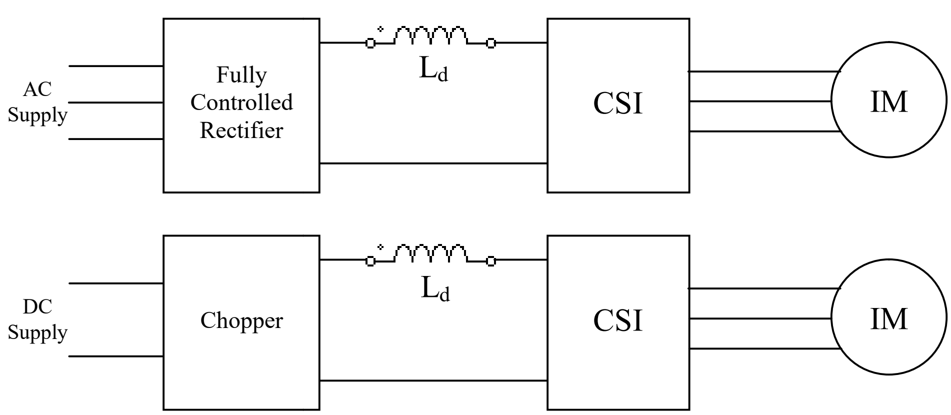
OBJECTIVE : To study CSI fed Induction motor Drive analysis using PSIM Software.

THEORY :

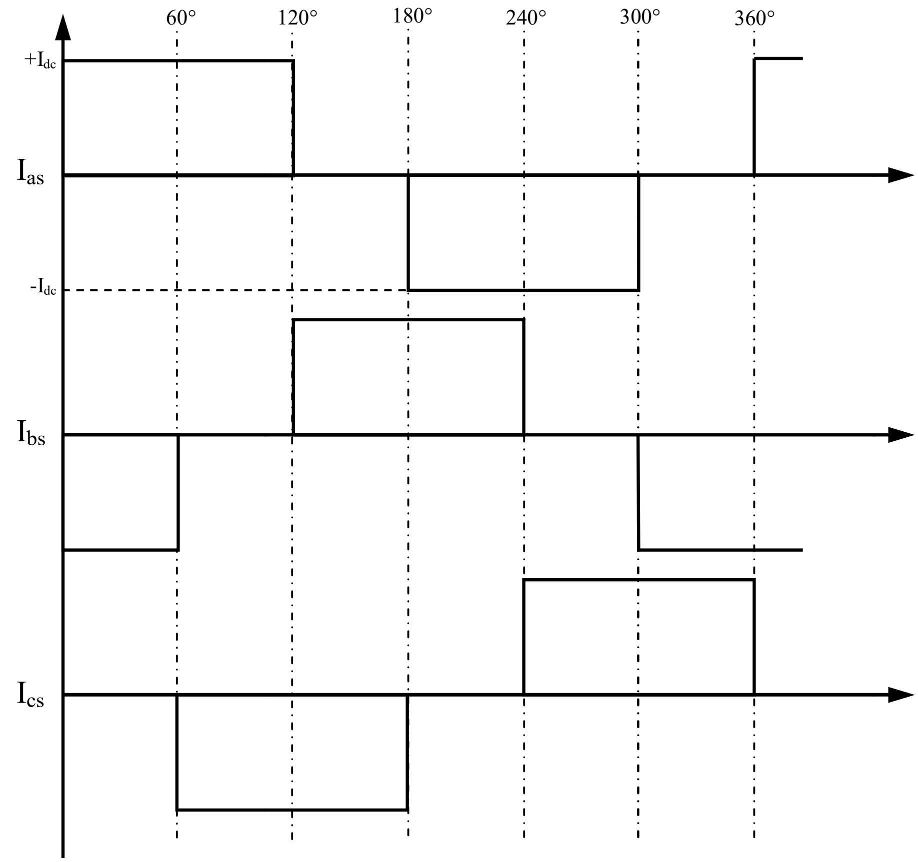
A thyristor current source inverter (CSI) is shown in fig. Diode $D_1 - D_6$ and capacitor $C_1 - C_6$ provide commutation of thyristor $D_1 - D_6$ which are fired with a phase difference of 60° in sequence of their number. Inverter behaves as a current source due to presence of large inductance L_d in dc link.



For a given speed, torque is controlled by varying dc link current I_d by changing the value of V_d. Therefore, when supply is ac, a controlled rectifier is connected between the supply and inverter and when supply is dc, a chopper is interposed between the supply and inverter. The maximum value of dc output voltage of fully-controlled rectifier and chopper are chosen so that the motor terminal voltage saturates at rated voltage.



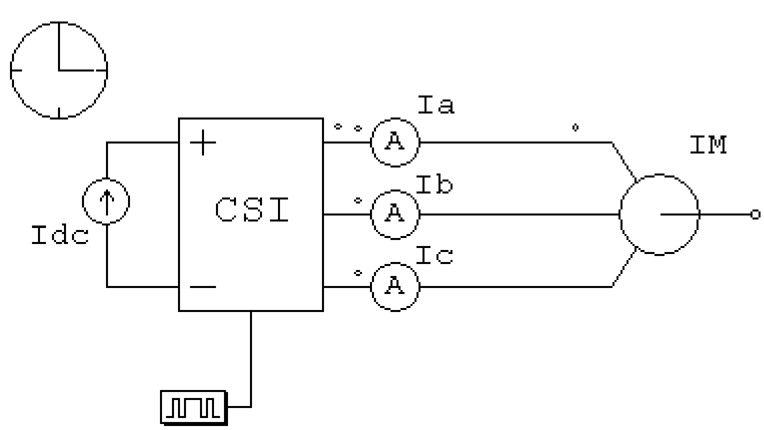
The output current waveform is shown in fig.

