Electric Vehicles

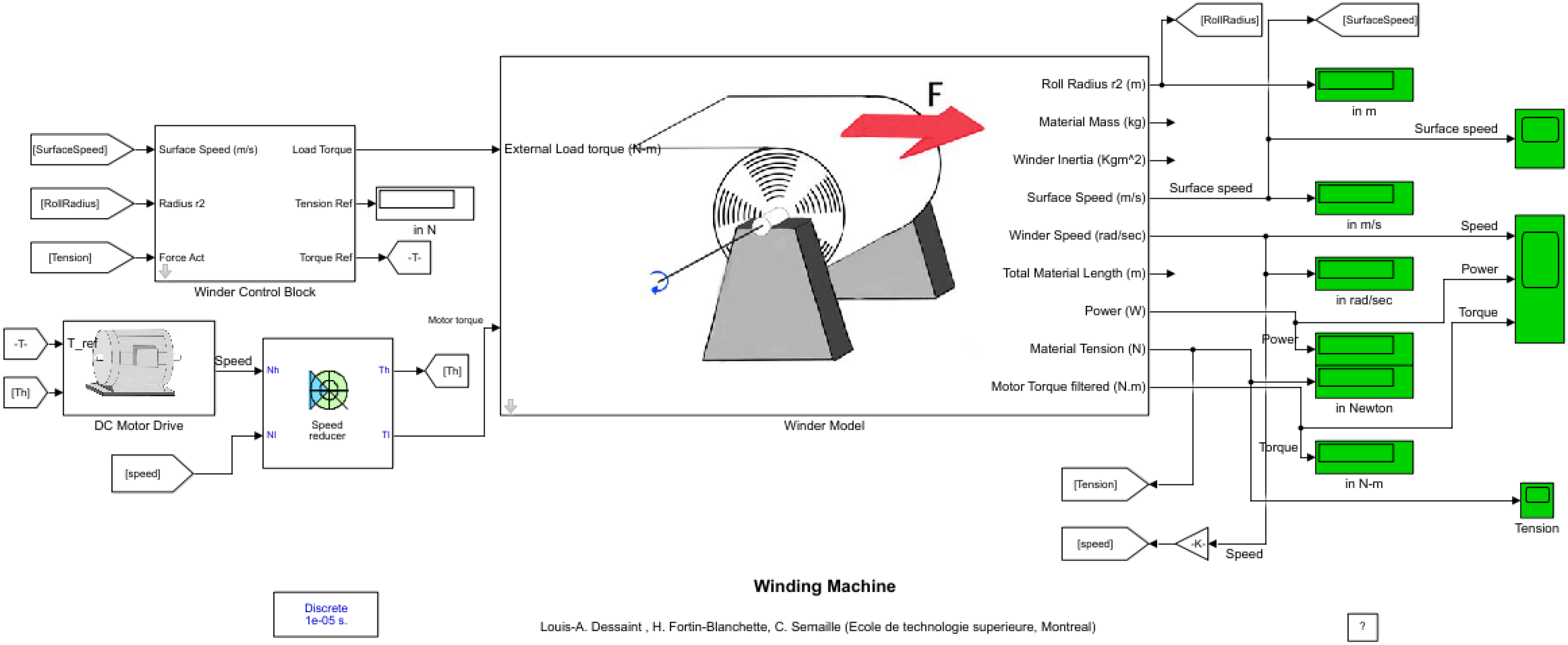
ELEC 5970/6970/6970-D02

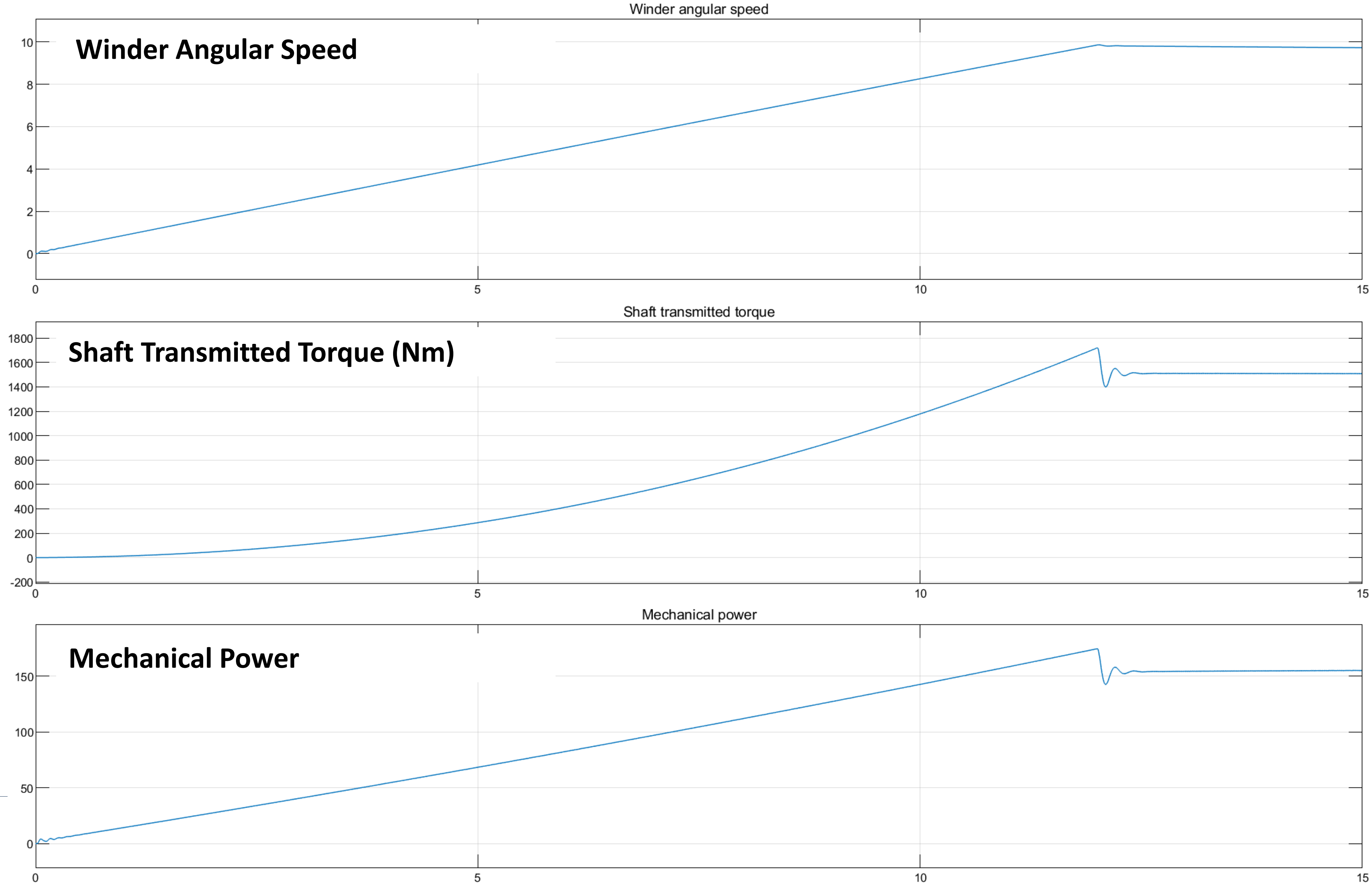
Matlab/Simulink Simulations

References:

- Iqbal Husain, ”Electric and Hybrid Vehicles, Design Fundamentals,” Third Edition, March 2021, CRC Press, Taylor & Francis Group, ISBN: 978-0429-49092-7

