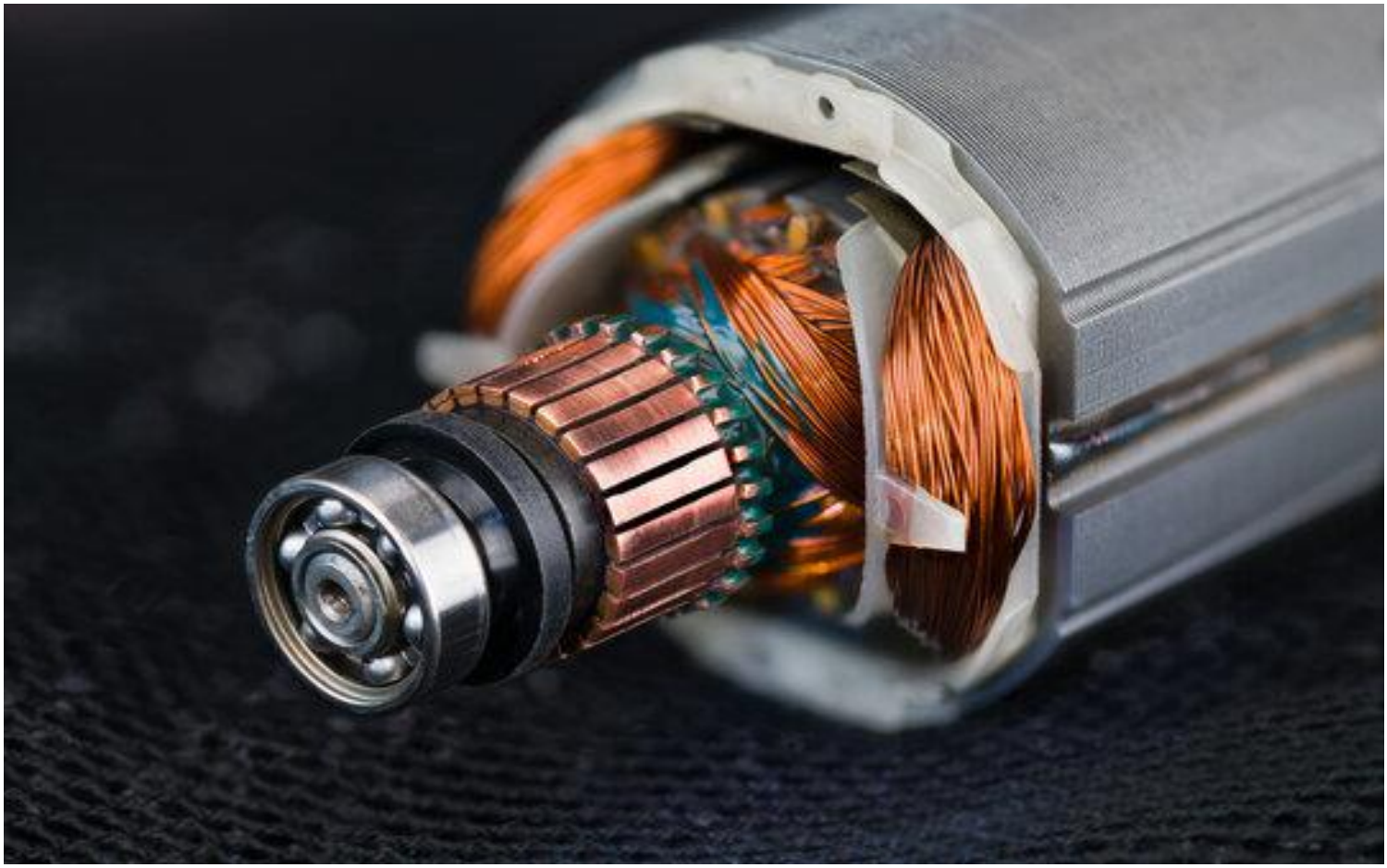


DC motor Drive

Contents

Introduction

Electric drives are essential components in modern industrial systems, providing precise control over the speed, torque, and position of electric motors. Among the various types of electric drives, DC motor drives remain popular due to their simple speed control, high starting torque, and straightforward design. Despite the increasing use of AC drives in some applications, DC drives are still preferred in heavy-duty industrial applications like rolling mills, cranes, and electric vehicles, where precise torque control is crucial.

System Overview

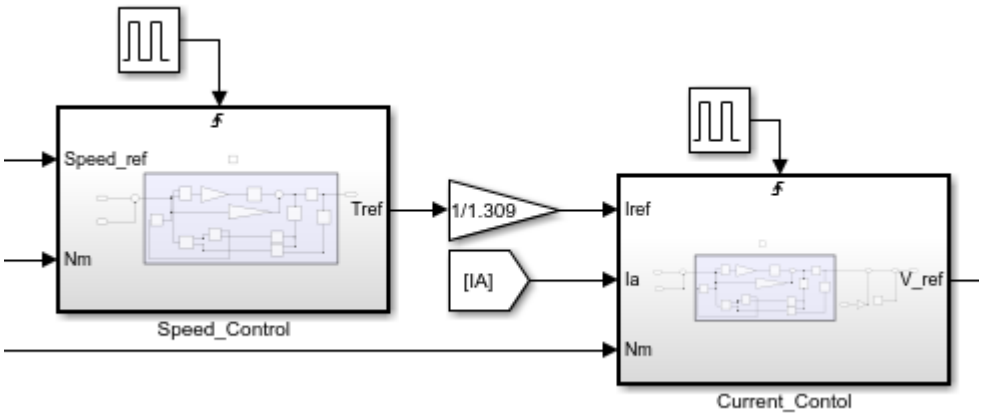
The overall control structure is a cascaded control system with:

1. An outer speed control loop
2. An inner current control loop

This is a common arrangement in DC motor drives, where the faster inner current loop provides fast torque control and protection, while the outer speed loop handles the desired motor speed for:

1. dual single-phase full-wave controlled rectifiers
2. a single-phase rectifier combined with a four-quadrant chopper operating in
   a. unipolar modulation modes.
   b. bipolar modulation modes.

We model this system as **Discrete**



Ratio Between Current Control and Speed Control

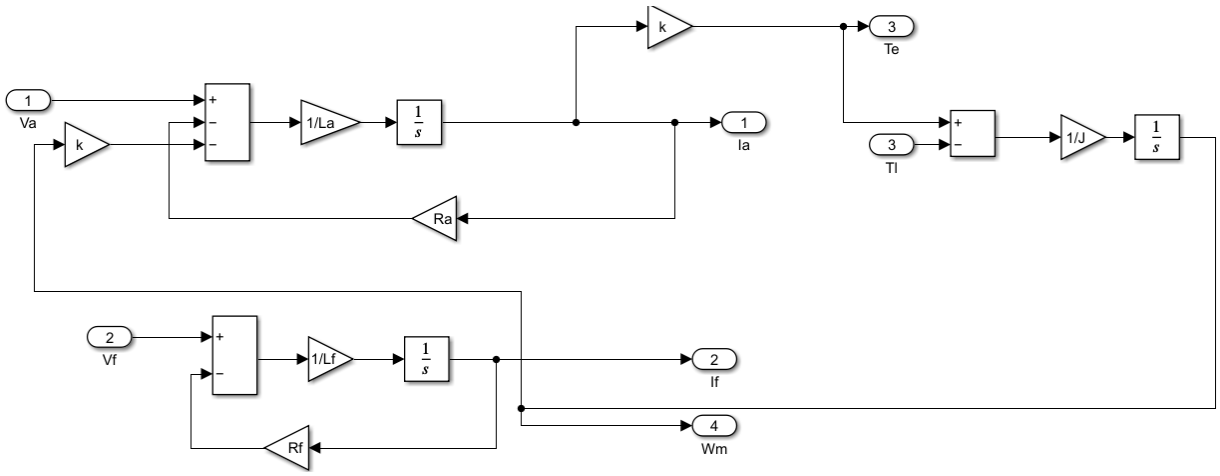
The ratio between the current control and speed control is critical in determining the overall system performance. From the diagrams:

Time Constant Ratio: The current control loop must be significantly faster than the speed control loop for stable operation. Typically, the current loop is designed to be 5-10 times faster than the speed loop.