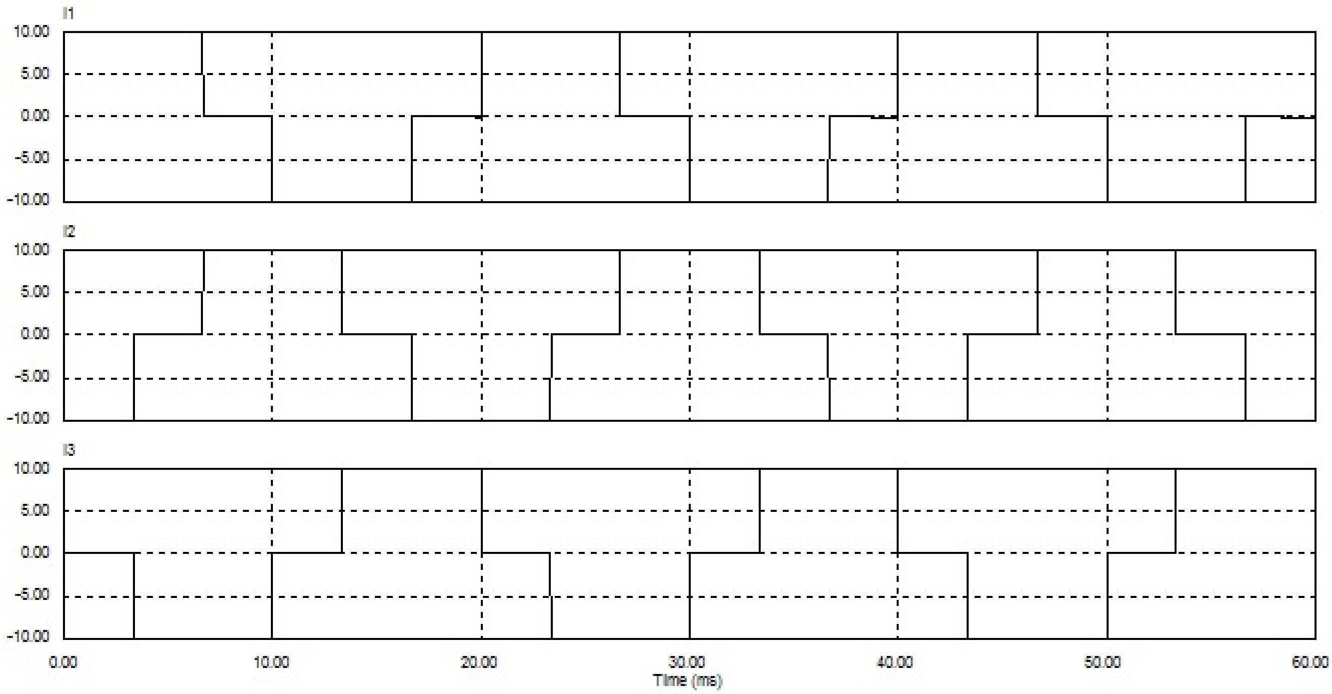


The fundamental component of motor phase current is

$$I_{ph} = \frac{\sqrt{6}}{\pi} I_d$$

CIRCUIT DIAGRAM FOR PSIM :





PROCEDURE :

1) Open the PSIM software and construct the circuit of half-controlled single phase rectifier.
2) Use the "element" icon to get all the relevant components or devices.
3) Reset the parameters of different devices by double clicking over them as specified below :

Device	*Description*	*Parameters*
IM	Induction Motor	R_s = 0.183, L_s = 0.0015, R_r = 0.277, L_r = 0.0022, L_m = 0.0538, MI = 0.0165, P = 4, All Flags = 1.
CSI	Current Source Inverter	All = 0.
I_{dc}	Current Source	Amplitude = 10.

4) Connect voltmeter as shown in the fig.
5) Now click 'simulation control' icon for transient analysis. Set the parameters with suitable values like Time Step = 1E-005, Total Time = 0.06, Print Time = 0, Print Step = 1, All Flags = 0.
6) Then click "run simulation" for simulation process. Graphical window will appear.
7) Observe the waveforms of the following: Output Current (I_a, I_b and I_c).
8) Also observe the waveforms of electromagnetic torque (Tem_IM).
9) Record the all above waveform in graph paper.

DISCUSSION :

TITLE : PWM Inverter fed 3 phase Induction Motor control.

OBJECTIVE : To study PWM Inverter fed 3 phase Induction Motor control using PSIM Software.

