

ELECTRICAL DRIVES AND SIMULATION

LAB MANUAL

Year : 2017-2018
Course Code : BPE102
Regulations : IARE– R16
Semester : II
Branch : PEED

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(Autonomous)
Dundigal – 500 043, Hyderabad
Department of Electrical and Electronics Engineering



INSTITUTE OF AERONAUTICAL ENGINEERING **(Autonomous)**

Dundigal, Hyderabad - 500 043

Department of Electrical and Electronics Engineering

VISION AND MISSION OF THE DEPARTMENT:

VISION

The vision of the Electrical and Electronics Engineering department is to build a research identity in all related areas of Electrical Engineering uniquely. Through core research and education, the students will be prepared as the best professional Engineers in the field of Electrical Engineering to face the challenges in such disciplines.

MISSION:

The Electrical and Electronics Engineering Department supports the mission of the College through high quality teaching, research and services that provide students a supportive environment. The department will make the best effort to promote intellectual, ethical and technological environment to the students. The department invokes the desire and ability of life-long learning in the students for pursuing successful career in engineering.



INSTITUTE OF AERONAUTICAL ENGINEERING (Autonomous)

Dundigal, Hyderabad - 500 043

1. PROGRAM OUTCOMES:

M.TECH - PROGRAM OUTCOMES (POS)	
PO-1	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems (Engineering knowledge).
PO-2	Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences (Problem analysis).
PO-3	Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations (Design/development of solutions).
PO-4	Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions (Conduct investigations of complex problems).
PO-5	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations (Modern tool usage).
PO-6	Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice (The engineer and society).
PO-7	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development (Environment and sustainability).
PO-8	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice (Ethics).
PO-9	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings (Individual and team work).
PO-10	Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions (Communication).
PO-11	Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments (Project management and finance).
PO-12	Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change (Life-long learning).

2. PROGRAM SPECIFIC OUTCOMES

PROGRAM SPECIFIC OUTCOMES (PSO's)	
PSO-1	Professional Skills: The ability to understand, analyze and develop computer programs in the areas related to algorithms, system software, multimedia, web design, big data analytics, and networking for efficient design of computer-based systems of varying complexity.
PSO-2	Problem-Solving Skills: The ability to apply standard practices and strategies in software project development using open-ended programming environments to deliver a quality product for business success.
PSO-3	Successful Career and Entrepreneurship: The ability to employ modern computer languages, environments, and platforms in creating innovative career paths to be an entrepreneur, and a zest for higher studies.

3. ATTAINMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

S.No	Experiment	Program Outcomes Attained	Program Specific Outcomes Attained
WEEK-1	Three phase permanent magnet synchronous motor drive simulation using MATLAB	PO1, PO9	PSO2, PSO3
WEEK-2	three phase voltage source with fixed low side bias simulation using MATLAB	PO1, PO9	PSO2, PSO3
WEEK-3	Three phase voltage source converter with space vector PWM simulation using MATLAB	PO1, PO2	PSO2, PSO3
WEEK-4	Buck converter simulation using MATLAB	PO2, PO9	PSO2, PSO3
WEEK-5	Six pulse cycloconverter simulation using MATLAB	PO1, PO9	PSO2, PSO3
WEEK-6	Speed control DC Motor using BJT-H bridge simulation using MATLAB	PO1, PO9	PSO2, PSO3
WEEK-7	Three phase thyristor converter simulation using MATLAB	PO1, PO9	PSO2, PSO3
WEEK-8	Three phase 48 pulse GTO converter simulation using MATLAB	PO1, PO2	PSO2, PSO3
WEEK-9	Three phase three level PWM converter simulation using MATLAB	PO1, PO9	PSO2, PSO3
WEEK-10	Three phase space – vector PWM converter simulation using MATLAB	PO1, PO9	PSO2, PSO3
WEEK-11	Three phase five level PWM converter simulation using MATLAB	PO1, PO9	PSO2, PSO3
WEEK-12	Chopper fed DC motor drive simulation using MATLAB	PO1, PO12	PSO2, PSO3

4. MAPPING COURSE OBJECTIVES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES:

Course Objectives	Program Outcomes												Program Specific Outcomes		
	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
I		√	√									√	√		
II		√	√									√	√		

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EXPERIMENT – 1

THREE PHASE PERMANENT MAGNET SYNCHRONOUS MOTOR DRIVE SIMULATION USING MATLAB

1.1 AIM:

To Construct Three phase permanent magnet synchronous motor drive simulation using MATLAB.

1.2 APPARATUS:

S.No	SOFTWARE USED	DESKTOP QUANTITY
1	MATLAB	36

1.3 BLOCK DIAGRAM:

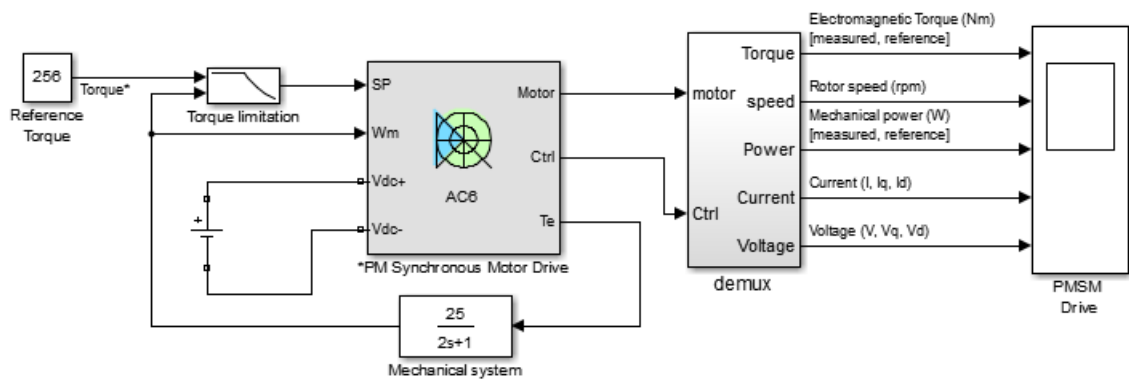


Fig – 1.1 Three Phase Permanent Magnet Synchronous Motor Drive Simulation Using MATLAB

1.4 DISCRPTION:

This circuit uses a modified version of the AC6 block of the Sim Power Systems™ electric drives library. It models a flux weakening vector control for a 100 kW, 12500 rpm, salient pole PMSM powered by a 288 Vdc source. The mechanical system is represented externally. That's why the input of the motor is the speed and the output is the electromagnetic torque.

The PM synchronous motor drive is composed of four main parts: The electrical motor, the Three-phase Inverter, the VECT controller and the Speed Controller.

- The electrical motor is a 288 Vdc, 100 kW PMSM. This motor has 8 pole and the magnets are buried (salient rotor's type).
- The Three-phase Inverter is a voltage source inverter, controlled by PWM. This block is built using the universal bridge Block.
- The VECT controller block computes the three reference motor line currents corresponding to the flux and torque references and then generates a corresponding PWM using a three-phase current regulator. When the nominal flux is required, an optimal control is used in order

to minimise the line current amplitude for the required torque. When a flux weakening is needed, the amplitude and the phase of the current are changed to extend the torque-speed operating range.

- The Speed Controller is used in torque regulation mode. The normalized flux value is computed with the speed of the machine in order to perform a flux weakening control.

The Torque limitation block is used to prevent the limitation due to the torque-speed characteristic of this motor for a 288 Vdc source. When the internal machine's voltage reaches the inverter voltage (because the desired torque is too high for the motor's speed), the inverter becomes in saturation mode (the desired current cannot flow anymore into motor). After this point, there will be a loss of current tracking which will decrease the motor current. This block is used to reduce the reference torque as a function of the motor's speed and the torque-speed characteristic in order to never operate in inverter saturation mode.

Motor torque, speed, power, currents and voltages signals are available at the output of the block.

1.5 SIMULATION:

Start the simulation. You can observe the motor torque (electromagnetic and reference), the rotor speed, the mechanical power (electromagnetic and reference), the stator currents (magnitude, I_q and I_d), and the stator voltages (magnitude, V_q and V_d)

- At $t = 0$ s, the torque set point is set to 256 Nm (the nominal torque of the motor). The electromagnetic torque reaches rapidly the reference.
- At $t = 0.104$ s, the rotor speed exceeds the nominal speed of 3000 rpm. Hence, a flux weakening is performed in order to limit the back electromotive force (BEMF) of the motor; therefore the I_d current component is increased (negatively). Also the reference torque is limited (due to the torque-speed characteristic of the motor) to prevent inverter saturation, causing a decrease in the I_q current component. Note that the magnitude of the current is constant; only the angle changes.

Now change the Reference Torque to 100 Nm and observe the results:

- At $t = 0$ s, the torque set point is set to 100 Nm. The current amplitude is optimal for this torque.
- At $t = 0.28$ s, the rotor speed exceeds the nominal speed of 3000 rpm. Hence, a flux weakening is performed in order to limit the back electromotive force (BEMF) of the motor; therefore the I_d current component is increased (negatively).
- At $t = 1.06$ s, the reference torque is limited (due to the torque-speed characteristic of the motor) to prevent inverter saturation, causing a decrease in the I_q current component. The magnitude of the current is maintained at a constant value, but the phase of current changes.

Note that the electromagnetic torque follows precisely the reference torque even in the flux weakening region.

1.6 PROCEDURE:

1. Make the connections as shown in the diagram by using MATLAB Simulink
2. Enter the rated values of the particular element
3. Draw the respective wave forms

1.7 RESULT:

1.8 PRE LAB VIVA QUESTIONS:

1. List the different types of electric Drives
2. What is mean by drive
3. What is mean by Powergui
4. What is the function of synchronous machine
5. Write the torque equation for synchronous machine

1.9 POST LAB VIVA QUESTIONS:

1. What is Permanent magnet principle
2. Types of the motors
3. What are the Advantages of PMSM?
4. Write some Applications of PMSM

EXPERIMENT – 2

THREE PHASE VOLTAGE SOURCE WITH FIXED LOW SIDE BIAS SIMULATION USING MATLAB

2.1 AIM:

To construct three phase voltage source with fixed low side bias simulation using MATLAB.