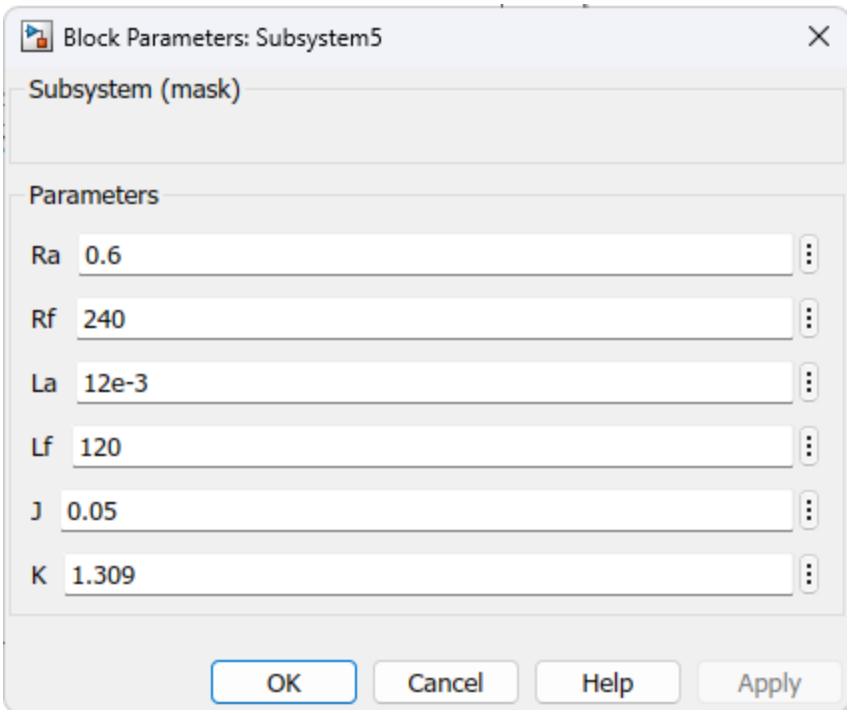
Speed loop sampling period: 1/1000 seconds (1 kHz)

Current loop sampling period: 1/10000 seconds (10 kHz)

DC machine modelling

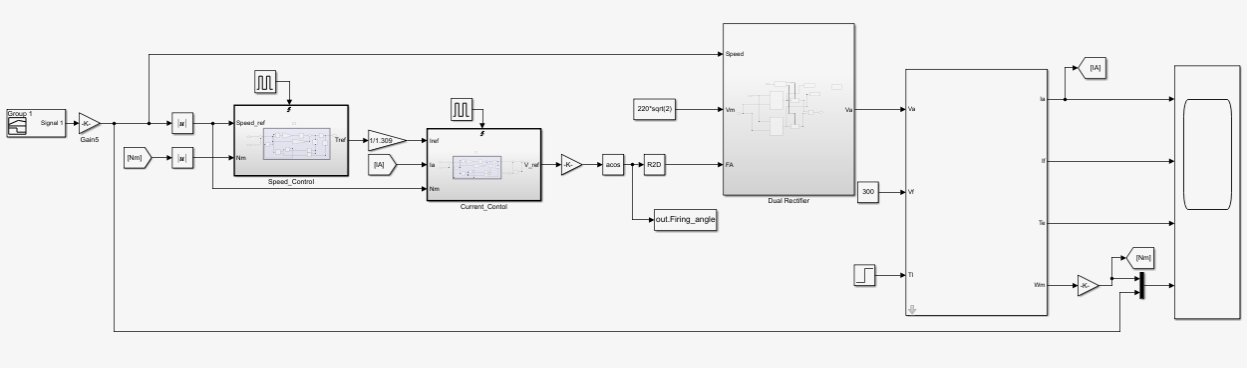


Dc machine modelling 1

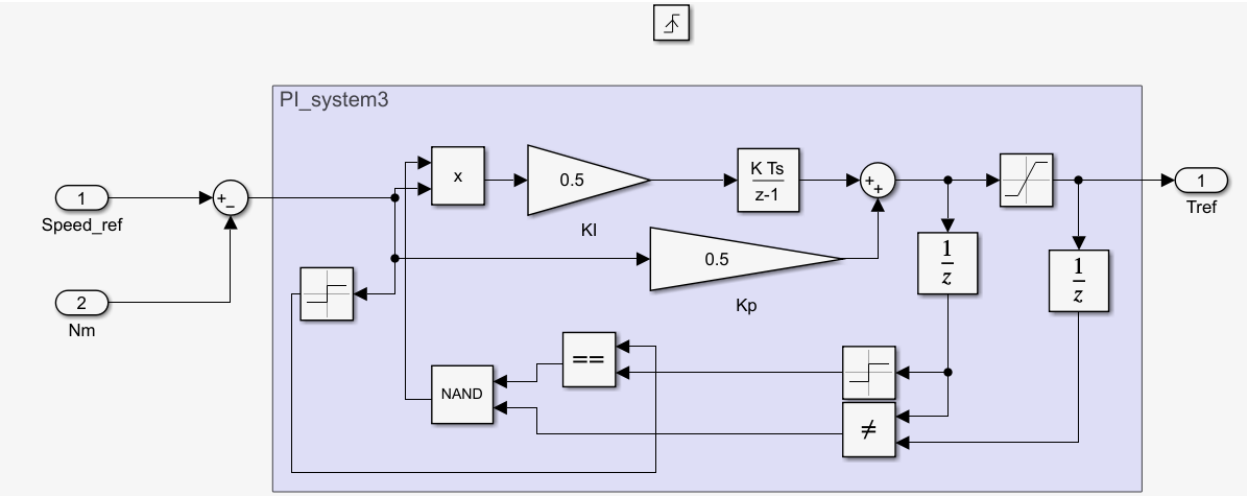


parameters dc machine

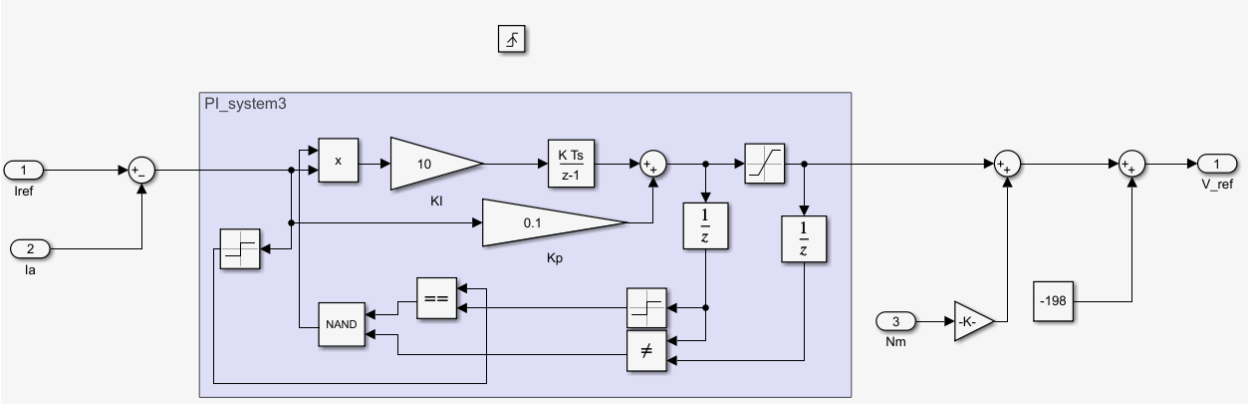
dual single-phase full-wave controlled rectifiers



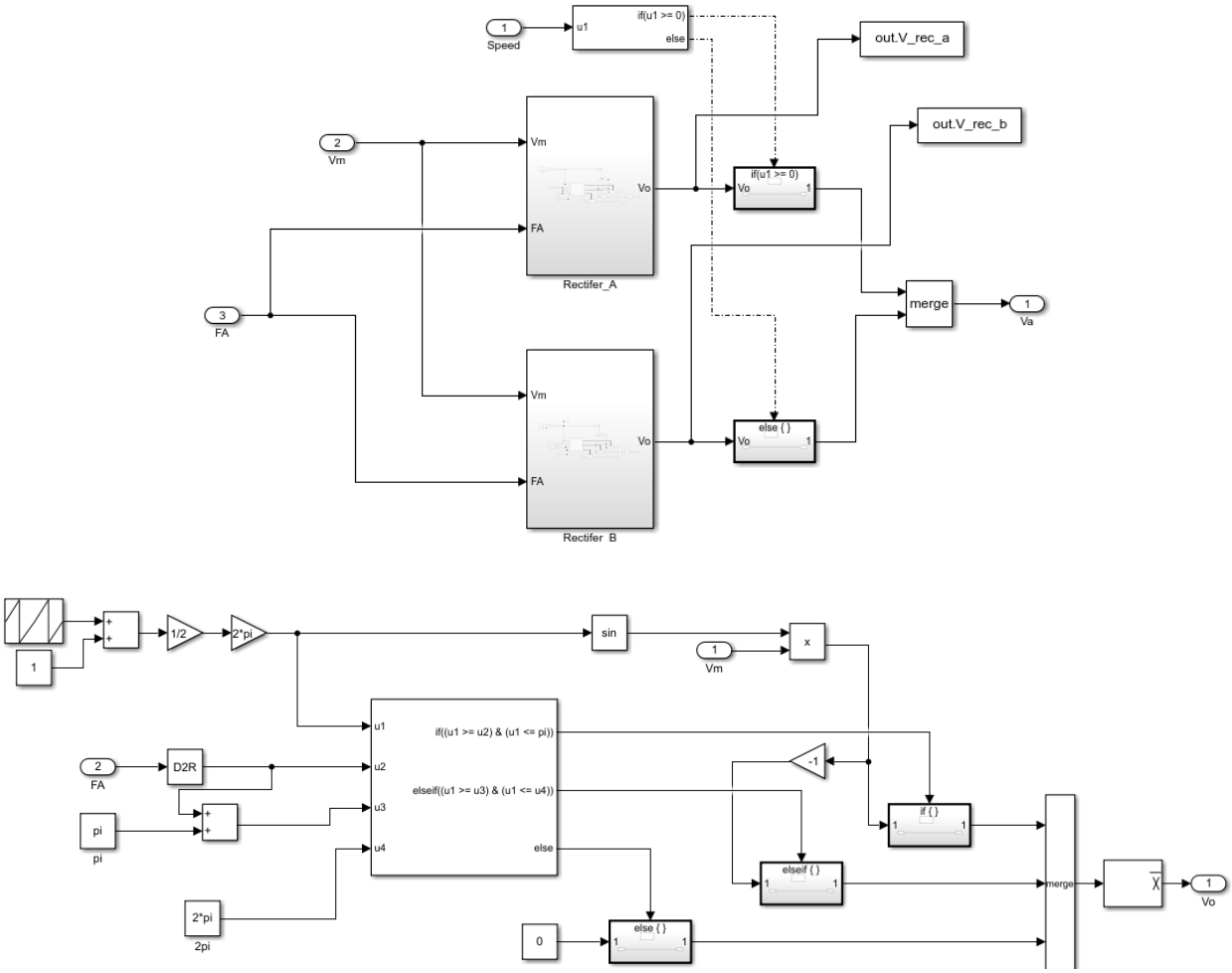
dual single-phase full-wave controlled rectifiers