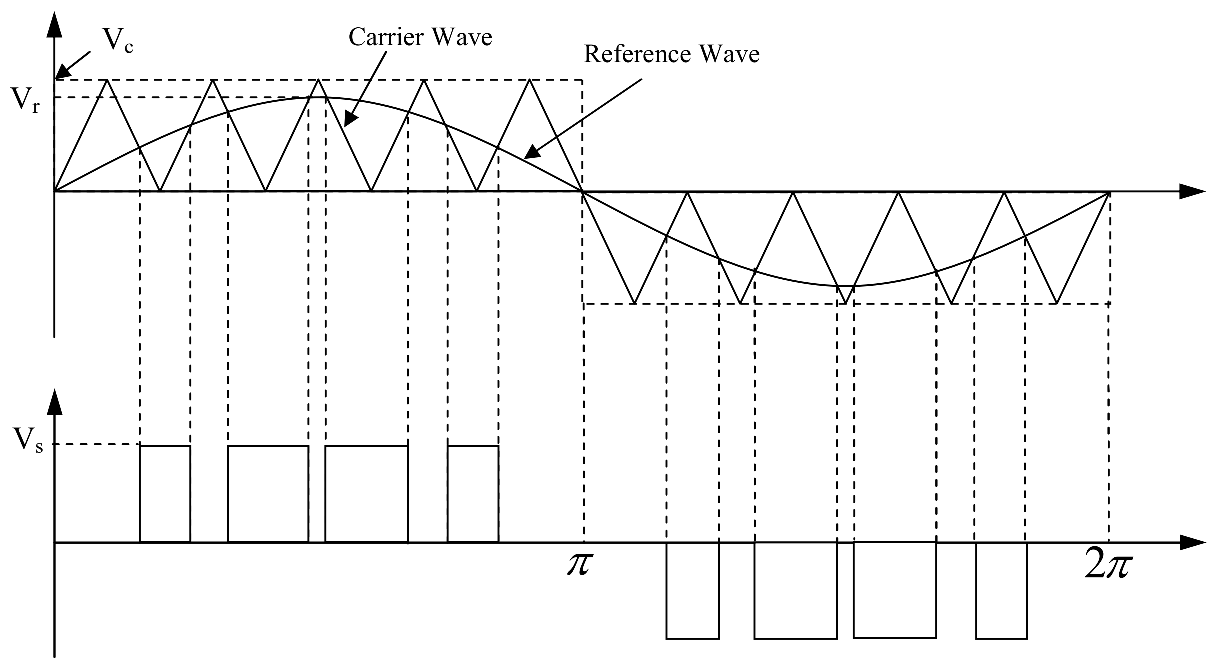
THEORY :

In Pulse Width Modulation (PWM) method, a fixed dc input voltage is given to inverter and a controlled ac output voltage is obtained by adjusting the ON and OFF period of inverter components. PWM techniques are characterized by constant amplitude pulses. The width of these pulses is modulated to obtain controlled inverter output voltage and to reduce its harmonics content. Different PWM techniques are as under

i. Single-pulse modulation (SPM)
ii. Multiple-pulse modulation (MPM)
iii. Sinusoidal-pulse modulation (SPM)

In PWM inverters, forced commutation is essential. The three PWM techniques listed above differ from each other in the harmonics content in their respective output voltages. Mostly in industrial application sinusoidal-pulse modulation is used to control three phase induction motor.

In SPM several pulses per half cycle are used as in case of MPM. In MPM the pulse width is equal for all pulses but in SPM pulse width is a sinusoidal function of angular position of pulse in a cycle. In SPM a high frequency triangular carrier wave v_c is compared with a sinusoidal reference wave v_r of desired frequency. The intersection of v_c and v_r waves determines the switching instants and commutation of the modulated pulse as shown in fig. The carrier and reference waves are mixed in a comparator. When sinusoidal wave has magnitude higher than triangular wave, comparator output is high, otherwise it is low.