2.2 APPARATUS:

S. No	SOFTWARE USED	DESKTOP QUANTITY
1	MATLAB	36

2.3 BLOCK DIAGRAM:

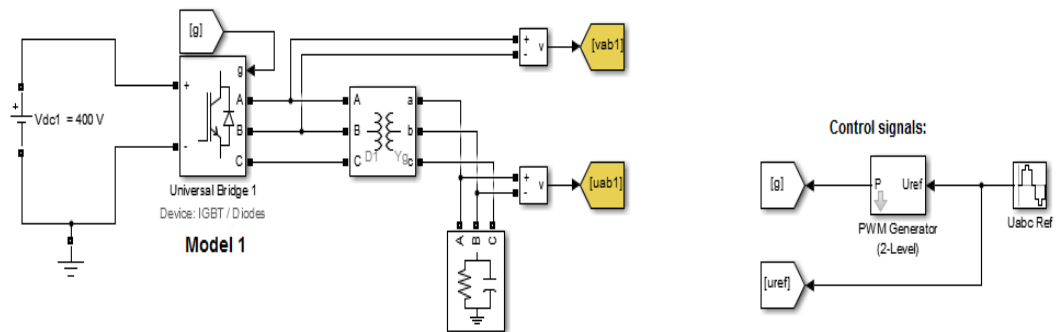


Fig – 2.1 Model - I

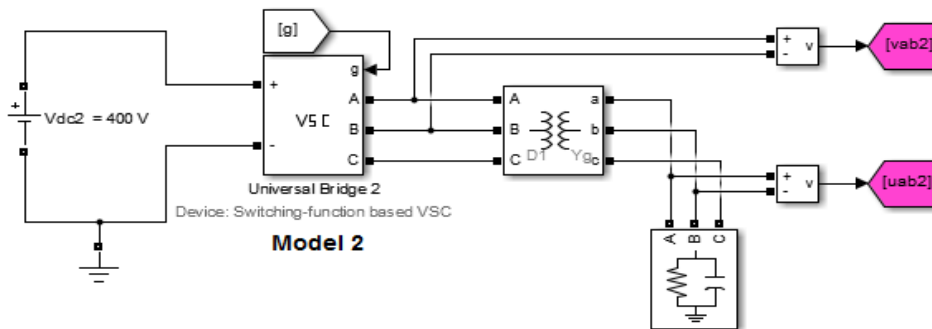


Fig – 2.2 Model - II

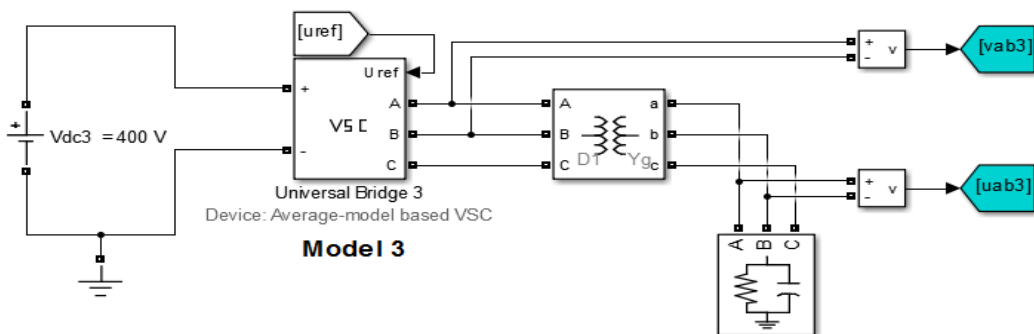


Fig – 2.3 Model – III

Three Phase Voltage Source with Fixed Low Side Bias Simulation using MATLAB

2.5 DESCRIPTION:

Model 1 is a detailed model using 6 IGBTs and 6 anti-parallel diodes.

Model 2 is a Switching-Function type equivalent model where switches are replaced by two sources of voltage on AC side and a current source on DC side. As for detailed model 1, this model uses the 6 IGBT pulses as control input (g). This model correctly represents harmonics generated by the VSC.

Model 3 is an average-model type. Unlike model 2 which uses pulses, this model uses the three reference signals (uref) representing the three average voltages generated at ABC terminals. The model does not represent harmonics. It can be used with larger sample times (typically 10 times larger than required by detailed model) while preserving the average voltage dynamics.

In both model 2 and model 3, the VSC is assumed to be ideal (AC instantaneous power= DC instantaneous power).

2.6 PROCEDURE:

1. Make the connections as shown in the diagram by using MATLAB Simulink
2. Enter the rated values of the particular element
3. Draw the respective wave forms

2.7 RESULT:

2.8 PRE LAB VIVA QUESTIONS:

1. List the different types of electric Drives
2. What is mean by drive
3. What is mean universal bridge
4. What is the function of three phase transformer
5. Define voltage source converter

2.9 POST LAB VIVA QUESTIONS:

1. What is the difference between VSC and VCI
2. What is the difference between VSC and CSI
3. What are the Advantages of VSC?
4. Write some Applications of VSC

EXPERIMENT – 3

THREE PHASE VOLTAGE SOURCE CONVERTER WITH SPACE VECTOR PWM SIMULATION USING MATLAB

3.1 AIM:

To construct three phase voltage source converter with space vector PWM simulation using MATLAB

3.2 APPARATUS:

S. No	SOFTWARE USED	DESKTOP QUANTITY
1	MATLAB	36

3.3 BLOCK DIAGRAM:

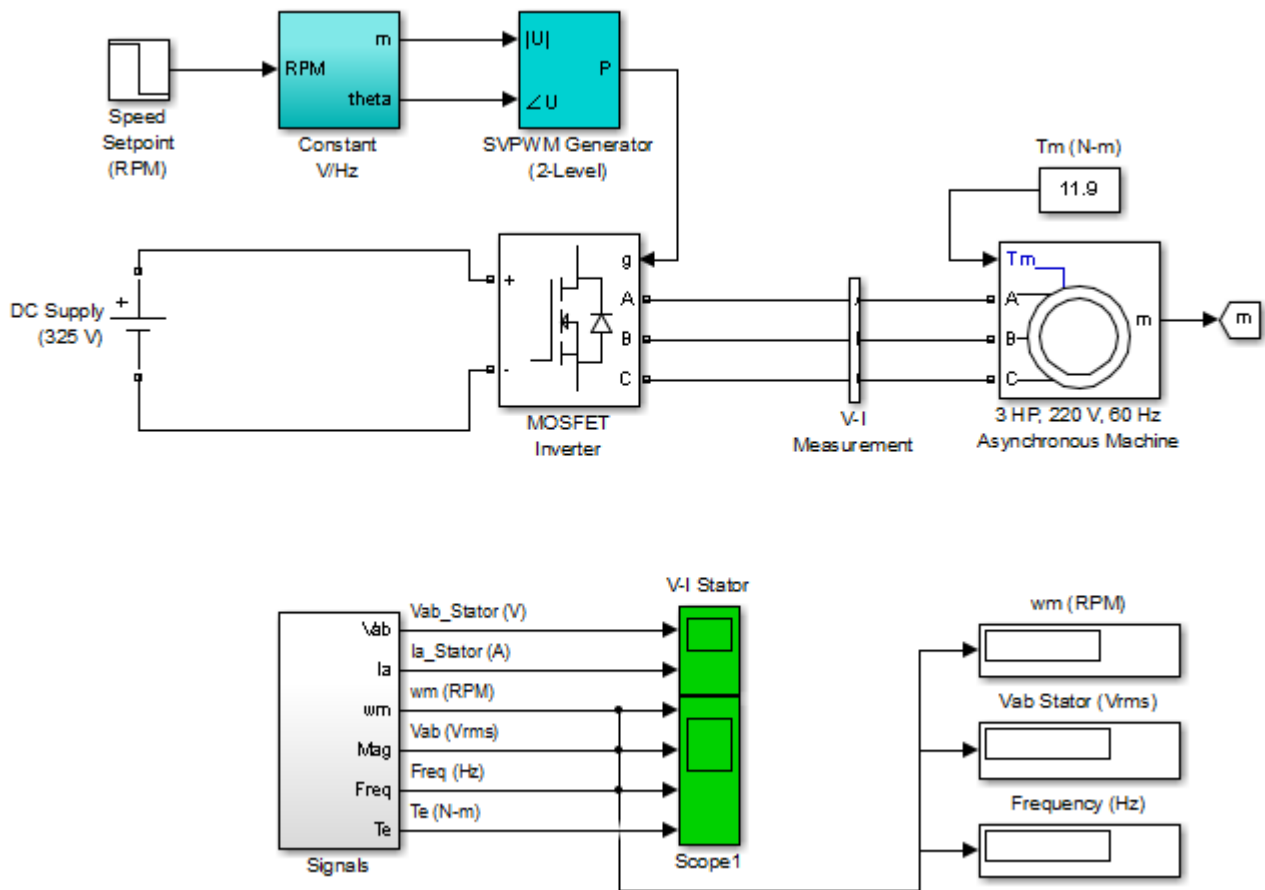


Fig – 3.1 Three Phase Voltage Source Converter with Space Vector PWM Simulation using MATLAB

3.4 DESCRIPTION:

A 3-phase squirrel-cage motor rated 3 HP, 220 V, 60 Hz, 1725 rpm is fed by a 3-phase MOSFET inverter connected to a DC voltage source of 325 V. The inverter is modeled using the "Universal

Bridge" block and the motor by the "Asynchronous Machine" block. Its stator leakage inductance L_s is set to twice its actual value to simulate the effect of a smoothing reactor placed between the inverter and the machine. The load torque applied to the machine's shaft is constant and set to its nominal value of 11.9 N.m.