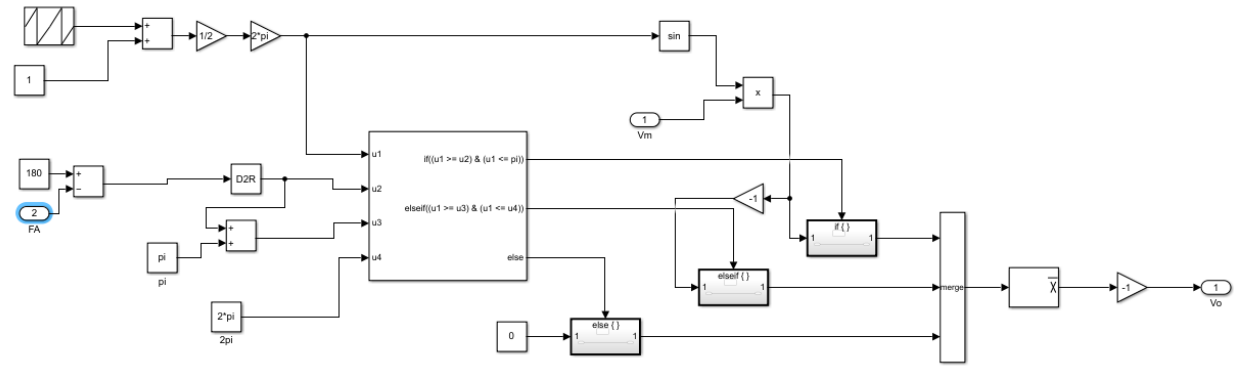
Speed control



current control

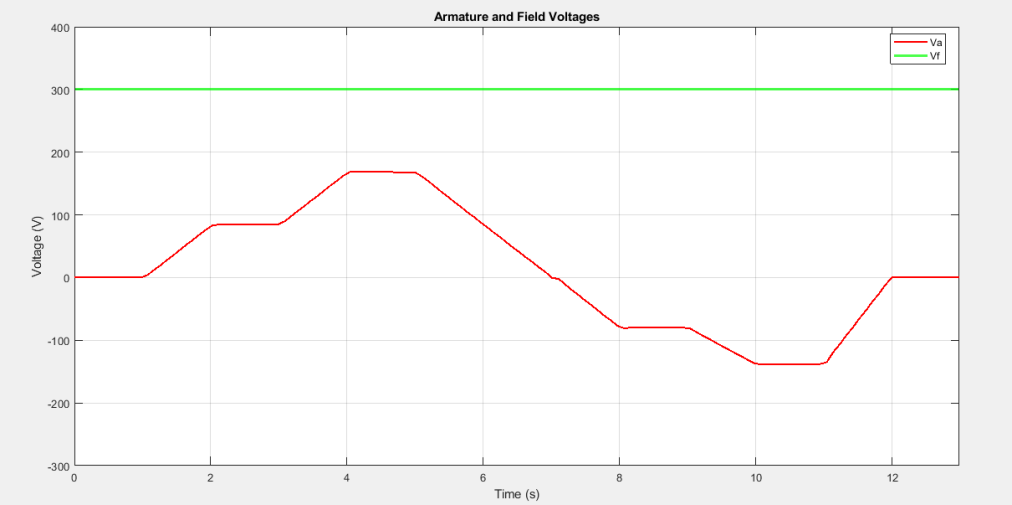


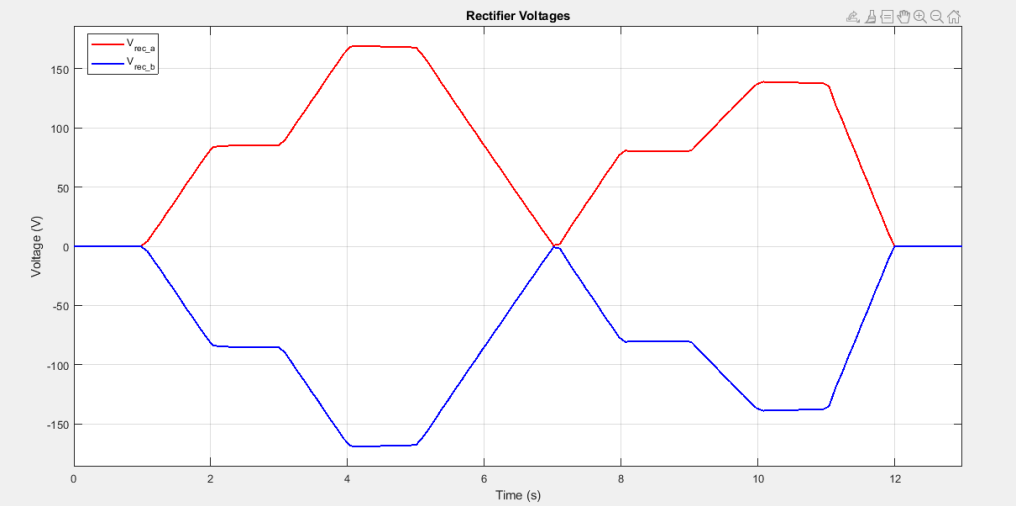
Rectifier A

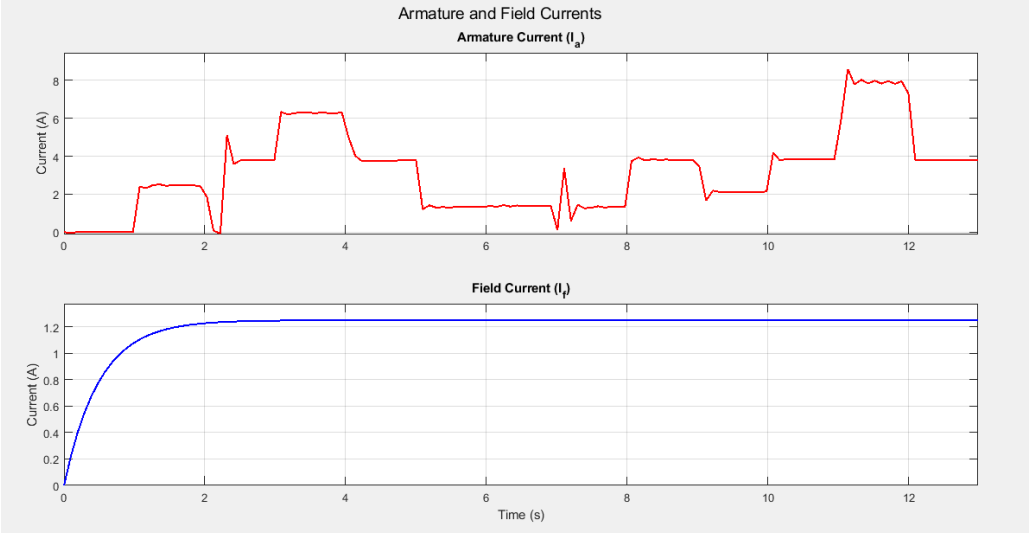


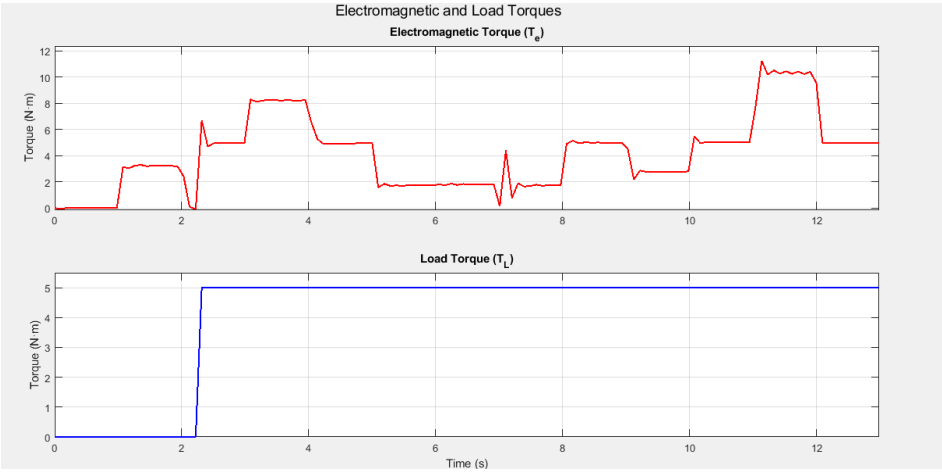
Rectifier B

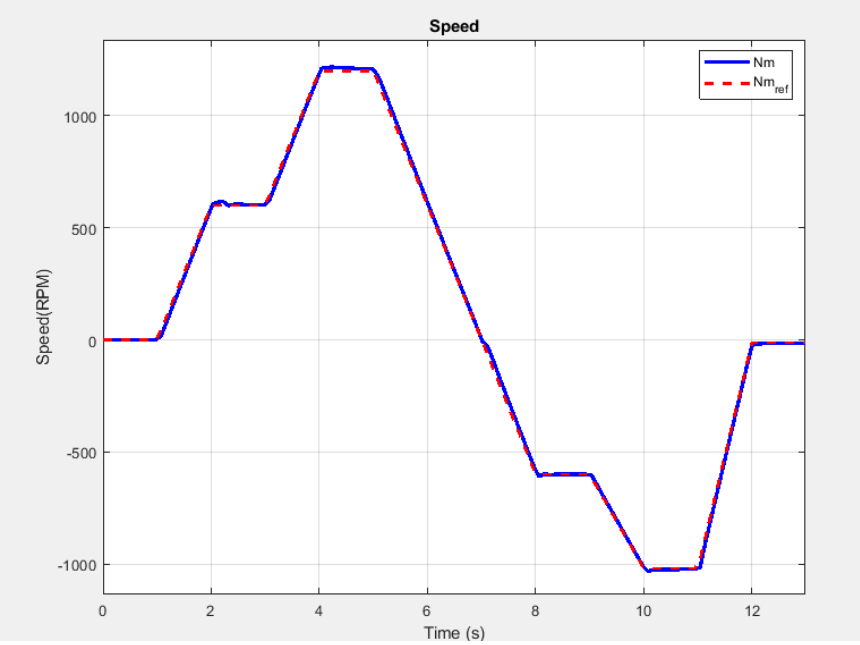
Outputs


Armature and Field Voltages
Va
Vf
Voltage (V)
Time (s)

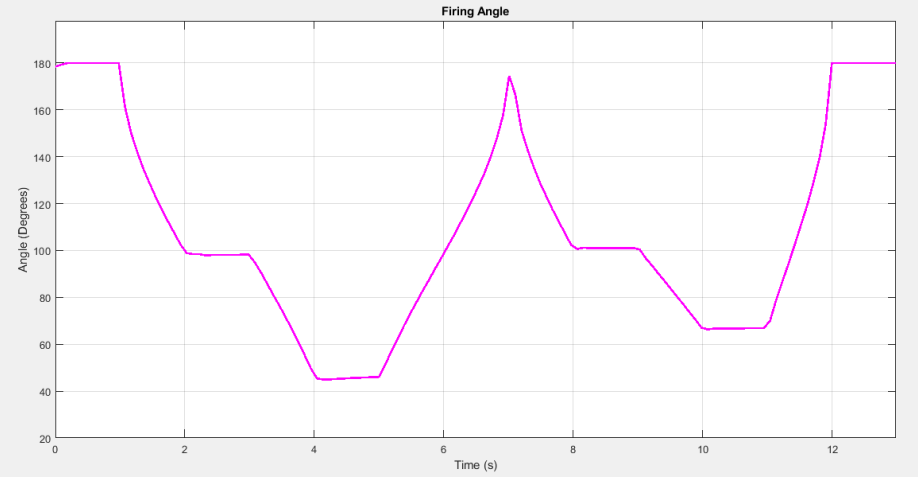

Rectifier Voltages
V rec_a
V rec_b