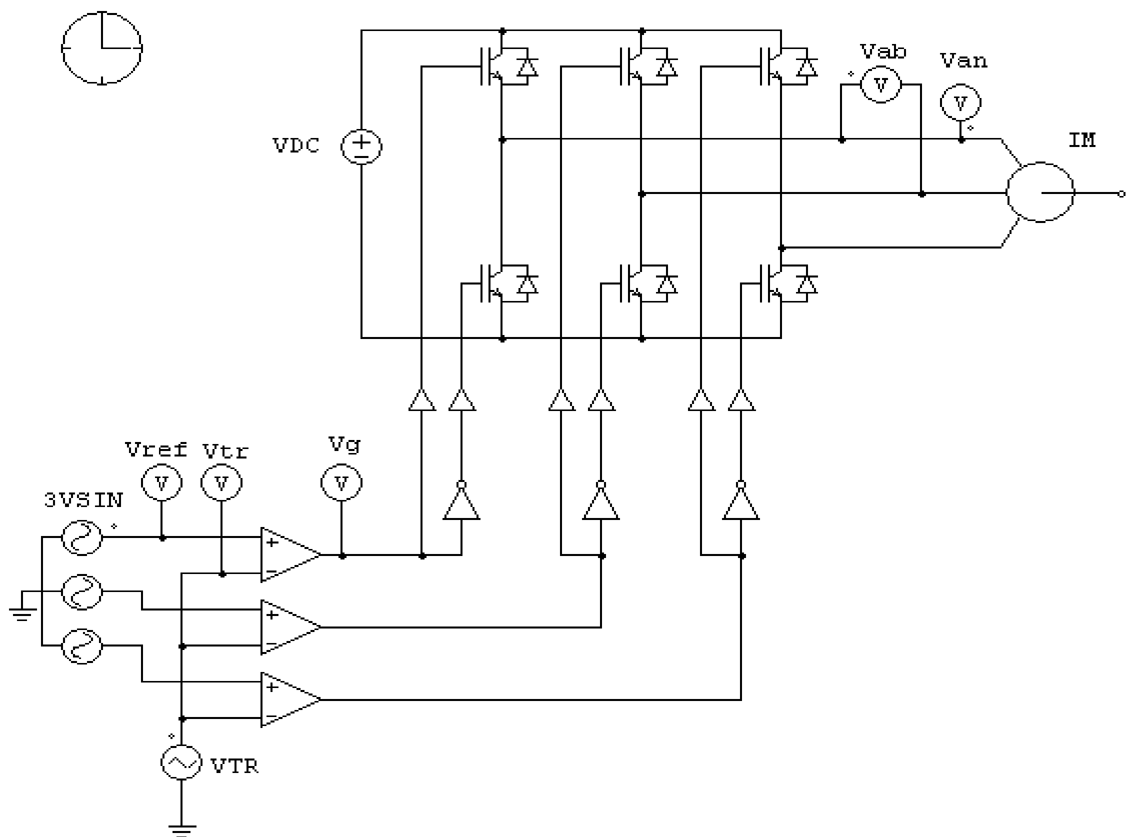


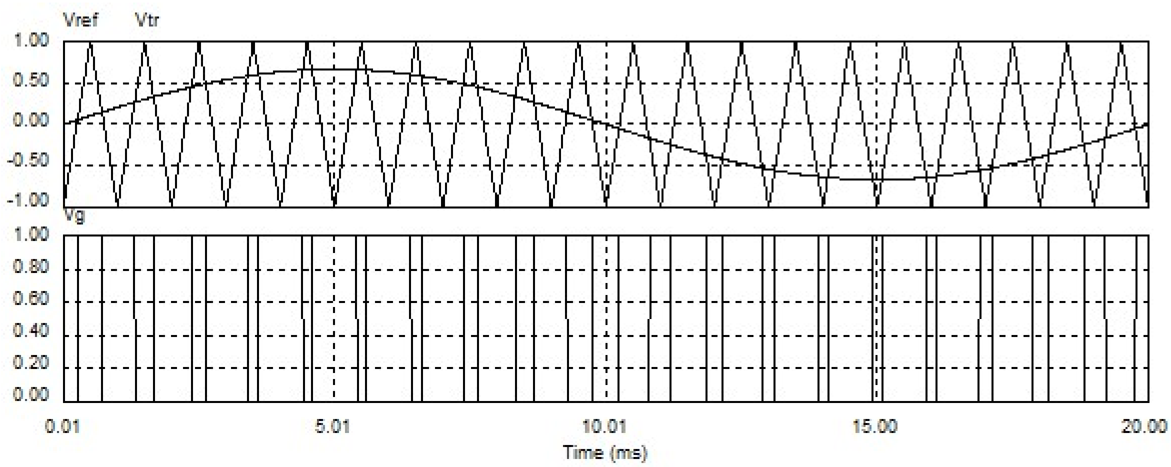
The fundamental component in the output phase voltage of PWM inverter operating with sinusoidal PWM is given by