The firing pulses to the inverter are generated by the "Space-Vector PWM modulator" block of the SPS library. The chopping frequency is set to 1980 Hz and the input reference vector to "magnitude-Angle".

Speed control of the motor is performed by the "Constant V/Hz" block. The magnitude and frequency of the stator voltages are set based on the speed set point. By varying the stator voltages magnitude in proportion with frequency, the stator flux is kept constant.

3.5 SIMULATION:

Start the simulation. Since the initial states have been automatically loaded, the simulation should start in steady-state. The initial motor speed should be 1720 RPM and the rms value of the stator voltages should be 220V@60Hz.

At 0.1s, the speed ω_r is down to 165.8V and the frequency to 45.2 Hz.

Stator voltage (phase AB) and phase A current waveforms can be observed in the "V-I Stator" Scope. You can do a FFT of these two quantities using the powergui FFT Analysis.

Regenerate Initial Conditions:

The initial states required to start this model in steady state with a 1725 rpm reference speed and a 11.9 N.m load torque have been saved in the "power_svpwm_init.mat" file. When you open this model, the InitFcn callback (in the Model Properties/Callbacks) automatically loads into your workspace the contents of this .mat file ("xInitial" variable).

If you modify this model, or change parameter values of power components, the initial conditions stored in the "xInitial" variable will no longer be valid and Simulink® will issue an error message. To regenerate the initial conditions for your modified model, follow the steps listed below:

1. In the Simulation/Configuration Parameters/Data Import/Export Parameters menu, uncheck the "Initial state" parameter.
2. Double click on the Step block labeled "Speed Setpoint (RPM)" and temporarily disable the change of reference speed by multiplying the Step time by 100.
3. Change the Simulation Mode from "Normal" to "Accelerator".
4. Start simulation. When simulation is completed, verify that steady state has been reached by looking at waveforms displayed on the scopes. The final states which have been saved in the "xFinal" structure with time can be used as initial states for future simulations. Executing the next two commands copies these final conditions in "xInitial" and saves this variable in a new file (myModel_init.mat). * >> xInitial=xFinal; * >> save myModel_init xInitial

5. In the File/Model Properties/Callbacks/InitFcn window, change the name of the initialization file from "power_svpwm_init" to "myModel_init". Next time you open this model, the variable xInitial saved in the myModel_init.mat file will be loaded in your workspace.
6. In the Simulation/Configuration Parameters menu, check "Initial state".
7. Start simulation and verify that your model starts in steady-state.
8. Double click on the Step block labeled "Speed Setpoint (RPM)" and re-enable the change of reference speed at t=0.1 s (remove the 100 multiplication factor in the Step time).
9. Change the Simulation Mode back to Normal.
10. Save your Model

3.5 PROCEDURE:

1. Make the connections as shown in the diagram by using MATLAB Simulink
2. Enter the rated values of the particular element
3. Draw the respective wave forms

3.6 RESULT:

3.7 PRE LAB VIVA QUESTIONS:

1. List the different types of electric Drives.
2. What is mean voltage source converter?
3. Define MOSFET?
4. What is the function of VSC?

3.8 POST LAB VIVA QUESTIONS:

1. What is the function of MOSFET?
2. What are the Advantages of three phase voltage source converter with space vector?
3. Write some Applications of voltage source converter.
4. What is the function of asynchronous machine?

EXPERIMENT – 4

BUCK CONVERTER SIMULATION USING MATLAB

4.1 AIM:

To construct buck converter simulation using MATLAB

4.2 APPARATUS:

S. No	SOFTWARE USED	DESKTOP QUANTITY
1	MATLAB	36

4.3 BLOCK DIAGRAM:

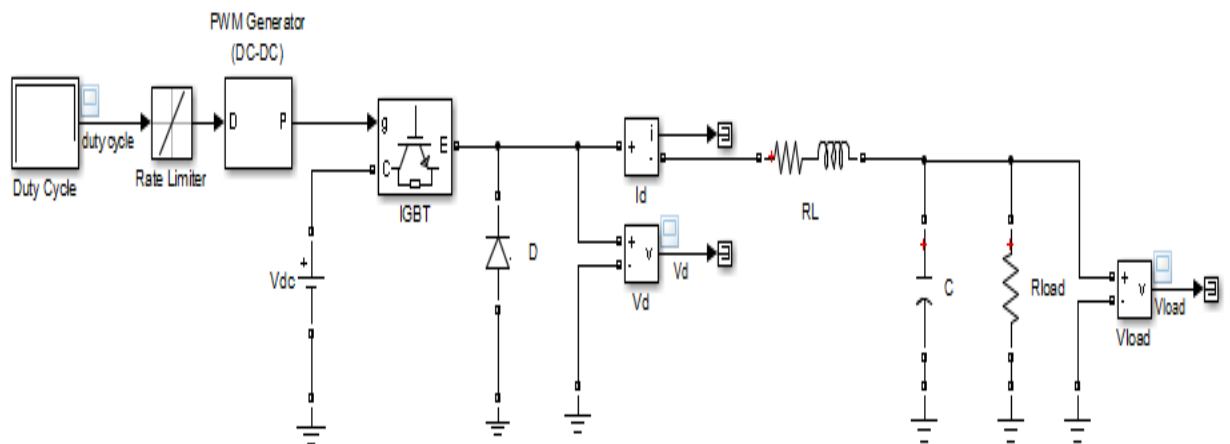


Fig – 4.1 Buck Converter Simulation using MATLAB

4.4 DESCRIPTION:

This example shows a DC-DC buck converter feeding an RC load from a 200 V source. The PWM frequency is set at 5 kHz and duty cycle varies between 0.1 and 0.8. With this 5 kHz PWM frequency, the sample time needed for a 0.5% resolution on duty cycle using a standard discretization method (Tustin or Backward Euler) is $T_s = 1e-6$ sec (1 MHz sampling frequency = $200 \times \text{PWM_freq} \rightarrow \text{resolution} = 1/200 = 0.5\%$). The example shows that using interpolation allows you to run the model with a much larger time step ($T_s = 20e-6$ sec) while preserving model accuracy.

4.5 SIMULATION:

By default, sample time is initialized to $20e-6$ sec (inside the Model Properties / PreloadFcn Callback). Open the powergui block and make sure that the solver type is Tustin and that interpolation is enabled. The simulation data inspector is enabled and the Vload signal is logged.

1. Perform a first simulation with interpolation in service.

2. Disable interpolation and specify $T_s = 1e-6$ in the command window. Perform a second simulation run.
3. In the powergui Solver tab, set Simulation Type to Continuous and select Use ideal switching devices. Perform a third simulation run with the continuous model.
4. Using the Data Inspector, compare the three simulation runs. Vload voltage obtained during the first two runs (interpolation with $T_s = 20e-6$ sec and no interpolation with $T_s = 1e-6$ sec) is very close to the continuous simulation.
5. Notice that the interpolation solver matches the continuous solver and is even more accurate than the standard discrete solver.
6. Compare simulation speeds of discrete models (interpolation with $T_s = 20e-6$ sec and no interpolation with $T_s = 1e-6$ sec). To achieve significant simulation times, increase simulation stop time to 0.5 sec. The diagnostic viewer displays the simulation time at the end of each simulation run. The speed increase obtained with the interpolation method is approximately 4X.

4.6 PROCEDURE:

1. Make the connections as shown in the diagram by using MATLAB Simulink
2. Enter the rated values of the particular element
3. Draw the respective wave forms

4.7 RESULT:

4.8 PRE LAB VIVA QUESTIONS:

1. Define duty cycle?
2. What is the function of IGBT?
3. What do you mean by PWM?
4. What is the function of buck converter?

4.9 POST LAB VIVA QUESTIONS:

1. Explain buck converter?
2. What is the difference between IGBT and MOSFET?
3. What are the Advantages of buck converter?
4. Write some Applications of buck converter?