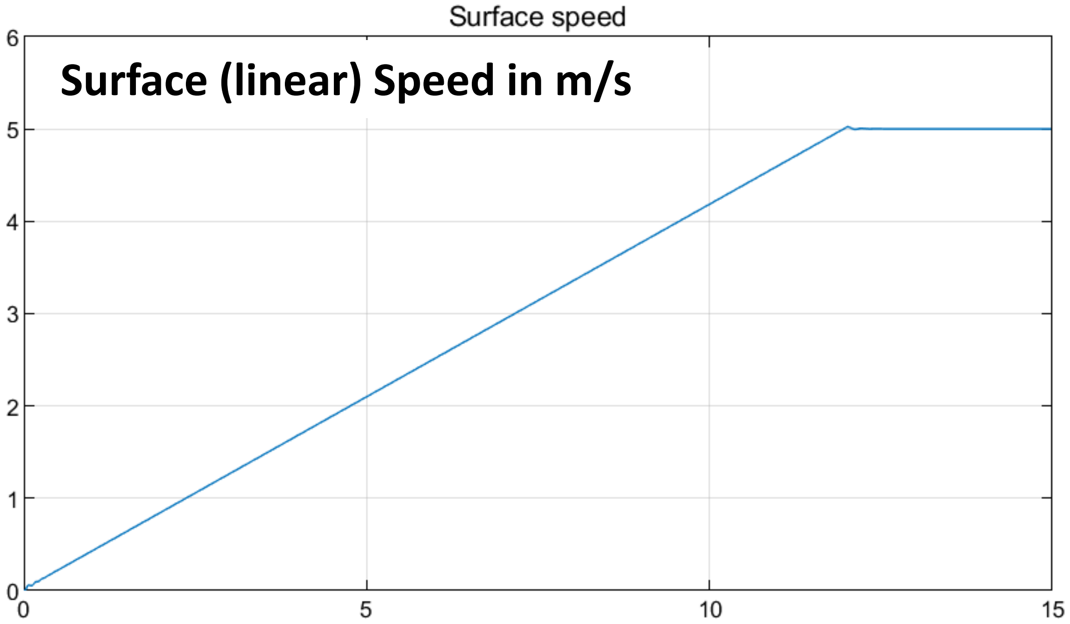
Matlab/Simulink/Simscape Simulations – cs_winder.slx