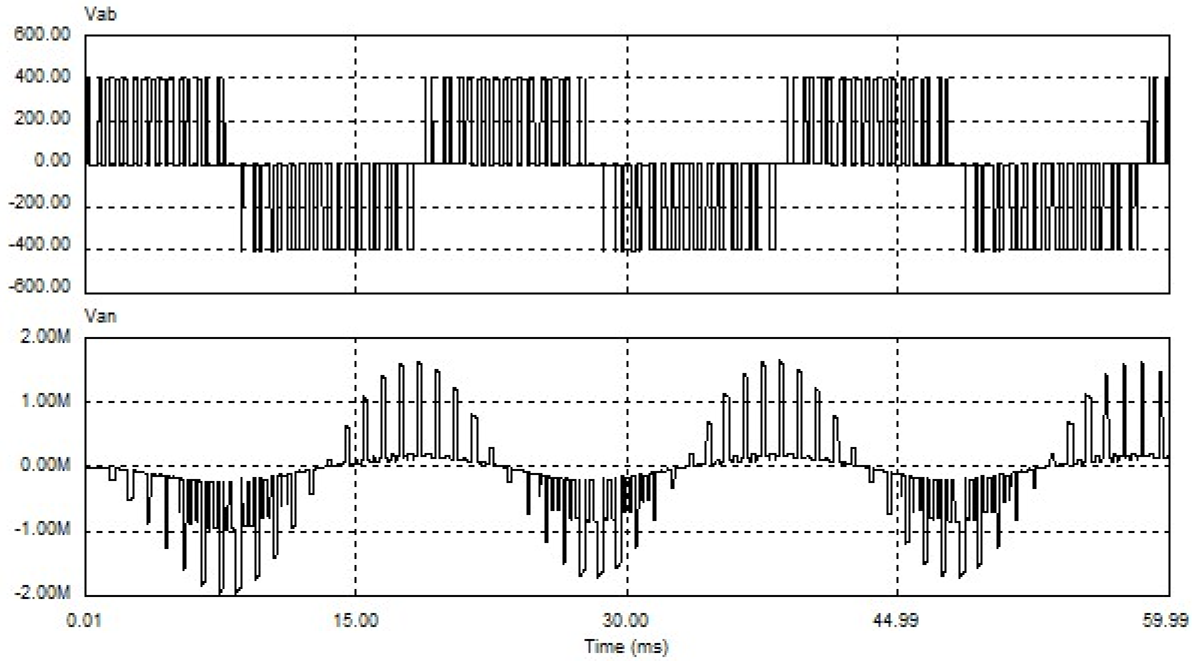
$$V_{ph} = m\frac{V_{dc}}{2\sqrt{2}}$$

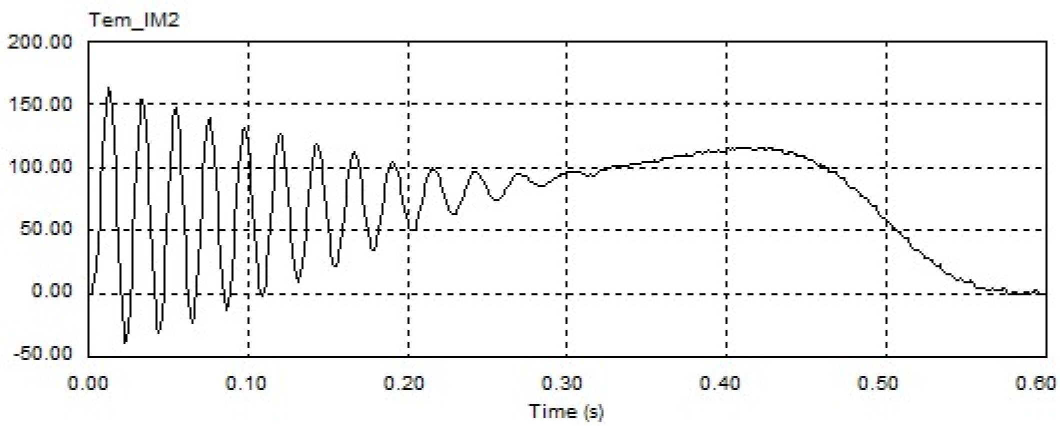
Where m is the modulation index. The ratio of peak amplitude of reference and carrier wave i.e. V_r/V_c is called modulation index (MI). The MI controls the harmonic content of output voltage waveform.

CIRCUIT DIAGRAM FOR PSIM :









PROCEDURE :

1) Open the PSIM software and construct the circuit of half-controlled single phase rectifier.
2) Use the “element” icon to get all the relevant components or devices.
3) Reset the parameters of different devices by double clicking over them as specified below :

Device	*Description*	*Parameters*
IM	Induction Motor	R_s = 0.183, L_s = 0.0015, R_r = 0.277, L_r = 0.0022, L_m = 0.0538, MI = 0.0165, P = 4, All Flags = 1.
VDC	DC voltage source	Amplitude = 400
IGBT 1-6	IGBT switches	All parameters = 0
VSIN3	3 ph sinusoidal voltage source	V (line-line-rms) = 0.816, Frequency = 50 Init. Angle (phase A) = 0
VTR	Triangular voltage source	Vp-p = 2, Frequency =1000, Duty Cycle = 0.5, DC Offset = -1, Tstart = 0

4) Connect voltmeter as shown in the fig.
5) Now click 'simulation control' icon for transient analysis. Set the parameters with suitable values like Time Step = 1E-005, Total Time = 0.6, Print Time = 0, Print Step = 1, All Flags = 0.
6) Then click "run simulation" for simulation process. Graphical window will appear.
7) Observe the waveforms of the following: Reference and Carrier wave (Vref, Vtr), Vab, Van.
8) Also observe the waveforms of electromagnetic torque (Tem_IM).
9) Record the all above waveform in graph paper.

DISCUSSION :

ELECTRIC DRIVE LAB MANUAL (EE 791)

JIS COLLEGE OF ENGINEERING

ELECTRICAL DEPARTMENT

TITLE : Regenerative / Dynamic braking operation for DC Motor - Study uses software.

OBJECTIVE : To study Regenerative/Dynamic braking operation for DC Motor using PSIM Software.

THEORY :

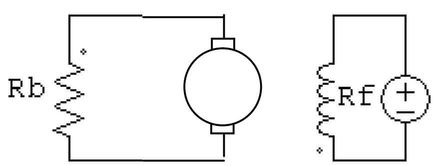
A. Dynamic or Rheostatic Braking

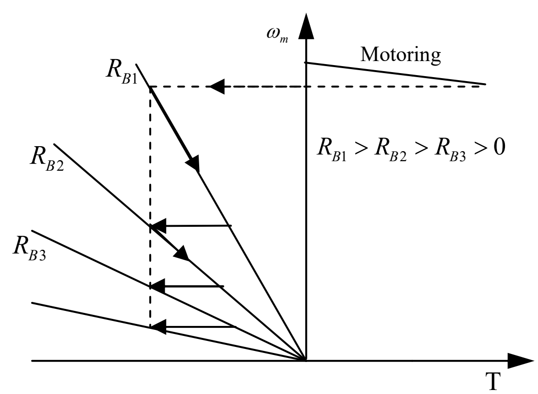
The Dynamic or Rheostatic braking implies operating the motor as a generator so that the mechanical energy is converted into electrical energy, which is dissipated as heat in the resistance of machine winding i.e. armature resistance or in resistance connected to them as an electrical load.

In dynamic braking of self-excited dc motor, motor armature and field is disconnected from the source and connected across a variable braking resistor R_B. The generated energy is dissipated in R_B and R_a. To prevent the machine from becoming demagnetized some arrangement for the polarity reversal of the field or the armature is to be made. Braking torque is developed as soon as the self-excited field current flows through the braking resistor because of rotation of the armature.

In separate excitation, a low voltage high current variable source and a resistor to limit the field current supply the motor field. During braking a variable resistor is switched over to the armature and a controlled current is fed through the field.

The connection diagram of dynamic braking of separately excited dc motor and the speed-torque curve during braking is shown in fig.