EXPERIMENT – 5

SIX PULSE CYCLOCONVERTER SIMULATION USING MATLAB

5.1 AIM:

To construct six pulse cycloconverter simulation using MATLAB

5.2 APPARATUS:

S. No	SOFTWARE USED	DESKTOP QUANTITY
1	MATLAB	36

5.3 BLOCK DIAGRAM:

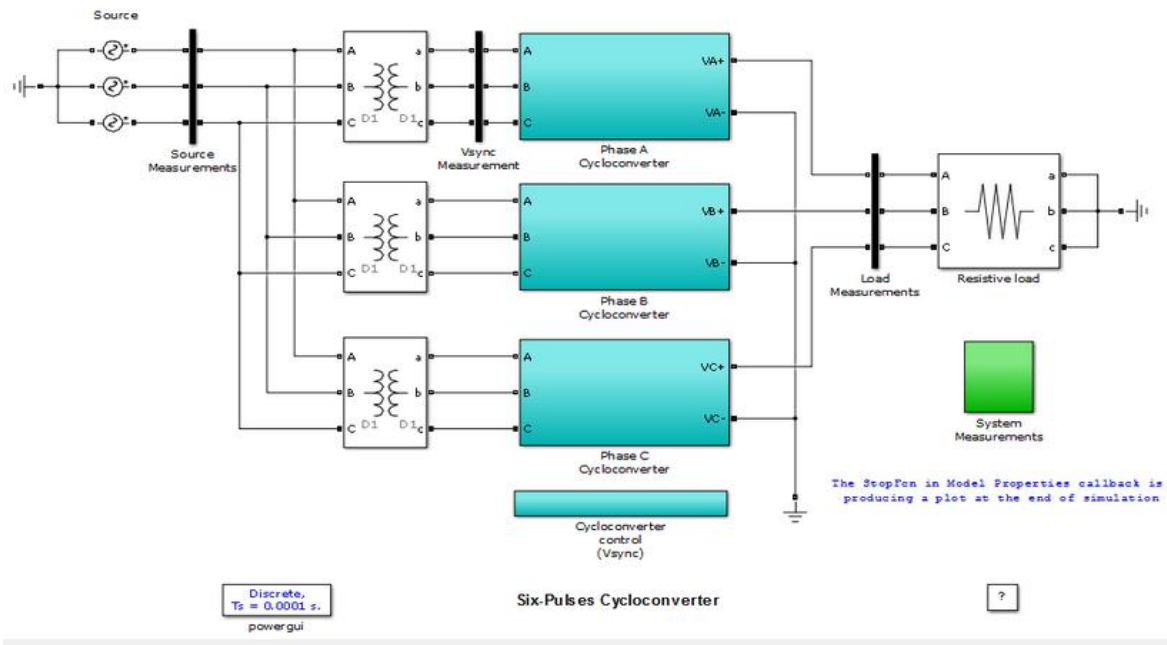


Fig – 5.1 Six pulse cycloconverter simulation using MATLAB

5.4 DESCRIPTION:

The system consists of three-phase to single-phase cycloconverter modules suitably arranged to implement a three-phase to three-phase architecture. Each module has a positive and negative cycle thyristor bridge connected in anti-parallel. To avoid circulating currents when one bridge is conducting, the anti-parallel bridge is blocked. A 5 degree 'dead zone' exists between the positive and negative cycle commutation. You can modify the dead zone value in File -> Model Properties -> Callbacks -> Init FCN. The output voltage waveforms are constructed by suitably modifying the firing angle of the thyristor bridges.

5.5 SIMULATION:

Start the simulation. Observe the load voltages from Scope 'Vabc_load' in System Measurements subsystem, and note that a 10Hz output has been constructed from a 60Hz input. A MATLAB® script executes on completion of the simulation to more clearly show the construction of phase-A output voltage from the three-phase input. The user may modify this execution as desired by editing File -> Model Properties -> Callbacks -> Stop Fcn. The user can adjust the output voltage magnitude and frequency by modifying 'Output voltage (V peak)' and 'Output frequency (Hz)' respectively.

5.6 PROCEDURE:

1. Make the connections as shown in the diagram by using MATLAB Simulink
2. Enter the rated values of the particular element
3. Draw the respective wave forms

5.7 RESULT:

5.8 PRE LAB VIVA QUESTIONS:

1. Define cycloconverter?
2. What is the function of resistive load?
3. What is mean by Powergui?
4. What is the function of three phase transformer?
5. What are the function of signal controllers?

5.9 POST LAB VIVA QUESTIONS:

1. What is the difference between three pulse and six pulse cycloconverter?
2. What are the different types of converters?
3. What are the Advantages of six pulse cycloconverter?
4. Write some Applications of six pulse cycloconverter?

EXPERIMENT – 6

SPEED CONTROL DC MOTOR USING BJT-H BRIDGE SIMULATION USING MATLAB

6.1 AIM:

To construct three speed control dc motor using bjt-h bridge simulation using MATLAB.

6.2 APPARATUS:

S. No	SOFTWARE USED	DESKTOP QUANTITY
1	MATLAB	36

6.3 BLOCK DIAGRAM:

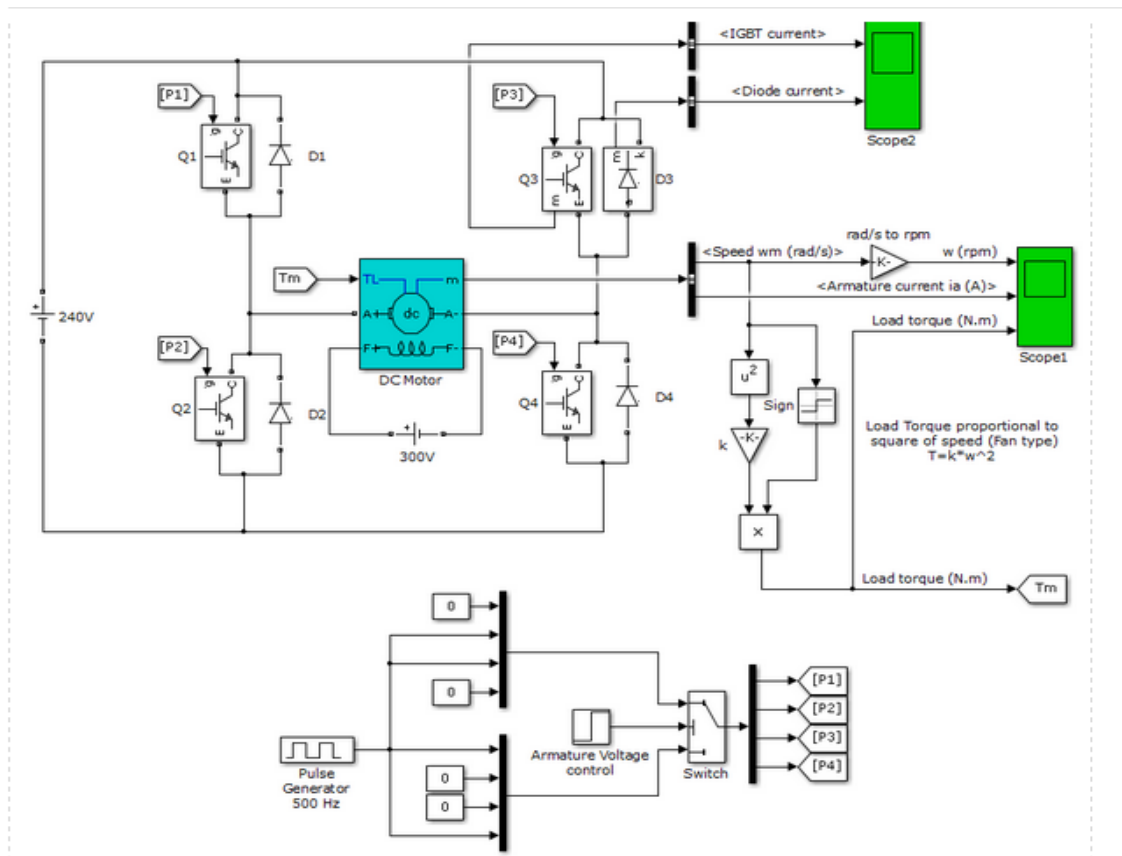


Fig – 6.1 Speed control DC motor using BJT-H bridge simulation using MATLAB

6.4 DESCRIPTION:

The bipolar junction transistor (BJT) when used for power switching applications operates as an IGBT. When it is conducting (BJT operating in the saturated region) a forward voltage V_f is developed between collector and emitter (in the range of 1 V). Therefore the IGBT block can be used to model the BJT device.

The IGBT block does not simulate the gate current controlling the BJT or IGBT. The switch is controlled by a simulink signal (1/0). The DC motor uses the preset model (5 HP 24V 1750 rpm). It simulates a fan type load (where Load torque is proportional to square of speed). The armature mean voltage can be varied from 0 to 240 V when the duty cycle (specified in the Pulse Generator block) is varied from 0 to 100%.

The H bridge consists of four BJT/Diode pairs (BJT simulated by IGBT models). Two transistors are switched simultaneously: Q1 and Q4 or Q2 and Q3. When Q1 and Q4 are fired, a positive voltage is applied to the motor and diodes D2-D3 operate as free-wheeling diodes when Q1 and Q3 are switched off. When Q2 and Q3 are fired, a negative voltage is applied to the motor and diodes D1-D4 operate as free-wheeling diodes when Q2 and Q3 are switched off.

6.5 SIMULATION:

The motor starts in the positive direction with a duty cycle of 75% (mean DC voltage of 180V). At $t = 0.5$ sec. the armature voltage is suddenly reversed and the motor runs in the negative direction. Scope1 shows motor speed, armature current and load torque and Scope2 shows currents flowing in BJT Q3 and diode D3.

6.6 PROCEDURE:

1. Make the connections as shown in the diagram by using MATLAB Simulink
2. Enter the rated values of the particular element
3. Draw the respective wave forms

6.7 RESULT:

6.8 PRE LAB VIVA QUESTIONS:

1. List the different types of electric Drives.
2. What is mean by drive?
3. What is mean by Powergui?
4. Define IGBT?
5. Write the torque equation for dc motor.

6.9 POST LAB VIVA QUESTIONS:

1. Define BJT?
2. Types of the motors.
3. Define H-Bridge?
4. What are the Advantages of speed control of dc motor using BJT-H Bridge?
5. Write some Applications of speed control of dc motor using BJT-H Bridge?

EXPERIMENT – 7

THREE PHASE THYRISTOR CONVERTER SIMULATION USING MATLAB

7.1 AIM:

To construct three phase thyristor converter simulation using MATLAB.