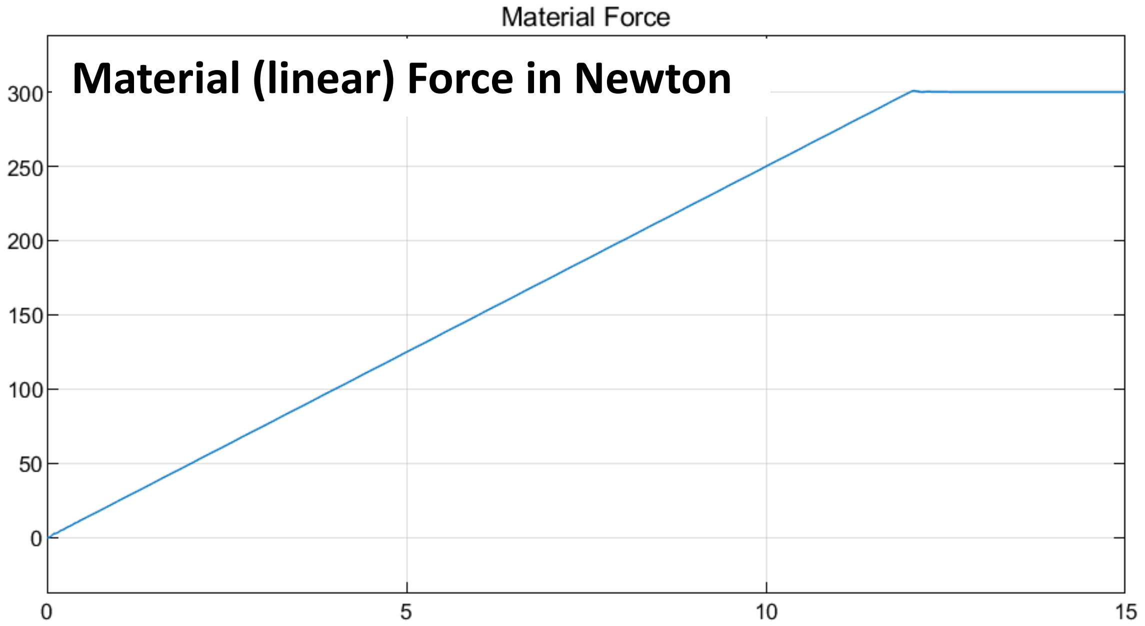




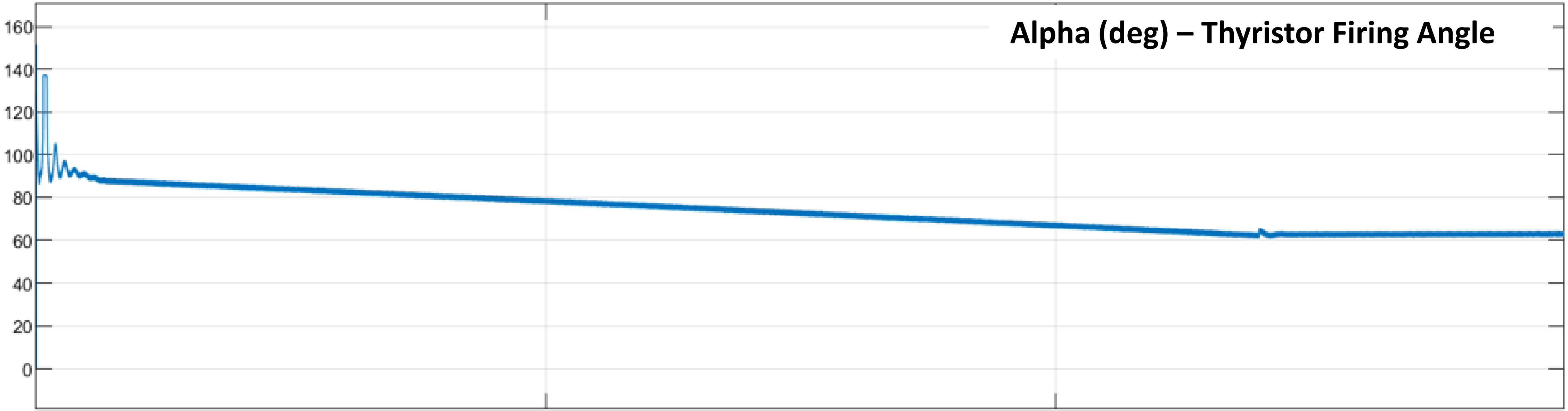
Winder angular speed
Winder Angular Speed
Shaft transmitted torque
Shaft Transmitted Torque (Nm)
Mechanical power
Mechanical Power