In dynamic braking of a d.c. motor armature terminals are alternately shorted and closed through a braking resistance R_b. The steady state braking torque developed by the motor is

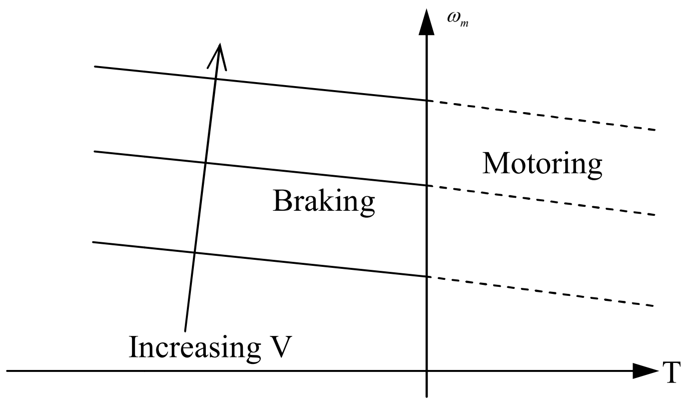
$$T_B = \frac{r_a I_{a,rms}^2 + R_b I_{b,rms}^2}{\omega}$$

where, $I_{a,rms}$ = motor rms current, $I_{b,rms}$ = Resistance rms current, ω= speed in rad/sec.

B. Regenerative Braking

Regenerative braking implies operating the motor as a generator, while it is still connected to supply network. Mechanical energy is converted into electrical energy, part of which is returned to supply and rest of the energy is lost as heat in windings and bearing of the electrical machine. Regeneration does not, in most cases, involve any switching operation, unless it is required to change the speed at which it become effective. Most electrical machines pass smoothly from motoring to generating region, when overdriven by load. In regenerative braking following condition should be satisfied - $E > V$ and negative I_a.

Field flux cannot be increased substantially beyond the rated value because of saturation, therefore for a fixed source voltage of rated value of regenerative braking is possible only for speed higher than rated value and with a variable voltage source it is also possible below the rated speed. In series motor as speed increases, armature current, and therefore flux decreases. Thus regenerative braking is not possible. The speed-torque characteristics curve during braking of separately excited dc motor is shown below



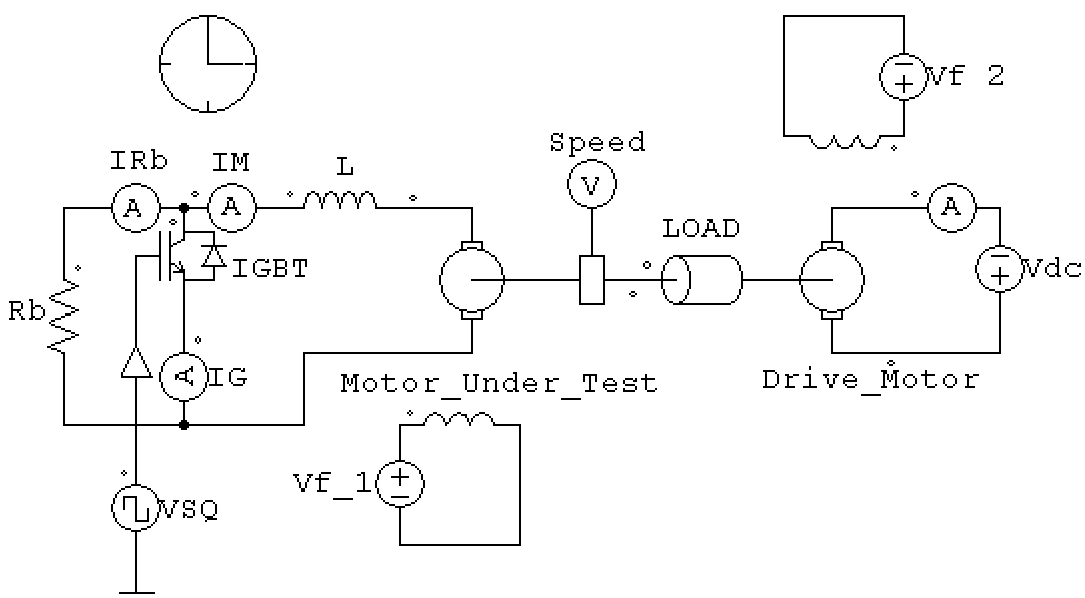
In regenerative braking method armature terminals are first shorted and then connected to a dc source. This is repetitively carried out. Steady state braking torque developed by the motor is