7.2 APPARATUS:

S. No	SOFTWARE USED	DESKTOP QUANTITY
1	MATLAB	36

7.3 BLOCK DIAGRAM:

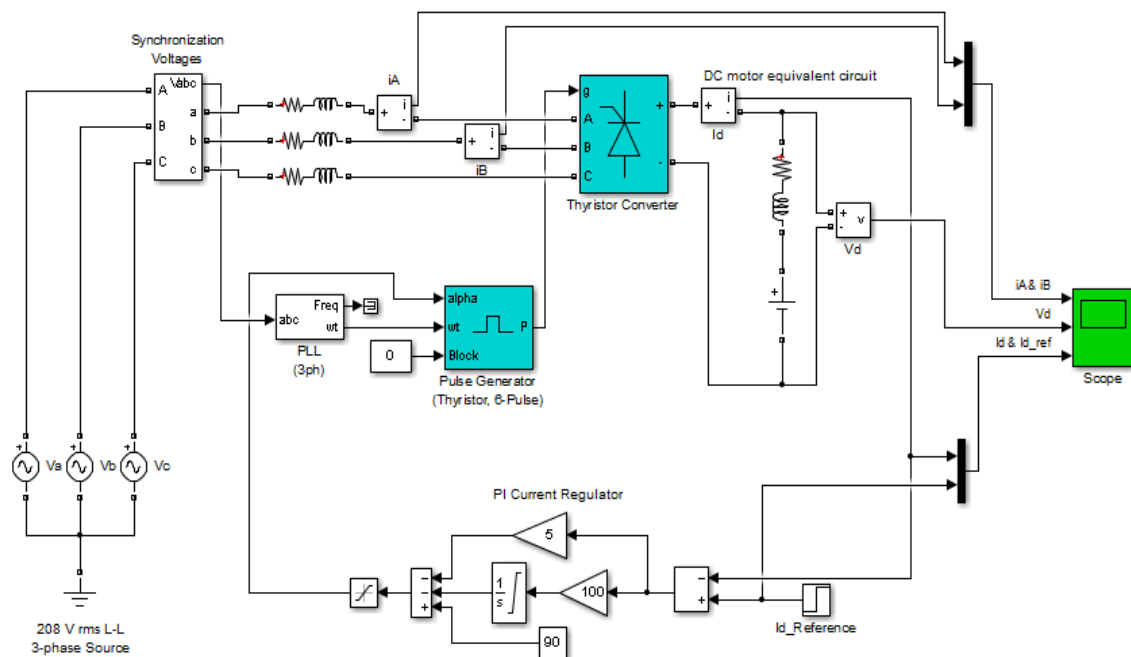


Fig – 7.1 Three phase thyristor converter simulation using MATLAB

7.4 DESCRIPTION:

A DC motor represented by a simplified RL-E model is fed from an inductive three-phase source through a six-pulse thyristor bridge. A pulse generator synchronized on the source voltages provides the trigger pulses for the six thyristors.

The converter output current is controlled by a PI current regulator built with Simulink® blocks. A step signal is applied to the reference input to test the dynamic response of the current regulator.

In order to allow further signal processing, signals displayed on the Scope block are sampled at 1/60/512 s (512 samples/ cycle) and stored in a variable named 'psbconveter_str' ('structure with time' format).

7.4 SIMULATION:

Start simulation and observe current and voltage waveforms on the Scope block.

When simulation is completed, open the Powergui and select FFT Analysis to display the 0 - 2000 Hz frequency spectrum of signals saved in the 'psbconverter_str' structure. The FFT will be performed on a 2-cycle window starting at $t = 0.1 - 2/60$ (last 2 cycles of recording). Input labeled 'Ia & Ib' and signal number 1 (Ia) should be already selected. Click on Display and observe the frequency spectrum of last two cycles of Ia. Harmonic currents ($6n \pm 1$) are displayed in % of the fundamental component.

The value of the fundamental current (magnitude = 27.48 A peak) and the Total Harmonic Distortion (THD) are also displayed. Harmonics in the 0 - 2000 Hz range contribute to 29% in THD. If you specify a 0-4000 Hz frequency range, notice that contributions of harmonics above 2000 Hz are negligible in the current THD.

Now select the input labeled Vd and display its spectrum. The DC voltage contains harmonics ($6n$) and its DC component is 145.4 V.

7.5 PROCEDURE

1. Make the connections as shown in the diagram by using MATLAB Simulink
2. Enter the rated values of the particular element
3. Draw the respective wave forms

7.6 RESULT:

7.7 PRE LAB VIVA QUESTIONS:

1. Define thyristor?
2. List out the thyristor family.
3. What are the advantages of thyristor converter?
4. What is mean by Powergui?
5. What is the function of DC motor?

7.8 POST LAB VIVA QUESTIONS:

1. What is the difference between single phase and three phase thyristor converter?
2. Types of the motors.
3. What are the Advantages of three phase thyristor converter?
4. Write some Applications of three phase thyristor converter?

EXPERIMENT – 8

THREE PHASE 48 PULSE GTO CONVERTER SIMULATION USING MATLAB

8.1 AIM:

To Construct three phase 48 pulse GTO converter simulation using MATLAB

8.2 APPARATUS:

S. No	SOFTWARE USED	DESKTOP QUANTITY
1	MATLAB	36

8.3 BLOCK DIAGRAM:

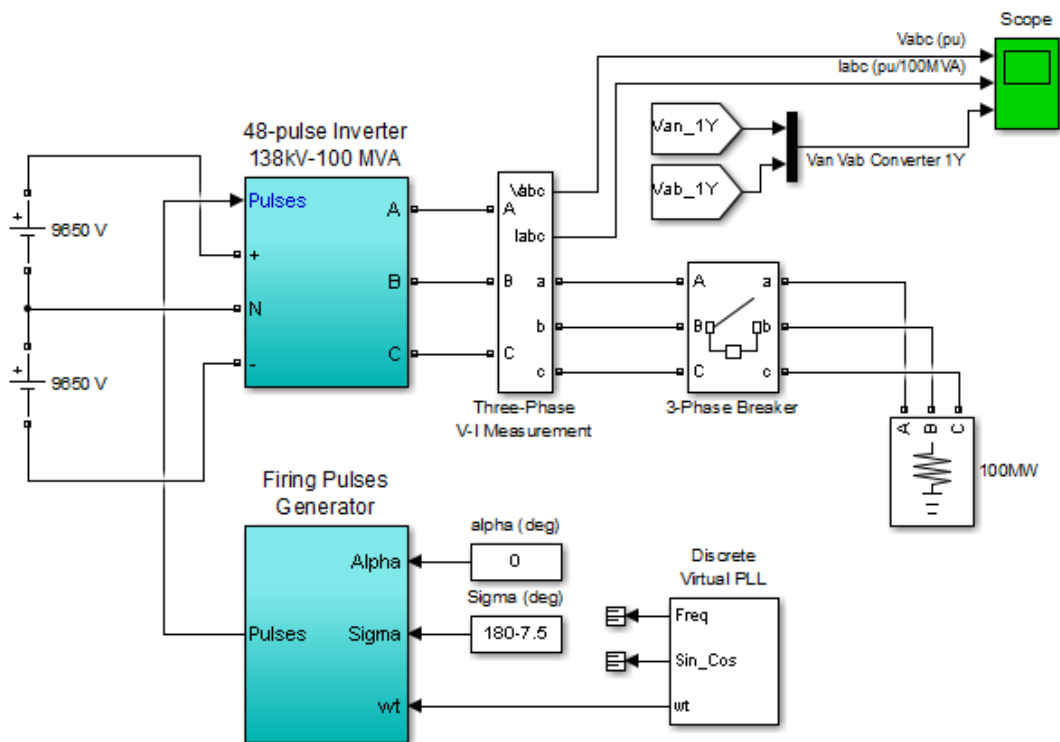


Fig – 8.1 Three phase 48 pulse gto converter simulation using MATLAB

8.4 DESCRIPTION:

In this example, ideal switches and zig-zag phase shifting transformers are used to build a GTO-type 100 MVA, 138 kV voltage source inverter. This type of converter is used in high-power (up to 200 MVA) Flexible AC Transmission Systems (FACTS) which are used to control power flow on transmission grids. It can be used, for example, to build a model of shunt or series static compensator (STATCOM or SSSC) or, using two such converters, a combination of shunt and series devices known as Unified Power Flow Controller (UPFC).

The inverter described in this example is a harmonic neutralized, 48-pulse GTO converter described in reference. It consists of four 3-phase, 3-level inverters and four phase-shifting transformers. Open

the "48-pulse inverter" subsystem. Notice that the DC bus ($V_{dc} = \pm 9650$ V) is connected to the four 3-phase inverters. The four voltages generated by the inverters are applied to secondary windings of four zig-zag phase-shifting transformers connected in Wye (Y) or Delta (D). The four transformer primary windings are connected in series and the converter pulse patterns are phase shifted so that the four voltage fundamental components sum in phase on the primary side.

Each 3-level inverter generates three square-wave voltages which can be $+V_{dc}$, 0, $-V_{dc}$. The duration of the $+V_{dc}$ or $-V_{dc}$ level (σ) can be adjusted between 0 and 180 degrees from the σ input of the Firing Pulse Generator block. Each inverter uses a Three-Level Bridge block where specified power electronic devices are Ideal Switches. In this model each leg of the inverter uses 3 ideal switches to obtain the 3 voltage levels ($+V_{dc}$, 0, $-V_{dc}$). This simple model simulates the behavior of a physical inverter where each leg consists of 4 GTOs, 4 antiparallel diodes and 2 neutral clamping diodes. Despite this simplified switch arrangement, the model still requires 4 pulses per arm as in the physical model. The pulse pattern sent to each leg of a 3-phase inverter is described inside the Firing Pulse Generator.

You can also select GTO/Diodes pairs instead of Ideal Switches as power electronic devices. It would allow you to specify forward voltage drops for GTOs and diodes and to observe currents flowing in GTOs and diodes by means of the Multimeter block.