Voltage (V)
Time (s)

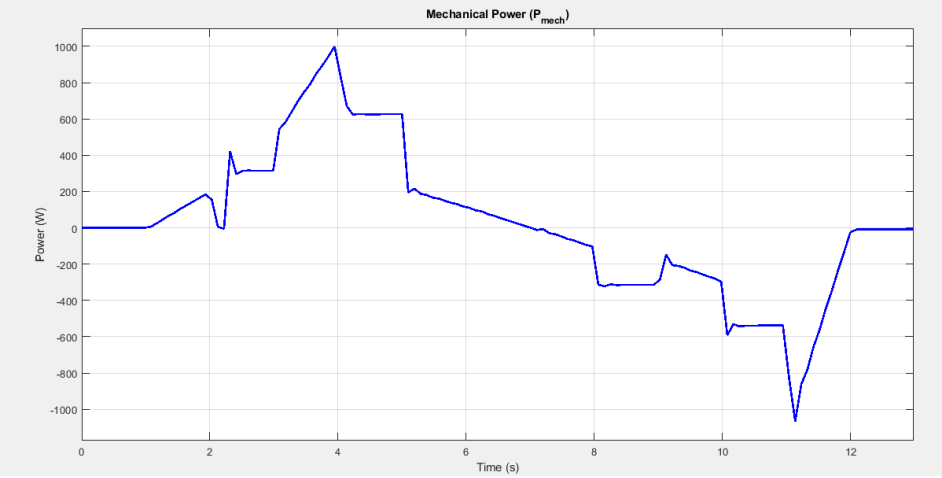

Armature and Field Currents
Armature Current (I a)
Current (A)
Field Current (I f)
Current (A)
Time (s)



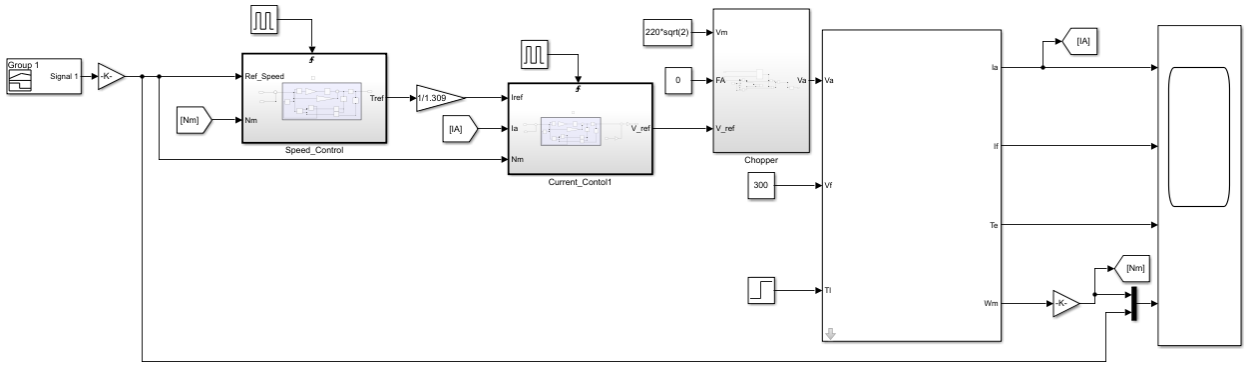


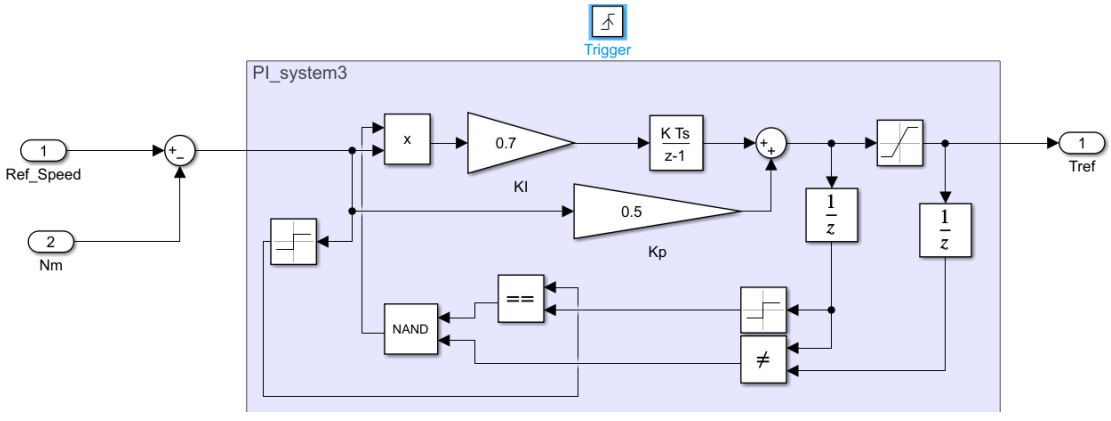
Based on firing angle will change Volt to control speed



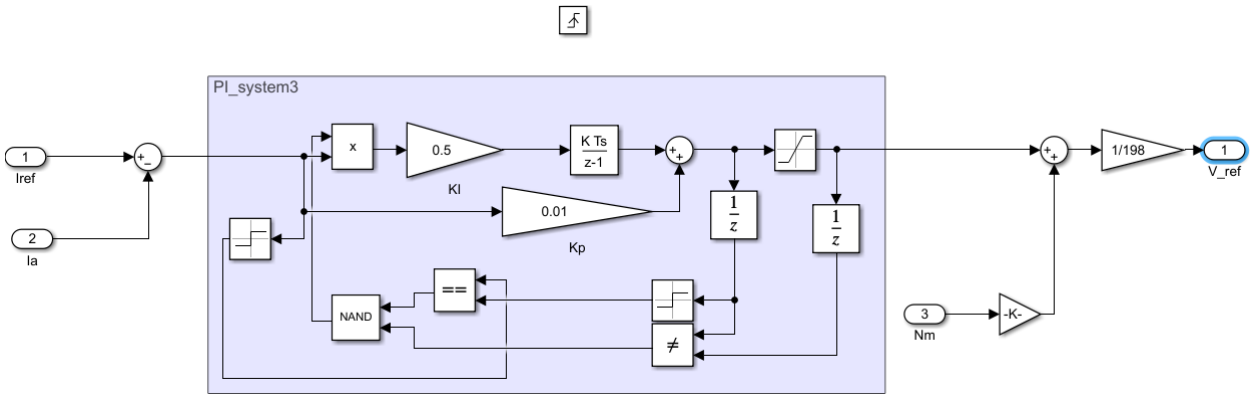


single-phase rectifier combined with a four-quadrant chopper operating unipolar modulation modes.