$$T_B = \frac{VI_0 + r_a I_{a,rms}^2}{\omega}$$

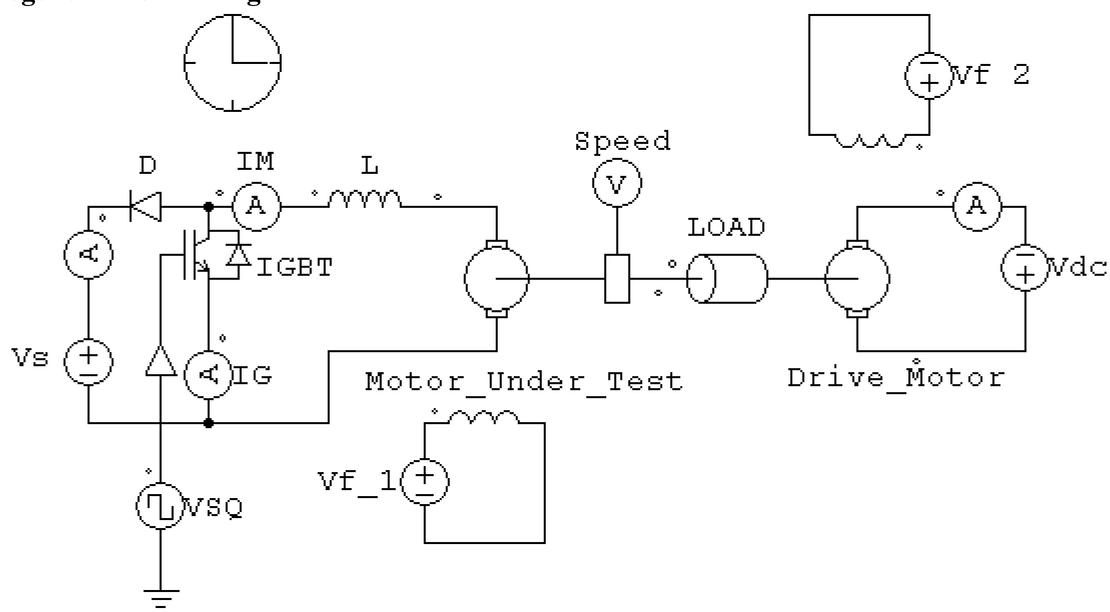
where I_0 = average current through the source.

CIRCUIT DIAGRAM FOR PSIM :

A. For Dynamic Braking



B. For Regenerative Braking



PROCEDURE :

A. For Dynamic Braking

1) Open the PSIM software and use the "element" icon to get all the relevant components/ devices.
2) Reset the parameters of different devices by double clicking over them as specified in the given Fig.1 Specify the two motor parameters as given below :

Device	*Description*	*Parameters*
Motor under Test	Separately Excited DC Motor	Ra=0.055, La=0.01, R_f=55, L_f=0.02, MI =0.2, Vt=220, Ia= 80, n(rated) = 1500, I_f =4, Torque Flag=0, Master/Slave Flag=0.
Drive Motor	Separately Excited DC Motor	Ra=0.055, La=0.01, R_f=55, L_f=0.02, MI =0.2, Vt=220, Ia= 80, n(rated) = 1500, I_f =4, Torque Flag= 1, Master/Slave Flag=1.
VDC		Amplitude = 55
Vf_1, Vf_2		Amplitude = 220
R	Resistance	Resistance = 20
L	Inductance	Inductance = 0.01

4) Set the duty cycle of the square voltage source VSQ (frequency 1000Hz) at $\delta = t_{on}/T = 0.2$.
5) Vary the speed of the dc machine under test from 20% to 100% of rated speed in steps of 10% by adjusting the applied voltage V_{DC} to the armature of the drive motor.
6) For each speed obtain the developed torque from the simulated output SIMVIEW (with final time 4/5 sec) and enter the measured average torque(to get measure option enable first go to 'measure' option-'measure' in Simview. Now select the curve written in word in simview to measure) and speed in observation table.
7) Repeat steps 4 through 6 for δ= 0.4, 0.6, 0.8 .

8) For any specific setting of δ and speed obtain the oscillographic traces of motor current, device current and braking resistor current in separate windows.
9) Make the speed vs torque plots of the results for all the four δ values on a single graph paper.

B. For Dynamic Braking

1) Now change the circuit as shown in Fig.2. Follow the procedure of dynamic braking 1-3.
2) Set the duty cycle of the square voltage source VSQ (frequency 1000Hz), $\delta = t_{on}/T = 0.1$ and follow the procedure 5-6 of dynamic braking.
3) Repeat steps 2 for δ= 0.2, 0.3, 0.4. Take the same set of readings. Note that at no stage average motor current exceeds its rated value.
4) For any specific setting of δ and speed obtain the oscillographic traces of motor current, device current and source input current.
5) Make the speed vs torque plots of the results for all the four δ values on a single graph paper.

OBSERVATION TABLE :

Sl. No.	Duty Cycle	Speed	Braking Torque (Measured)	Motor rms Current	Braking resistor rms current	Predicted Braking Torque

DISCUSSION :

TITLE : Regenerative / Dynamic braking operation for Induction Motor - Study uses software.

OBJECTIVE : To study Regenerative/Dynamic braking operation for IM using PSIM Software.

THEORY :

A. Dynamic or Rheostatic Braking

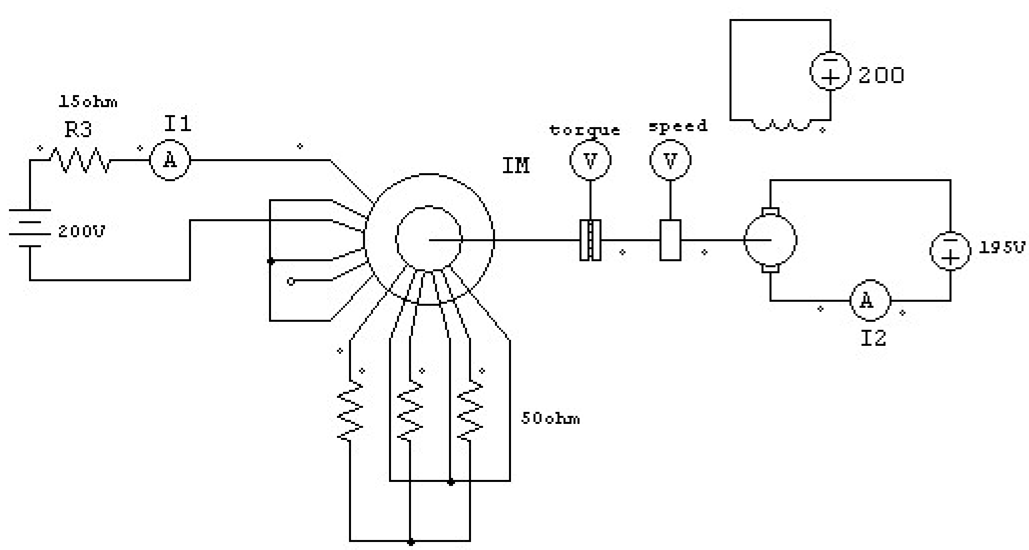
In dynamic braking the motor speed is reduced by applying a fixed dc field to the stator. Braking is achieved by connecting the stator winding to a dc source and the rotor windings (wound rotor) are terminated to a suitable variable resistor. The magnitude of the braking torque depends on the field strength set up by the stator windings, rotor speed and rotor circuit resistance. The magnitude of the braking torque can be controlled by controlling the dc voltage to the stator by SCR bridge and by adjusting the rotor resistance.