The phase shifts produced by the secondary delta connections (-30 degrees) and by the primary zig-zag connections ($+7.5$ degrees for transformers 1Y and 1D, and -7.5 degrees for transformers 2Y and 2D) allows to neutralize harmonics up to 45th harmonic, as explained below:

The 30-degree phase-shift between the Y and D secondaries cancels harmonics $5+12n$ (5, 17, 29, 41, ...) and $7+12n$ (7, 19, 31, 43, ...). In addition, the 15-degree phase shift between the two groups of transformers (1Y and 1D leading by 7.5 degrees, 2Y and 2D lagging by $+7.5$ degrees) allows cancellation of harmonics $11+24n$ (11, 35, ...) and $13+24n$ (13, 37, ...). Considering that all $3n$ the harmonics are not transmitted by the Y and D secondaries, the first harmonic which are not cancelled by the transformers are 23rd, 25th, 47th and 49th. By choosing an appropriate conduction angle for the 3-level inverters ($\sigma = 180 - 7.5 = 172.5$ degrees), the 23rd and 25th can be minimized. The first significant harmonics are therefore the 47th and 49th. This type of inverter generates an almost sinusoidal waveform consisting of 48-steps.

The inverter is operated in open loop at constant DC voltage. During the first three cycles the inverter operates at no load. Then, at $t = 0.05$ s, a 100 MVA resistive load is connected at the 138-kV terminals.

8.5 SIMULATION:

Run the simulation and observe the following waveforms on the Scope block:

Voltages generated by the inverter (trace 1), load currents (trace 2), phase-neutral voltage and phase-phase voltage of one of the four inverters (1Y) superimposed on trace 3. When the inverter is operating at no load, you can observe the three 48-step voltage waveform. When the load

is switched on the voltage becomes smoother because harmonics are filtered by the transformer leakage reactances.

Once the simulation is completed, open the Powergui and select "FFT Analysis" to display the 0-4000 Hz frequency spectrum of signals saved in the two "psb48pulse_str" structure. Select signal labeled 'Vabc (pu)'. The FFT will be performed on a 1-cycle window of phase A voltage starting at $t = 0.025 - 1/60$ s (inverter operating at no load). Click on Display and observe the frequency spectrum.

The fundamental component of Voltage (in pu) as well as THD are displayed above the spectrum window. Notice that the first significant harmonics are 47th and 49th (approx. 2%). Notice also that 23rd and 25th are reduced below 0.3%. In order to appreciate the efficiency of harmonic neutralization, you can also observe the frequency spectrum of phase-phase voltage generated by each individual inverter. Select input labeled "Van Vab Converter 1Y" and signal number 2 and click on Display. Observe that THD in the 0 - 4000 Hz frequency range is 25%.

You can also run another simulation by specifying different values of sigma at the input of the pulse generator. You can verify that, in order to cancel a particular harmonic n in the phase-phase voltage of each individual converter, the Sigma value (in degrees) is given by:

$$\text{Sigma} = 180 * (1 - 1/n)$$

Verify also that choosing Sigma = 180 degrees is equivalent to using 2-level converters and that voltage waveform is degraded to 24 pulses

8.6 PROCEDURE:

1. Make the connections as shown in the diagram by using MULTISIM/MATLAB Simulink
2. Enter the rated values of the particular element
3. Draw the respective wave forms

8.7 RESULT:

8.8 PRE LAB VIVA QUESTIONS:

1. List the different types of electric Drives.
2. What is mean by drive?
3. What is mean by Powergui?
4. What is the function of GTO?
5. Define inverter?

8.9 POST LAB VIVA QUESTIONS:

1. What is Permanent magnet principle?
2. Types of the motors.
3. What are the Advantages of three phase 48 pulse GTO converter?
4. Write some Applications of three phase 48 pulse GTO converter?

EXPERIMENT – 9

THREE PHASE THREE LEVEL PWM CONVERTER SIMULATION USING MATLAB

9.1 AIM:

To Construct three phase three level PWM converter simulation using MATLAB

9.2 APPARATUS:

S. No	SOFTWARE USED	DESKTOP QUANTITY
1	MATLAB	36

9.3 BLOCK DIAGRAM:

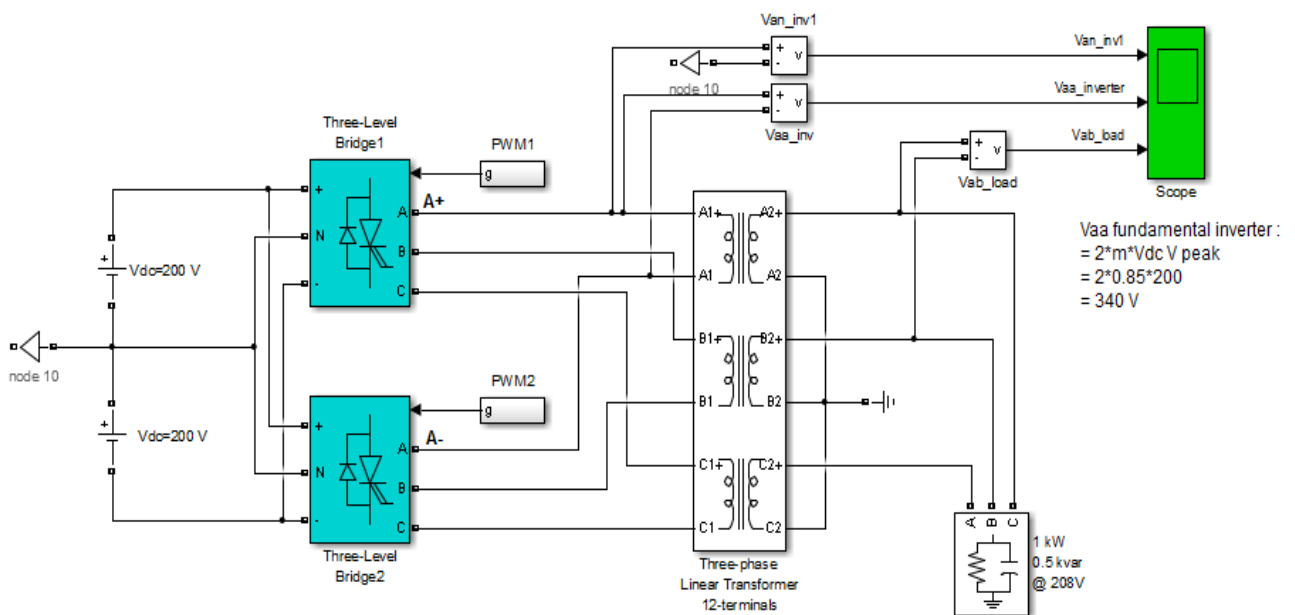


Fig – 9.1 Three phase three level PWM converter simulation using MATLAB

9.4 DESCRIPTION:

The system consists of two three-phase three-level PWM voltage source converters connected in twin configuration. The inverter feeds an AC load (1kW, 500 var 60Hz @ 208 Vrms) through a three-phase transformer. Harmonic filtering is performed by the transformer leakage inductance (8%) and load capacitance (500 var).

Each of the two inverters uses the Three-Level Bridge block where the specified power electronic devices are IGBT/Diode pairs. Each arm consists of 4 IGBTs, 4 antiparallel diodes, and 2 neutral clamping diodes.

The inverter is controlled in open loop. PWM Generator blocks generate sets of 12 pulses. They can operate either in synchronized or un-synchronized mode. When operating in synchronized mode, the carrier triangular signal is synchronized on a PLL reference angle connected to input 'wt'.

In synchronized mode, the carrier chopping frequency is specified by the switching ratio as a multiple of the output frequency.

Three sinusoidal 0.85 pu modulating signals are used to obtain a modulation index of 0.85. The carrier signals are synchronized on the modulating signals. In the PWM Generator block, you can instead select 'Unsynchronized' and 'Internal generation of modulating signals'. In such a case the magnitude (modulation index), frequency and phase angle of the output signals are specified directly inside the PWM Generator block menu.

For this example the DC bus voltage is 400V (+/- 200 V), chopping frequency is 1080 Hz (18×60 Hz), magnitude of the three modulating signals is 0.85 (corresponding to a modulation index $m = 0.85$) and the frequency of the three generated signals is 60 Hz.

In order to allow further signal processing, signals displayed on the Scope block (sampled at simulation sampling rate of 3240 samples/ cycle) are stored in a variable named 'psb3phPWM3level_str' (structures with time).

9.5 SIMULATION:

Run the simulation and observe the following three waveforms on the Scope block: Phase-neutral voltage V_{an_inv1} generated by inverter 1 (trace 1), phase A voltage $V_{aa_inverter}$ generated by the twin inverter (trace 2) and phase-phase load voltage V_{ab_load} (trace 3). The V_{an_inv1} waveform clearly shows the three levels: +200 V, 0 V, and -200 V.

Once the simulation is completed, open the Powergui and select 'FFT Analysis' to display the 0 - 5000 Hz frequency spectrum of signals saved in the 'psb3phPWM3level_str' structure. The FFT will be performed on a 2-cycle window starting at $t = 0.1 - 2/60$ (last 2 cycles of recording). Select the input labeled ' $V_{aa_inverter}$ '. Click on Display and observe the frequency spectrum of last 2 cycles.

The fundamental component of $V_{aa_inverter}$ and THD for the 0 - 5000 Hz frequency range are displayed above the spectrum window. Because of the forward voltage drops in the IGBTs ($V_f=1$ V) and diodes ($V_{fd}=1$ V), the magnitude of the fundamental voltage of the inverter (335 V) is slightly lower than the theoretical value (340 V for $m=0.85$). As expected for a twin inverter, first harmonics occur around multiples of double of carrier frequency ($n \times 2 \times 1080$ Hz $\pm k \times 60$ Hz).

The same circuit using two-level inverters in twin configuration is available in the psb3phPWM model. Run this model and compare the harmonic contents in the 2-level and 3-level inverter voltage for the same modulation index ($m = 0.85$). Harmonics occur at the same frequencies but their magnitude is approximately two times lower for a 3-level inverter

9.6 PROCEDURE:

1. Make the connections as shown in the diagram by using MATLAB Simulink
2. Enter the rated values of the particular element
3. Draw the respective wave forms

9.7 RESULT:

9.8 PRE LAB VIVA QUESTIONS:

1. List the different types of electric drives.
2. What is mean by drive?
3. What is mean by Powergui?
4. What is the function of synchronous machine?
5. Write the torque equation for synchronous machine?