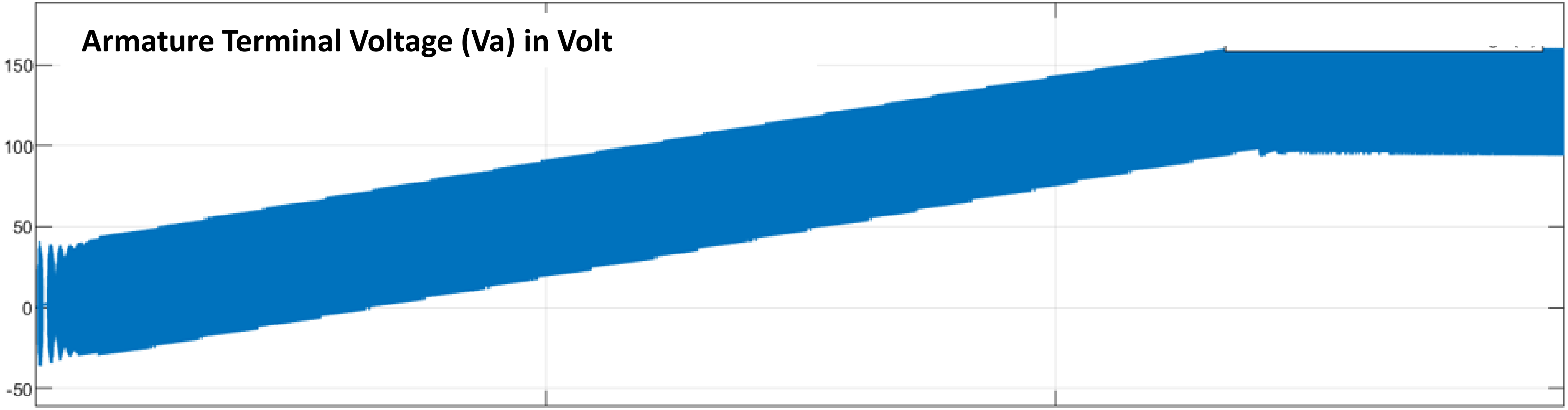
Matlab/Simulink/Simscape Simulations

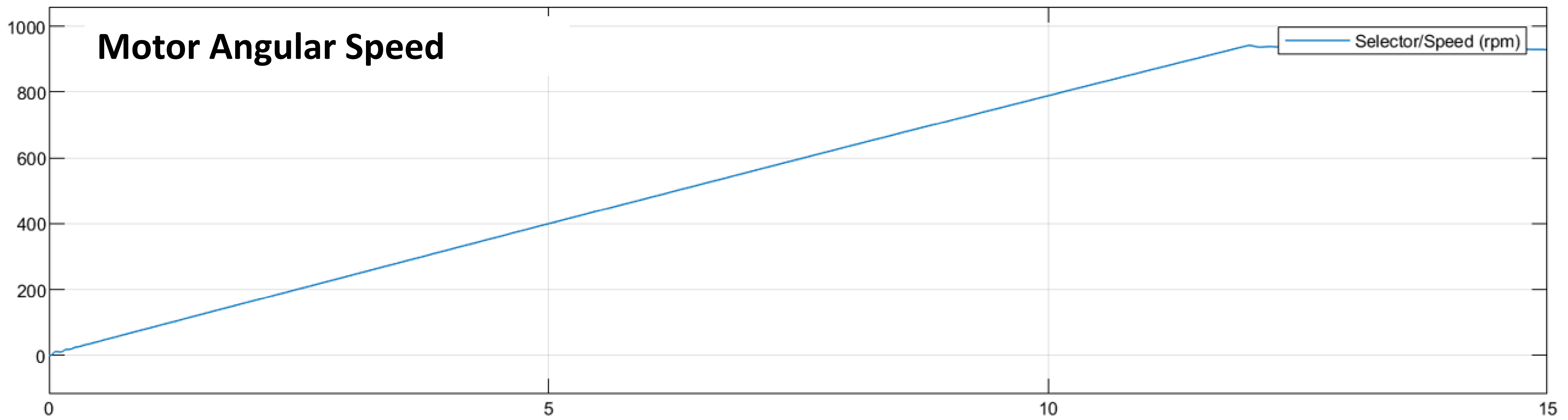


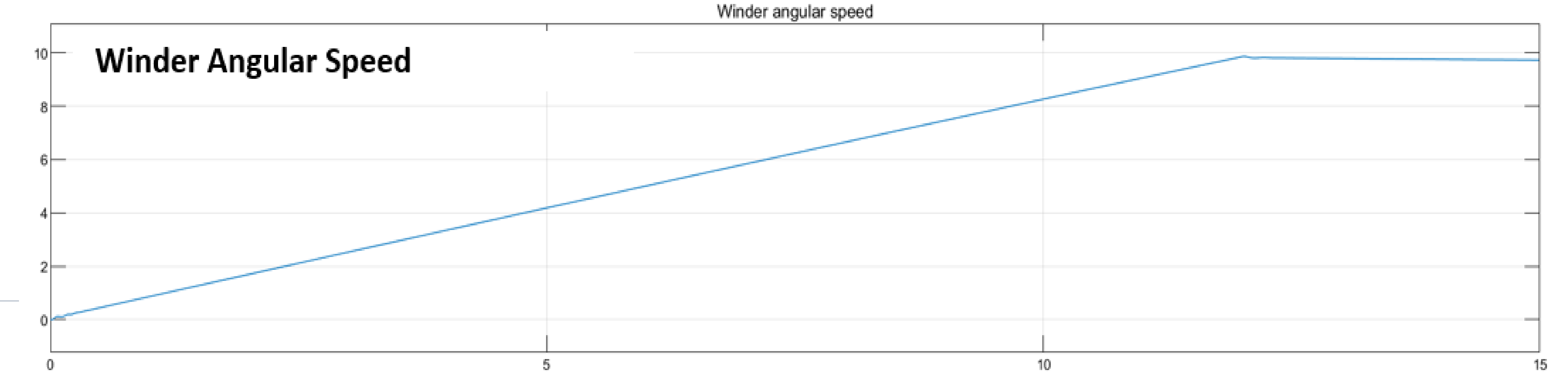


Matlab/Simulink/Simscape Simulations





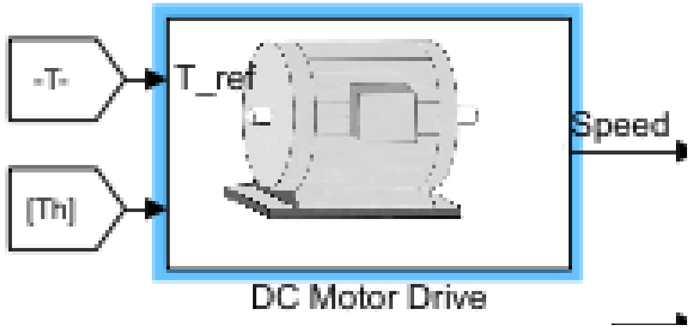

Motor Angular Speed
Selector/Speed (rpm)
1000
800
600
400
200
0
0
5
10
15

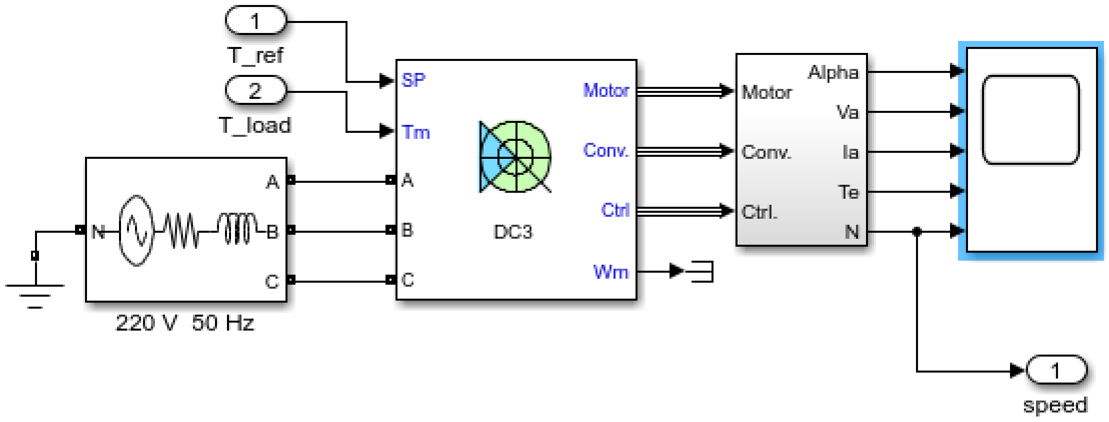

Winder angular speed
Winder Angular Speed
10
8
6
4
2
0
0
5
10
15

Matlab/Simulink/Simscape Simulations

The Two-Quadrant Three Phase Rectifier DC Drive block uses these blocks from the Electric Drives/Fundamental Drive Blocks library:

- Speed Controller (DC)
- Regulation Switch
- Current Controller (DC)
- Bridge Firing Unit (DC)