B. Regenerative Braking

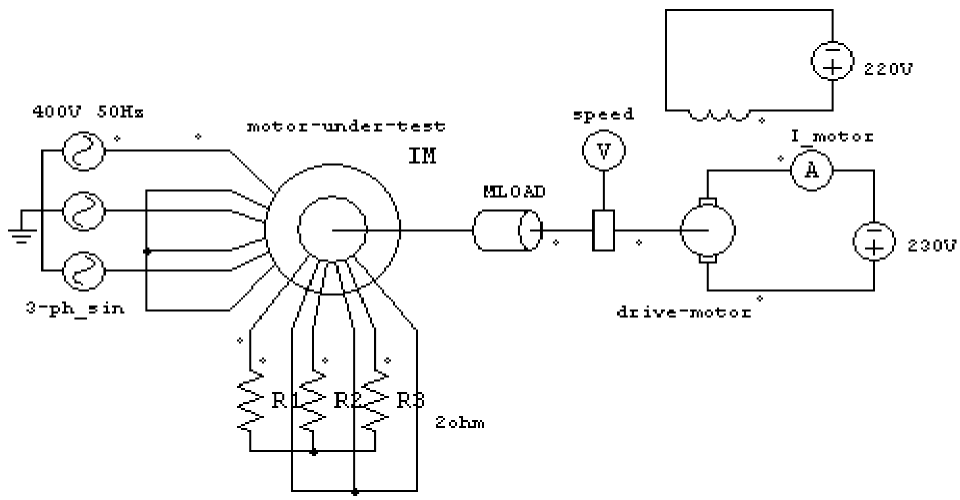
In the regenerative braking mode the rotor is rotated above the synchronous speed under the influence of external torque and energy is reverting back to the supply. Under this scheme the motor looks like a generator connected in parallel with the supply and at the same time it draws reactive power for excitation. The torque in the regenerative condition is negative and the value of the maximum torque developed is more than that in the motoring condition.

CIRCUIT DIAGRAM FOR PSIM :

A. For Dynamic Braking



B. For Regenerative Braking



PROCEDURE :

A. For Dynamic Braking

1) Open the PSIM software and make the circuit as shown in Fig.1 below.
2) Use the “element” icon to get all the relevant components/ devices.
3) Specify the two motor parameters as given below :

Device	*Description*	*Parameters*
Motor under Test	3 phase Slip Ring Type Induction Machine	Rs=1.32, Ls=0.0136, Rr=1.23, L_r=0.0136, Lm =0.2215, Ns/Nr=1, Poles= 4, MI= 0.225, Torque Flag= 0, Master/Slave Flag=0.
Driver Motor	Separately Excited DC Motor	Ra=0.055, La=0.01, R_f=55, L_f=0.02, MI =0.154, Vt=220, Ia= 80, n(rated) = 1500, I_f =4, Torque Flag=0, Master/Slave Flag=1.

4) Connect rotor resistances 50 ohm with the rotor circuit of the slip ring motor.
5) Connect the two terminals of the slip ring motor to a dc supply 200V with a resistance 15 ohm as shown in fig. 1.
6) Vary the speed of the d.c. drive_motor from 20% to 100% of rated speed in steps of 10% by adjusting the armature voltage of the drive motor.
7) For each speed obtain the developed torque from the simulated output SIMVIEW (with final time 6/8 sec) and enter the measured average torque and speed in the result table below.
8) Measure the braking resistor current I1 and motor current I2 in each speed.
9) Make the speed vs torque plots with the above results.

B. For Regenerative Braking:

1) Now change the circuit as shown in Fig.2. Follow the procedure of dynamic braking 1-3.
2) Connect rotor resistances 2 ohm with the rotor circuit of the slip ring motor.
3) Connect a mechanical load of 9 N-m with the slip ring motor.
4) Connect a 3 phase sinusoidal ac supply 400V, 50Hz with the stator of the slip ring motor as shown.
5) Vary the speed from 1510 rpm to 1650 rpm in steps of 10 or 15 rpm by adjusting the armature voltage of the drive motor. Note down the developed torque in each case.
6) Also measure the dc motor average currents.

OBSERVATION TABLE :

A. For Dynamic Braking

Sl. No.	Speed	Braking Torque (Measured)	Average Motor Current	Average braking resistor current	Predicted Braking Torque

B. For Dynamic Braking

Sl. No.	Speed	Braking Torque (Measured)	Average Motor Current	Predicted Braking Torque

DISCUSSION :