9.9 POST LAB VIVA QUESTIONS:

1. Define firing angle?
2. What is mean by firing pulse?
3. What are the Advantages of PMSM?
4. Write some Applications of PMSM?

EXPERIMENT – 10

THREE PHASE SPACE – VECTOR PWM CONVERTER SIMULATION USING MATLAB

10.1 AIM:

To Construct three phase space – vector PWM converter simulation using MATLAB.

10.2 APPARATUS:

S. No	SOFTWARE USED	DESKTOP QUANTITY
1	MATLAB	36

10.3 BLOCK DIAGRAM:

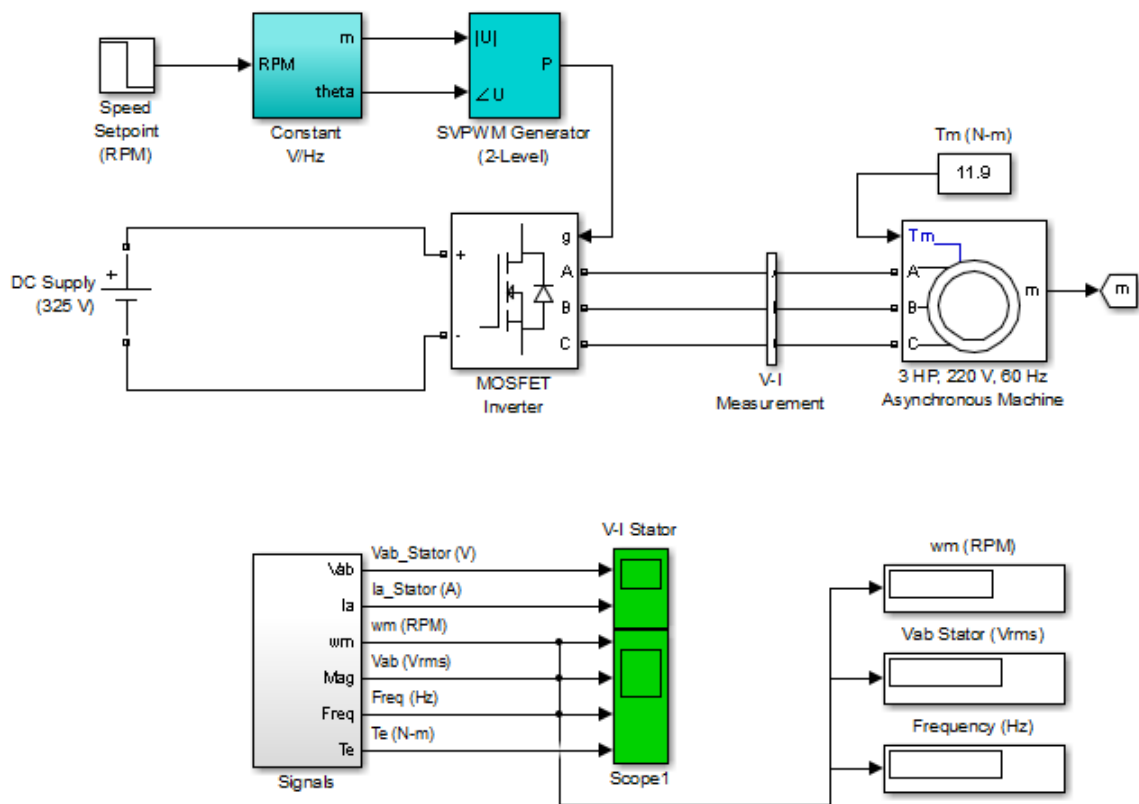


Fig – 10.1 Three phase space – vector PWM converter simulation using MATLAB

10.4 DESCRIPTION:

A 3-phase squirrel-cage motor rated 3 HP, 220 V, 60 Hz, 1725 rpm is fed by a 3-phase MOSFET inverter connected to a DC voltage source of 325 V. The inverter is modeled using the "Universal Bridge" block and the motor by the "Asynchronous Machine" block. Its stator leakage inductance L_{ls} is set to twice its actual value to simulate the effect of a smoothing reactor placed between the inverter and the machine. The load torque applied to the machine's shaft is constant and set to its nominal value of 11.9 N.m.

The firing pulses to the inverter are generated by the "Space-Vector PWM modulator" block of the SPS library. The chopping frequency is set to 1980 Hz and the input reference vector to "Magnitude-Angle".

Speed control of the motor is performed by the "Constant V/Hz" block. The magnitude and frequency of the stator voltages are set based on the speed set point. By varying the stator voltages magnitude in proportion with frequency, the stator flux is kept constant.

10.5 SIMULATION:

Start the simulation. Since the initial states have been automatically loaded, the simulation should start in steady-state. The initial motor speed should be 1720 RPM and the rms value of the stator voltages should be 220V@60Hz.

At 0.1s, the speed setpoint is changed from 1725 to 1300 RPM. You can observe the system dynamic looking inside Scope 1. When the motor reaches a constant speed of 1275 RPM, the stator voltage rms value is down to 165.8V and the frequency to 45.2 Hz.

Stator voltage (phase AB) and phase A current waveforms can be observed in the "V-I Stator" Scope. You can do a FFT of these two quantities using the powergui FFT Analysis.

Regenerate Initial Conditions:

The initial states required to start this model in steady state with a 1725 rpm reference speed and a 11.9 N.m load torque have been saved in the "power_svpwm_init.mat" file. When you open this model, the InitFcn callback (in the Model Properties/Callbacks) automatically loads into your workspace the contents of this .mat file ("xInitial" variable).

If you modify this model, or change parameter values of power components, the initial conditions stored in the "xInitial" variable will no longer be valid and Simulink® will issue an error message. To regenerate the initial conditions for your modified model, follow the steps listed below:

1. In the Simulation/Configuration Parameters/Data Import/Export Parameters menu, uncheck the "Initial state" parameter.
2. Double click on the Step block labeled "Speed Setpoint (RPM)" and temporarily disable the change of reference speed by multiplying the Step time by 100.
3. Change the Simulation Mode from "Normal" to "Accelerator".
4. Start simulation. When simulation is completed, verify that steady state has been reached by looking at waveforms displayed on the scopes. The final states which have been saved in the "xFinal" structure with time can be used as initial states for future simulations. Executing the next two commands copies these final conditions in "xInitial" and saves this variable in a new file (myModel_init.mat). `* >> xInitial=xFinal; * >> save myModel_init xInitial`
5. In the File/Model Properties/Callbacks/InitFcn window, change the name of the initialization file from "power_svpwm_init" to "myModel_init". Next time you open this model, the variable xInitial saved in the myModel_init.mat file will be loaded in your workspace.

6. In the Simulation/Configuration Parameters menu, check "Initial state".
7. Start simulation and verify that your model starts in steady-state.
8. Double click on the Step block labeled "Speed Setpoint (RPM)" and re-enable the change of reference speed at $t=0.1$ s (remove the 100 multiplication factor in the Step time).
9. Change the Simulation Mode back to Normal.
10. Save your Model

10.6 PROCEDURE:

1. Make the connections as shown in the diagram by using MATLAB Simulink
2. Enter the rated values of the particular element
3. Draw the respective wave forms

10.7 RESULT:

10.8 PRE LAB VIVA QUESTIONS:

1. Define MOSFET?
2. What is mean by drive?
3. What is mean by Powergui?
4. What is the function of SVPWM?

10.9 POST LAB VIVA QUESTIONS:

1. What are the Advantages of three phase space – vector PWM converter?
2. Write some Applications of three phase space – vector PWM converter?
3. What are the disadvantages of three phase space – vector PWM converter?

EXPERIMENT – 11

FIVE PHASE FIVE LEVEL PWM CONVERTER SIMULATION USING MATLAB

11.1 AIM:

To Construct three phase five level PWM converter simulation using MATLAB

11.2 APPARATUS:

S. No	SOFTWARE USED	DESKTOP QUANTITY
1	MATLAB	36

11.3 BLOCK DIAGRAM:

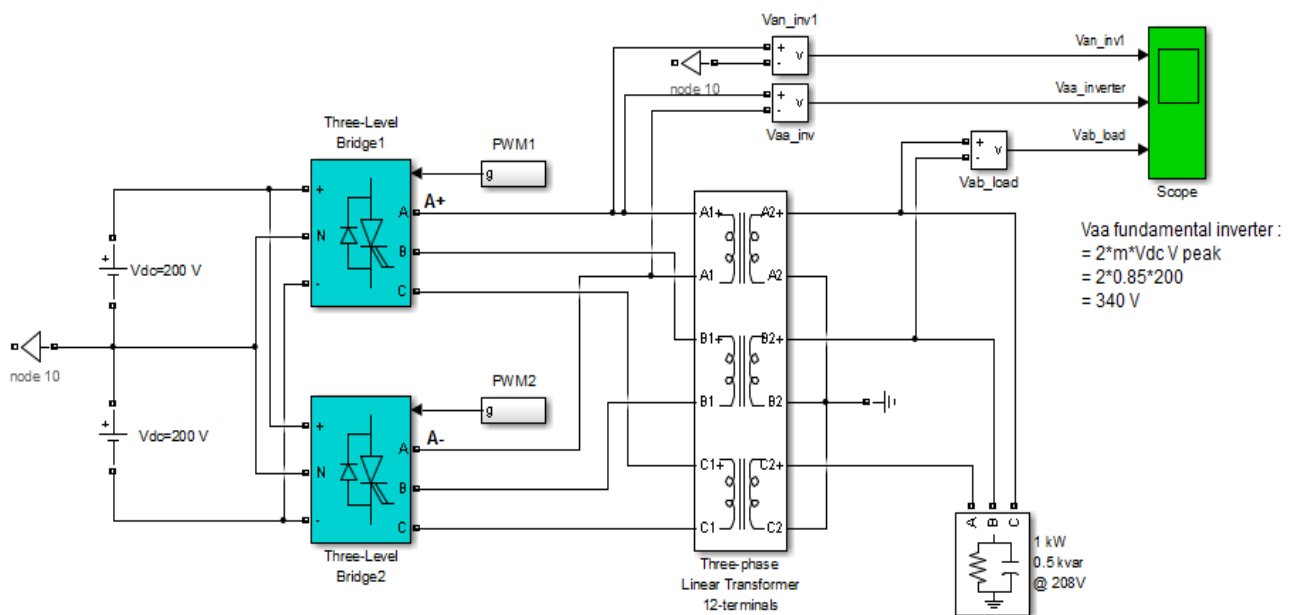


Fig – 11.1 Three phase three level PWM converter simulation using MATLAB

11.4 DESCRIPTION:

The system consists of two three-phase three-level PWM voltage source converters connected in twin configuration. The inverter feeds an AC load (1kW, 500 var 60Hz @ 208 Vrms) through a three-phase transformer. Harmonic filtering is performed by the transformer leakage inductance (8%) and load capacitance (500 var).