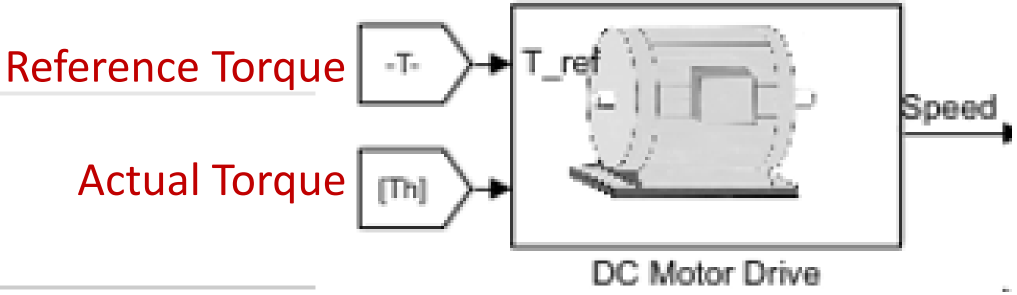




Two-Quadrant Three-Phase Rectifier DC Drive

R2022a

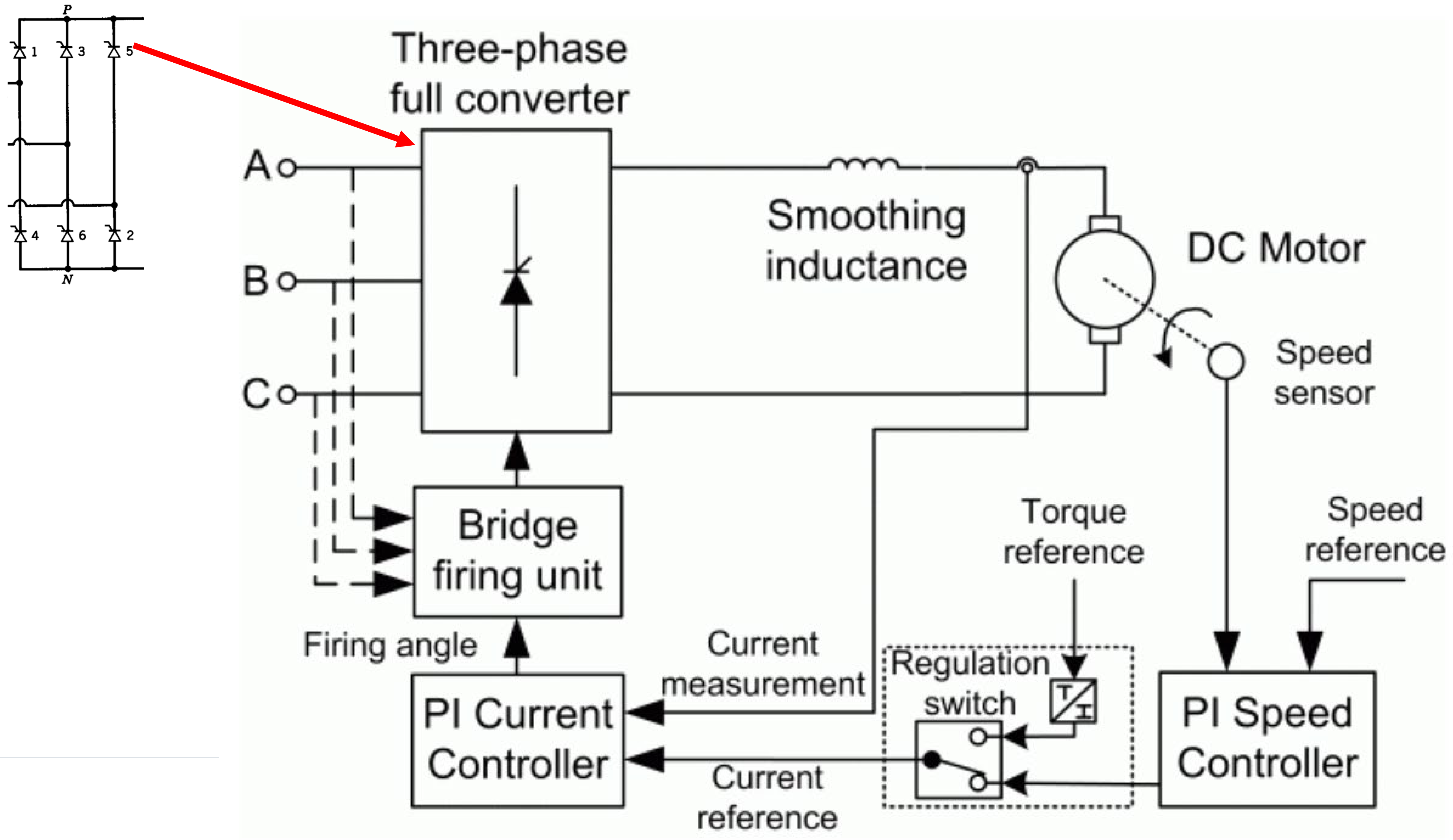
Implement two-quadrant three-phase rectifier DC drive