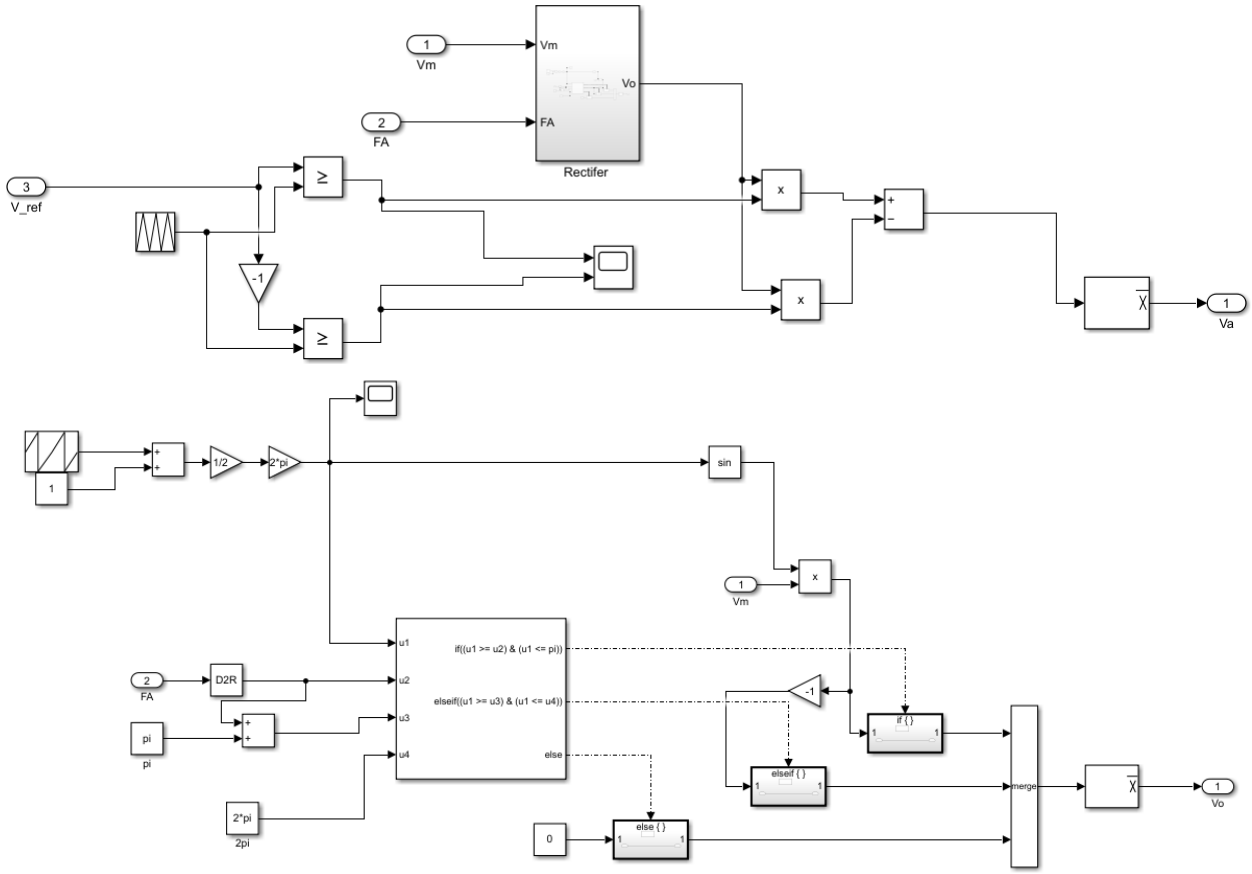




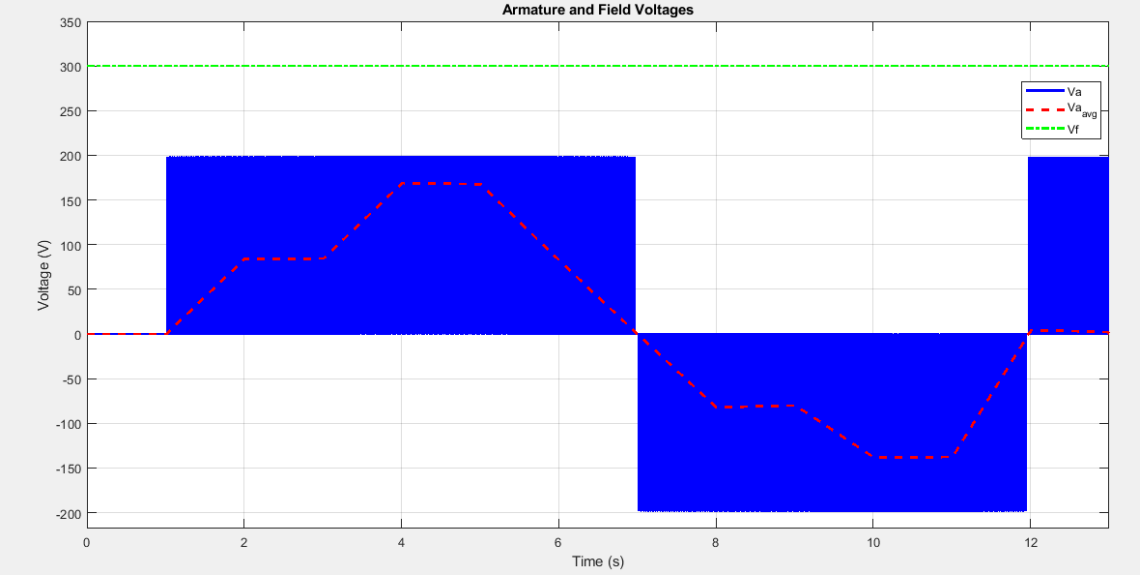
Speed control

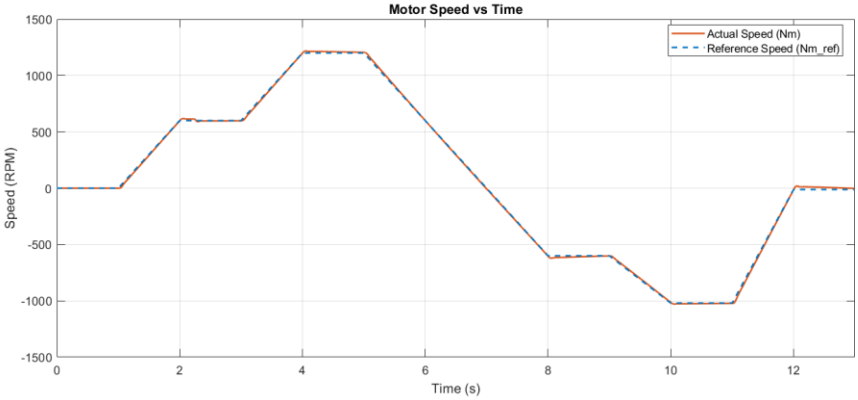


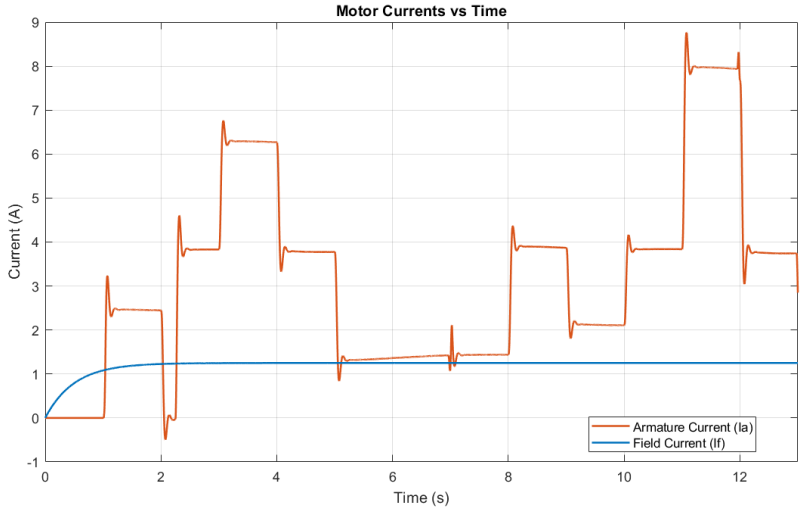
Current control

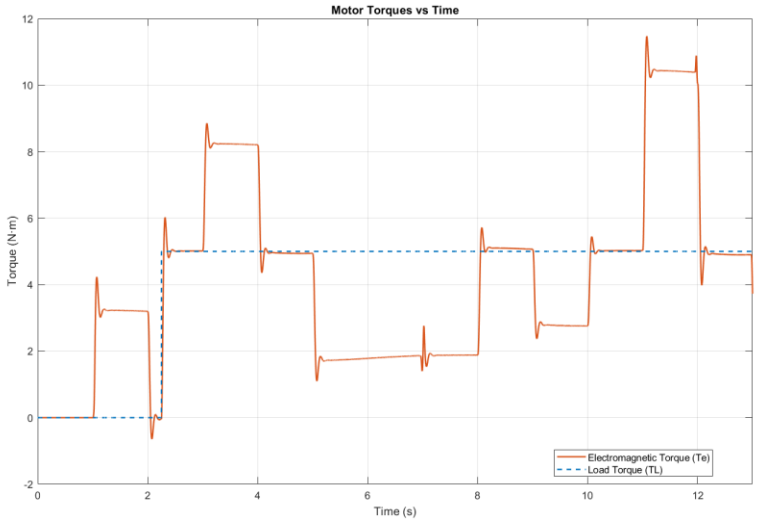


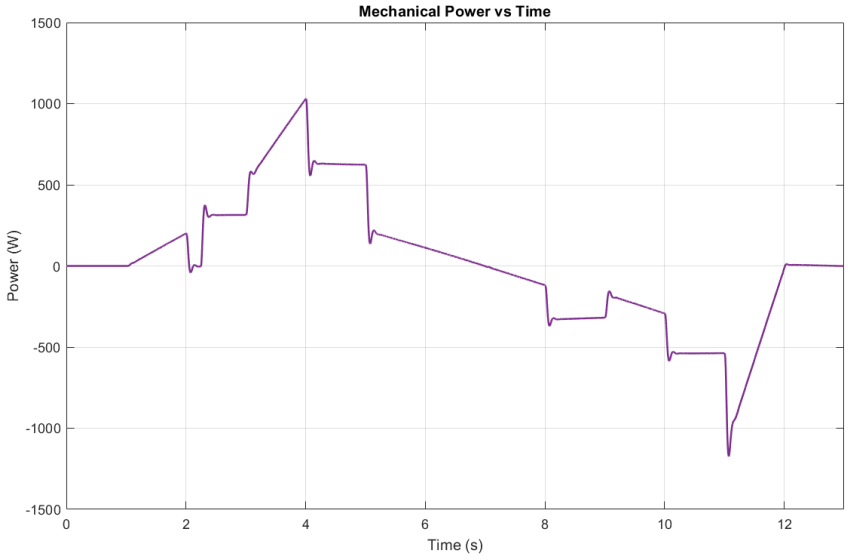
Outputs

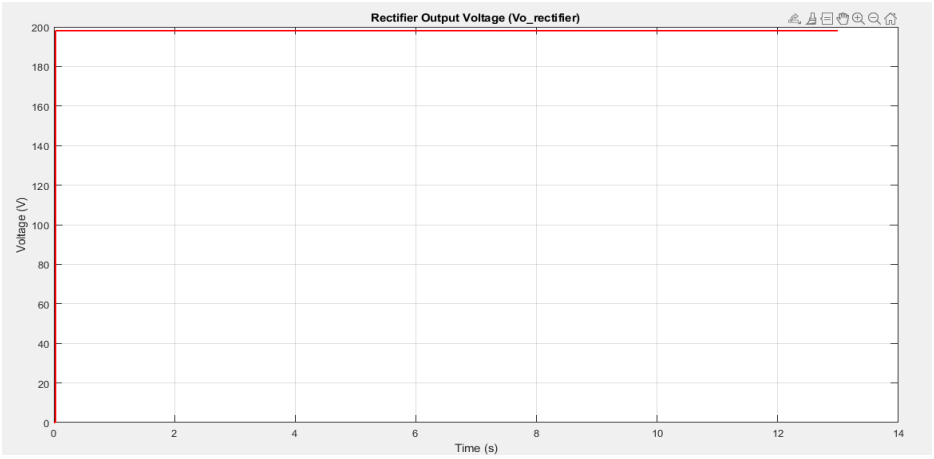

Armature and Field Voltages
Va
Va avg
Vf
Voltage (V)
Time (s)


Motor Speed vs Time