Each of the two inverters uses the Three-Level Bridge block where the specified power electronic devices are IGBT/Diode pairs. Each arm consists of 4 IGBTs, 4 antiparallel diodes, and 2 neutral clamping diodes.

The inverter is controlled in open loop. PWM Generator blocks generate sets of 12 pulses. They can operate either in synchronized or un-synchronized mode. When operating in synchronized mode, the carrier triangular signal is synchronized on a PLL reference angle connected to input 'wt'.

In synchronized mode, the carrier chopping frequency is specified by the switching ratio as a multiple of the output frequency.

Three sinusoidal 0.85 pu modulating signals are used to obtain a modulation index of 0.85. The carrier signals are synchronized on the modulating signals. In the PWM Generator block, you can instead select 'Unsynchronized' and 'Internal generation of modulating signals'. In such a case the magnitude (modulation index), frequency and phase angle of the output signals are specified directly inside the PWM Generator block menu.

For this example the DC bus voltage is 400V (+/- 200 V), chopping frequency is 1080 Hz (18×60 Hz), magnitude of the three modulating signals is 0.85 (corresponding to a modulation index $m = 0.85$) and the frequency of the three generated signals is 60 Hz.

In order to allow further signal processing, signals displayed on the Scope block (sampled at simulation sampling rate of 3240 samples/ cycle) are stored in a variable named 'psb3phPWM3level_str' (structures with time).

11.5 SIMULATION:

Run the simulation and observe the following three waveforms on the Scope block: Phase-neutral voltage V_{an_inv1} generated by inverter 1 (trace 1), phase A voltage $V_{aa_inverter}$ generated by the twin inverter (trace 2) and phase-phase load voltage V_{ab_load} (trace 3). The V_{an_inv1} waveform clearly shows the three levels: +200 V, 0 V, and -200 V.

Once the simulation is completed, open the Powergui and select 'FFT Analysis' to display the 0 - 5000 Hz frequency spectrum of signals saved in the 'psb3phPWM3level_str' structure. The FFT will be performed on a 2-cycle window starting at $t = 0.1 - 2/60$ (last 2 cycles of recording). Select the input labeled ' $V_{aa_inverter}$ '. Click on Display and observe the frequency spectrum of last 2 cycles.

The fundamental component of $V_{aa_inverter}$ and THD for the 0 - 5000 Hz frequency range are displayed above the spectrum window. Because of the forward voltage drops in the IGBTs ($V_f=1$ V) and diodes ($V_{fd}=1$ V), the magnitude of the fundamental voltage of the inverter (335 V) is slightly lower than the theoretical value (340 V for $m=0.85$). As expected for a twin inverter, first harmonics occur around multiples of double of carrier frequency ($n \times 2 \times 1080$ Hz $\pm k \times 60$ Hz).

The same circuit using two-level inverters in twin configuration is available in the psb3phPWM model. Run this model and compare the harmonic contents in the 2-level and 3-level inverter voltage for the same modulation index ($m = 0.85$). Harmonics occur at the same frequencies but their magnitude is approximately two times lower for a 3-level inverter

11.6 PROCEDURE:

4. Make the connections as shown in the diagram by using MATLAB Simulink
5. Enter the rated values of the particular element
6. Draw the respective wave forms

11.7 RESULT:

11.8 PRE LAB VIVA QUESTIONS:

6. List the different types of electric drives.
7. What is mean by drive?
8. What is mean by Powergui?
9. What is the function of synchronous machine?
10. Write the torque equation for synchronous machine?

11.9 POST LAB VIVA QUESTIONS:

5. Define firing angle?
6. What is mean by firing pulse
7. What are the Advantages of PMSM?
8. Write some Applications of PMSM

EXPERIMENT – 12

CHOPPER FED DC MOTOR DRIVE SIMULATION USING MATLAB

12.1 AIM:

To construct chopper fed dc motor drive simulation using MATLAB

12.2 APPARATUS:

S.No	SOFTWARE USED	DESKTOP QUANTITY
1	MATLAB	36

12.3 BLOCK DIAGRAM:

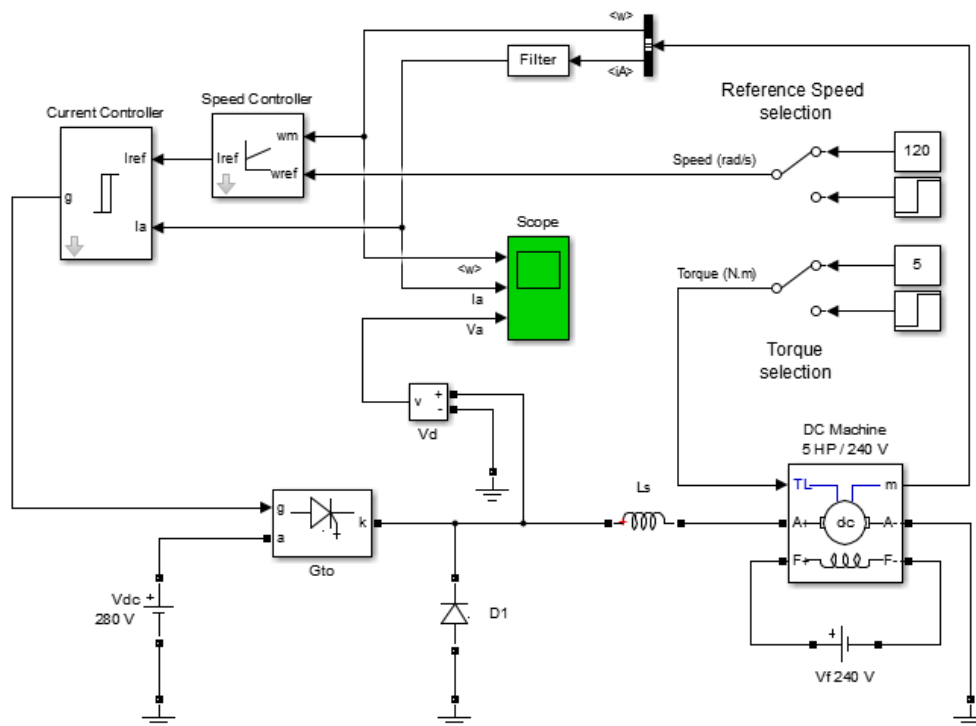


Fig – 12.1 Chopper fed dc motor drive simulation using MATLAB

12.4 DESCRIPTION:

The DC motor is fed by the DC source through a chopper which consists of GTO thyristor and free-wheeling diode D1. The motor drives a mechanical load characterized by inertia J, friction coefficient B, and load torque TL.

The hysteresis current controller compares the sensed current with the reference and generates the trigger signal for the GTO thyristor to force the motor current to follow the reference. The speed control loop uses a proportional-integral controller which produces the reference for the current loop. Current and Voltage Measurement blocks provide signals for visualization purpose.

12.5 SIMULATION:

Motor starting:

Start the simulation. Observe the motor current, voltage, and speed during the starting on the scope. At the end of the simulation time (1.5 s), the system has reached its steady-state.

Response to a change in reference speed and load torque

The initial conditions state vector 'xInitial' to start with $\omega_m = 120$ rad/s and $T_L = 5$ N.m has been saved in the 'power_dcdrive_init.mat' file. This file is automatically loaded in your workspace when you start the simulation (see Model Properties). In order to use these initial conditions you have to enable them. Check the Simulation/Configuration Parameters menu, then select "Data Import/Export" and check "Initial state".

Now, double click the two Manual Switch blocks to switch from the constant "Ref. Speed (rad/s)" and "Torque (N.m)" blocks to the Step blocks. (Reference speed ω_{ref} changed from 120 to 160 rad/s at $t = 0.4$ s and load torque changed from 5 to 25 N.m at $t = 1.2$ s). Restart the simulation and observe the drive response to successive changes in speed reference and load torque.

12.6 PROCEDURE:

1. Make the connections as shown in the diagram by using MATLAB Simulink
2. Enter the rated values of the particular element
3. Draw the respective wave forms

12.7 RESULT:

12.8 PRE LAB VIVA QUESTIONS:

1. Define different types of converters?
2. What is mean by drive?
3. What is mean by Powergui?
4. What is the function of chopper?

12.9 POST LAB VIVA QUESTIONS:

1. Define filter?
2. What is mean by current controlled source?
3. What are the Advantages of chopper fed dc motor drive simulation?
4. Write some Applications of chopper fed dc motor drive simulation?