Actual Speed (Nm)
Reference Speed (Nm_ref)
Speed (RPM)
Time (s)

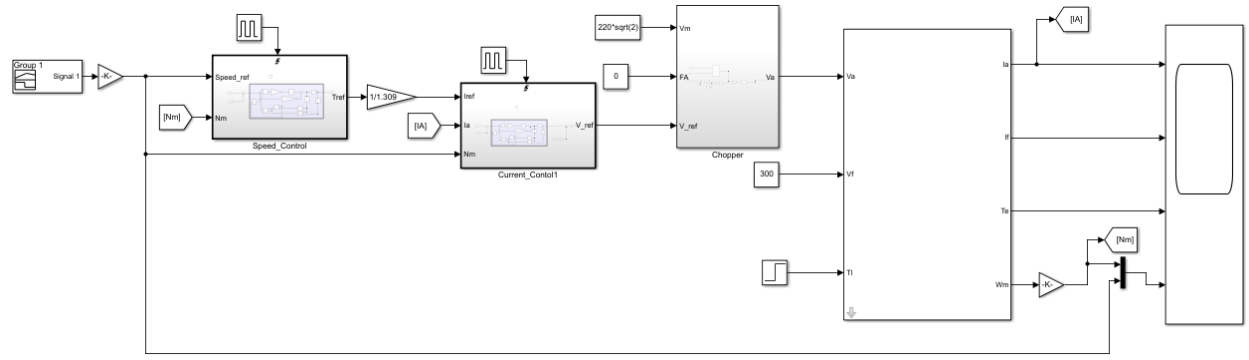

Motor Currents vs Time
Armature Current (Ia)
Field Current (If)
Current (A)
Time (s)

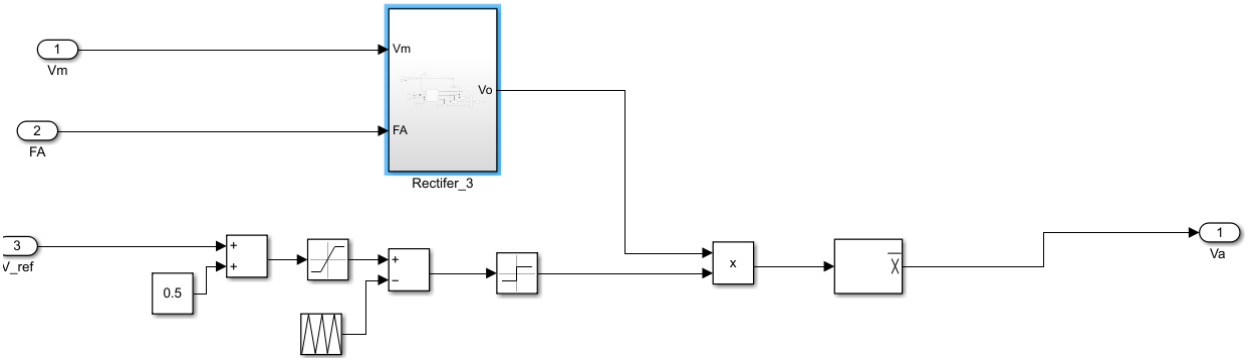

Motor Torques vs Time
Torque (N·m)
Time (s)
Electromagnetic Torque (Te)
Load Torque (TL)

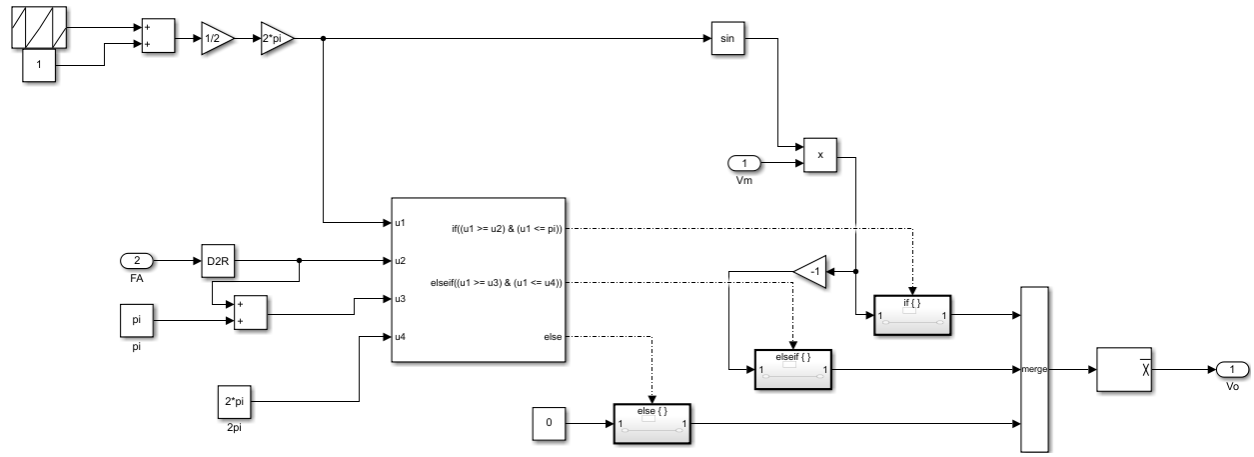

Mechanical Power vs Time
Power (W)
Time (s)

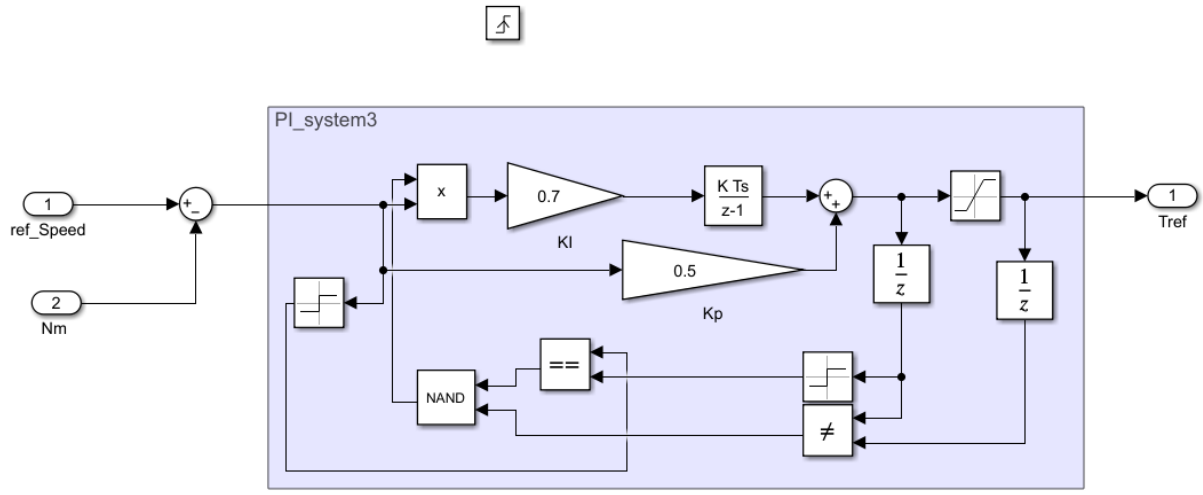

Rectifier Output Voltage (Vo_rectifier)
Voltage (V)
Time (s)

single-phase rectifier combined with a four-quadrant chopper operating bipolar modulation modes.

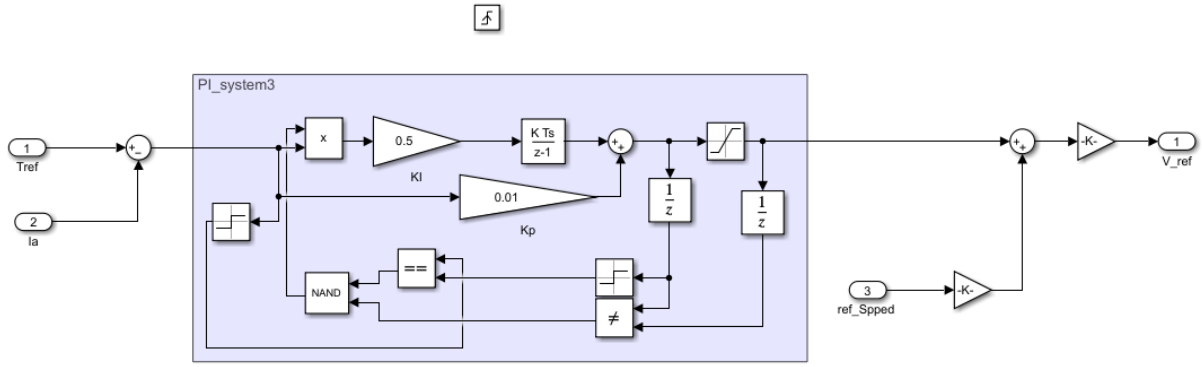




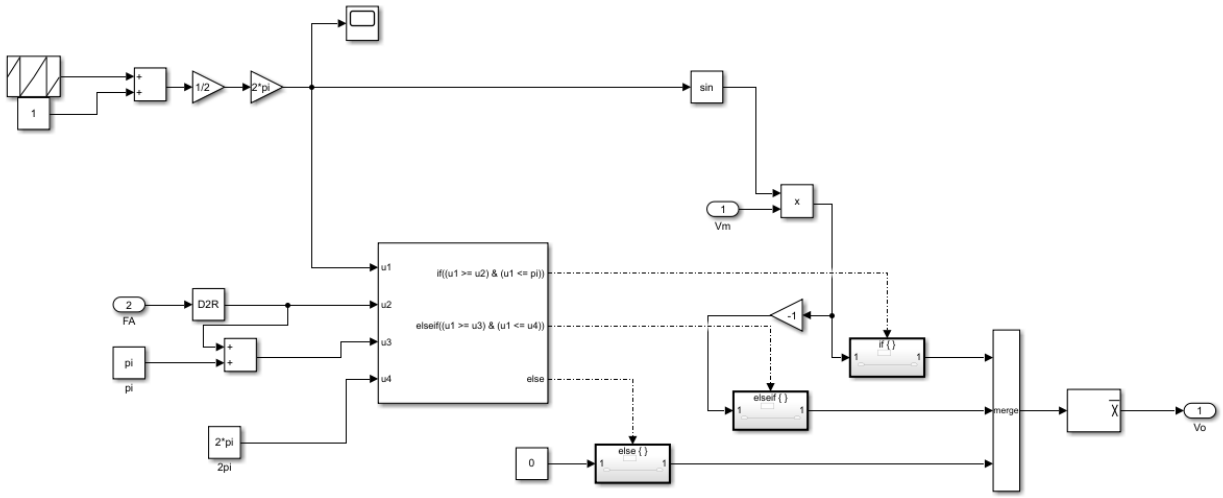




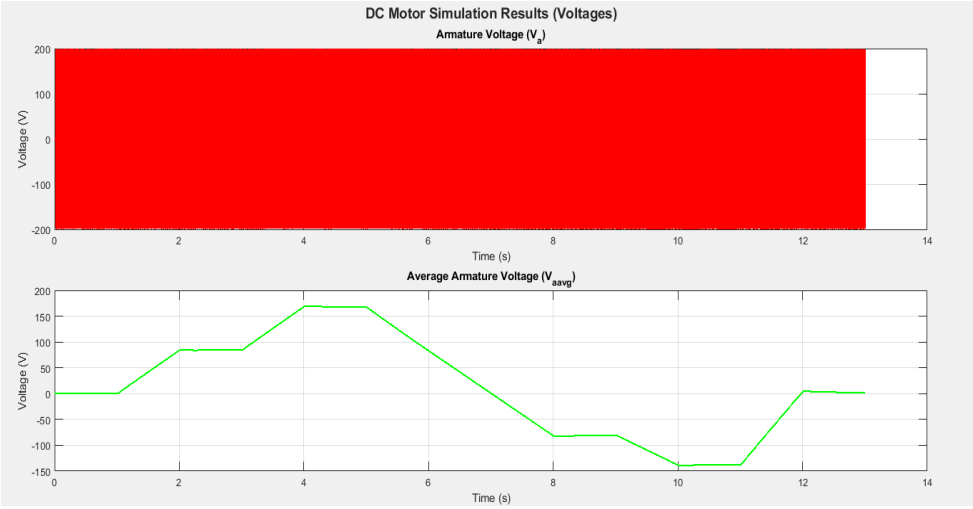
Speed control

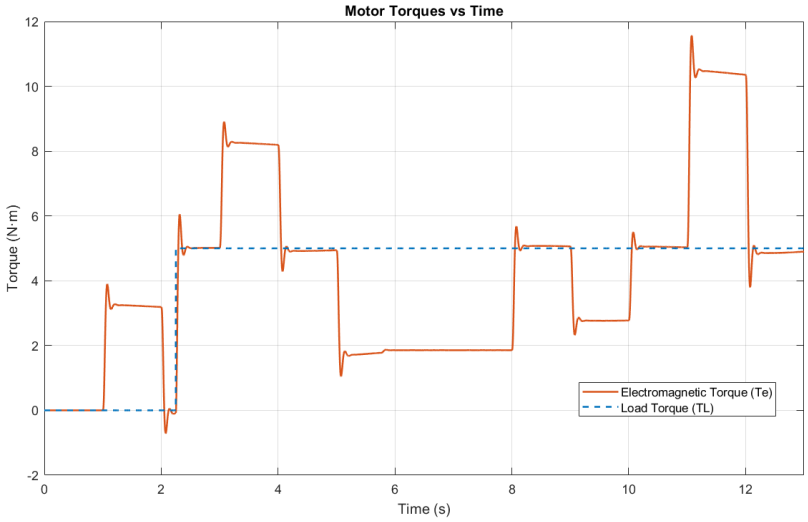


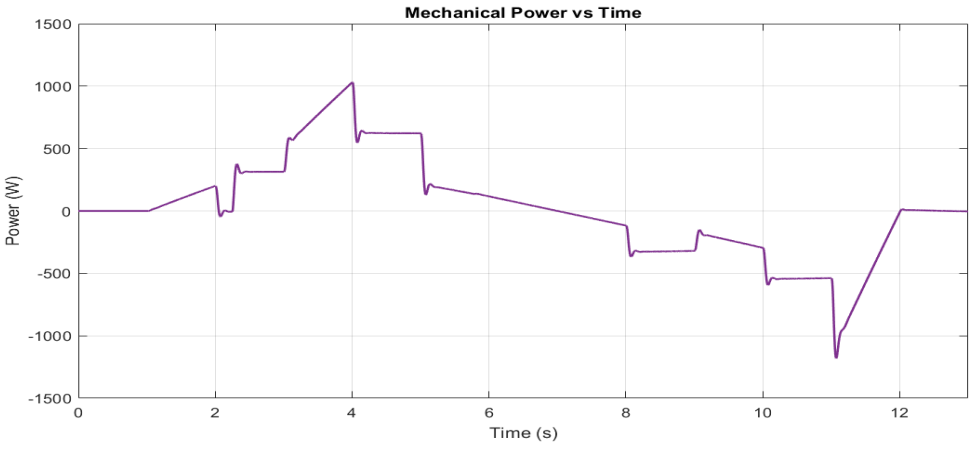
Current control

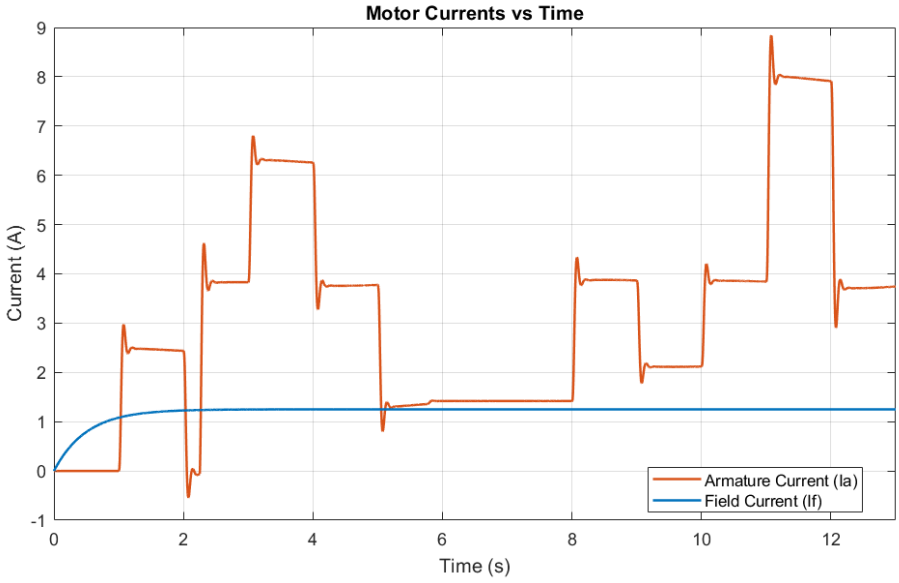


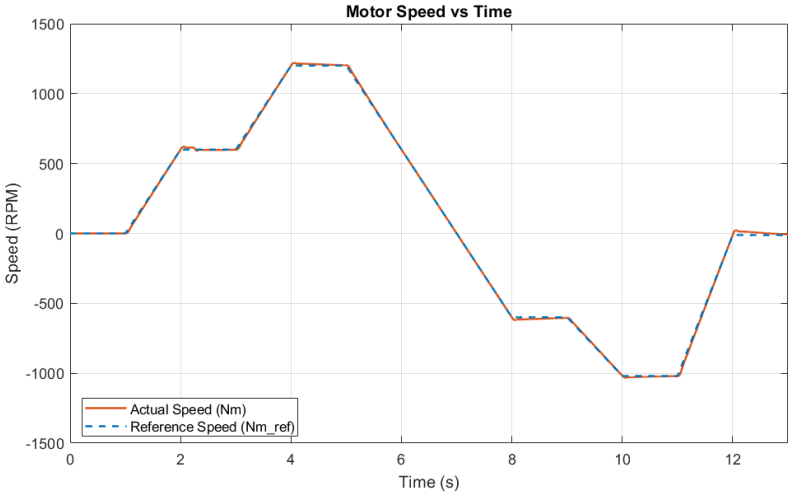
Outputs

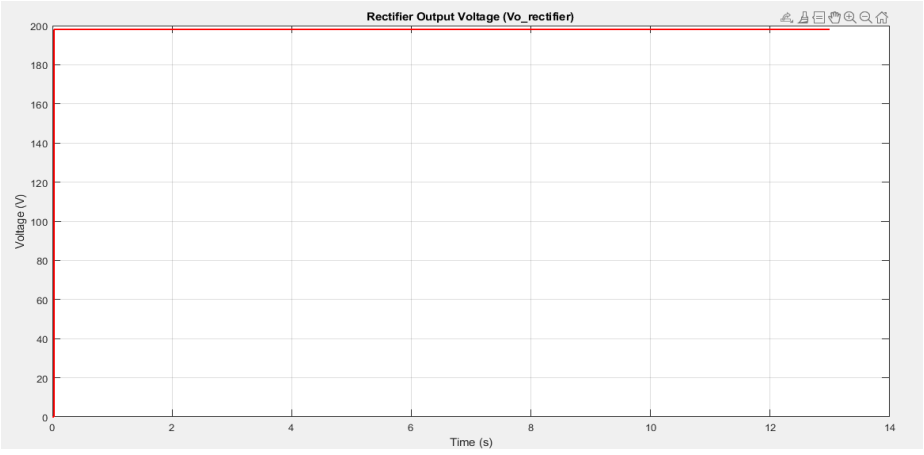

DC Motor Simulation Results (Voltages)
Armature Voltage (V_a)
Voltage (V)
Time (s)
Average Armature Voltage (V_{aavg})
Voltage (V)
Time (s)


Motor Torques vs Time
Torque (N·m)
Time (s)
Electromagnetic Torque (Te)
Load Torque (TL)

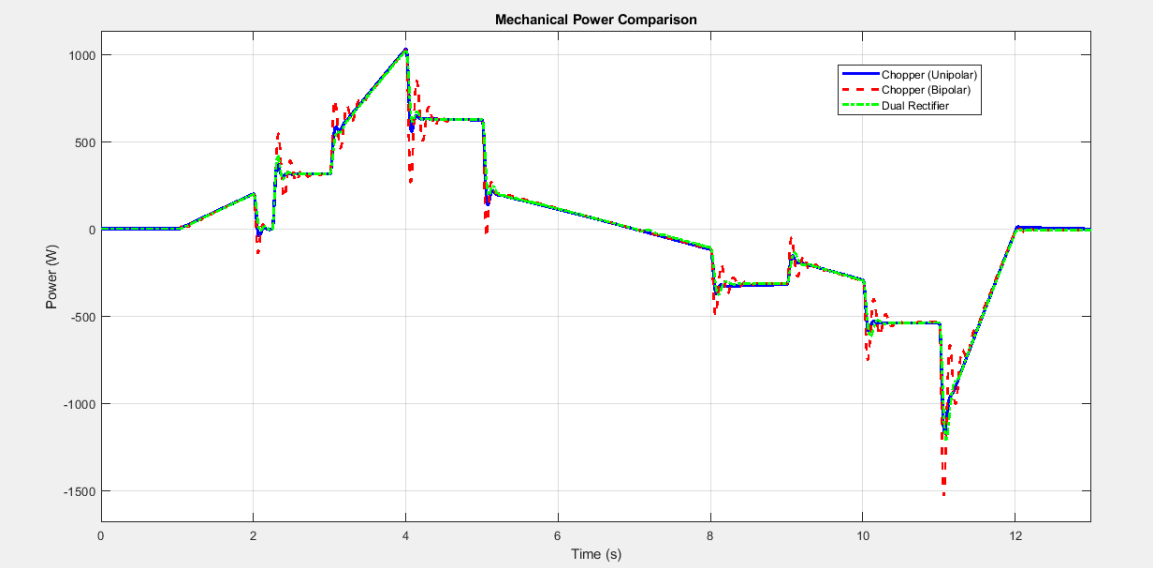

Mechanical Power vs Time
Power (W)
Time (s)


Motor Currents vs Time
Current (A)
Time (s)
Armature Current (Ia)
Field Current (If)


Motor Speed vs Time
Speed (RPM)
Time (s)
Actual Speed (Nm)
Reference Speed (Nm_ref)


Rectifier Output Voltage (Vo_rectifier)
Voltage (V)
Time (s)

Comparison



1. **Single-Phase Rectifier + Four-Quadrant Chopper (Bipolar Modulation)**

Bipolar modulation leads to higher switching losses due to frequent transitions between positive and negative power.

Smooth transitions between quadrants, suitable for applications requiring bidirectional power flow.

2. **Single-Phase Rectifier + Four-Quadrant Chopper (Unipolar Modulation)**

Unipolar modulation reduces switching losses compared to bipolar modulation.

Simpler control but limited to specific power flow directions unless complemented with other modes.

3. **Dual Single-Phase Full-Wave Controlled Rectifiers**

Dual rectifiers provide higher power handling and better control.

Typically used in applications requiring precise power regulation, such as motor drives or grid-tied systems.

Conclusion

This project successfully demonstrated the design and simulation of a separately excited DC motor drive using MATLAB **without relying on pre-built machine, converter, or modulator blocks**, aligning with the project's strict requirements.

The **discrete-time** models developed provided a comprehensive understanding of DC motor control, power electronics, and their interactions under dynamic operating conditions. The results highlighted the unique advantages and challenges associated with each power electronic configuration. Dual single-phase rectifier systems offered greater control flexibility and smoother torque characteristics, while single-phase rectifier and chopper configurations exhibited higher efficiency and lower component count. The unipolar and bipolar modulation schemes each presented distinct trade-offs in terms of switching losses, control complexity, and harmonic content.