Description

The Two-Quadrant Three-Phase Rectifier DC Drive (DC3) block represents a two-quadrant, three-phase, thyristor-based (or phase controlled) drive for DC motors. This drive features closed-loop speed control with two-quadrant operation. The speed control loop outputs the reference armature current of the machine. Using a PI current controller, the thyristor firing angle corresponding to the commanded armature current is derived. This firing angle is then used to obtain the required gate signals for the rectifier through a thyristor bridge firing unit.

The main advantage of this drive, compared with other DC drives, is its implementation simplicity. However, for all two-quadrant DC drives, reversible and regenerative operations (reverse motoring and forward regeneration), which are required in most DC drives, cannot be obtained.


P
1
3
5
4
6
2
N
Three-phase
full converter
A
B
C
Smoothing
inductance
DC Motor
Speed
sensor
Bridge
firing unit
Firing angle
Torque
reference
Speed
reference
Current
measurement
Regulation
switch
T
I
PI Current
Controller
Current
reference
PI Speed
Controller

Matlab/Simulink/Simscape Simulations

Remarks

The machine is separately excited with a constant DC field voltage source. There is thus no field voltage control. By default, the field current is set to its steady-state value when a simulation is started.

The armature voltage is provided by a three-phase rectifier controlled by two PI regulators. Armature current oscillations are reduced by a smoothing inductance connected in series with the armature circuit.

The average-value converter represents the average behavior of a three-phase rectifier for continuous armature current. This model is thus not suitable for simulating DC drives under discontinuous armature current conditions. The converter outputs a continuous voltage value equal to the average-value of the real-life rectified voltage. The armature voltage, armature current, and electromagnetic torque ripples are thus not represented. The input currents have the frequency and amplitude of the fundamental current component of the real-life input currents.

General

Output bus mode

Select how the output variables are organized. If you select `Multiple output buses`, the block has three separate output buses for motor, converter, and controller variables. If you select `Single output bus`, all variables output on a single bus.

Model detail level

Select between the detailed and the average-value inverter. Default is `Detailed`.

Mechanical input

Select between the load torque, the motor speed and the mechanical rotational port as mechanical input. Default is `Torque Tm`.

If you select and apply a load torque, the output is the motor speed according to the following differential equation that describes the mechanical system dynamics:

$$T_e = J\frac{d}{dt}\omega_r + F\omega_r + T_m$$

This mechanical system is included in the motor model.

Electric Vehicles

ELEC 5970/6970/6970-D01

EV Dynamic Simulations

Vehicle Control, Permanent Magnet Synchronous Motor (PMSM) Drive
Vehicle Dynamics, Cooling System

References:
- Iqbal Husain, "Electric and Hybrid Vehicles, Design Fundamentals," Third Edition, March 2021, CRC Press, Taylor & Francis Group, ISBN: 978-0429-49092-7

Simulation

This example shows an electric vehicle model suitable for Hardware-In-the-Loop (HIL) deployment. Energy-based modeling is used to avoid high frequency switching, and solvers set for fixed-step simulation.

The test run shows the vehicle accelerating to a steady speed up an inclined followed by a period of descent during which electrical power is returned to the battery.

Auburn University\Courses\Electric Vehicles\Matlab\EE_Auto_EV

Description

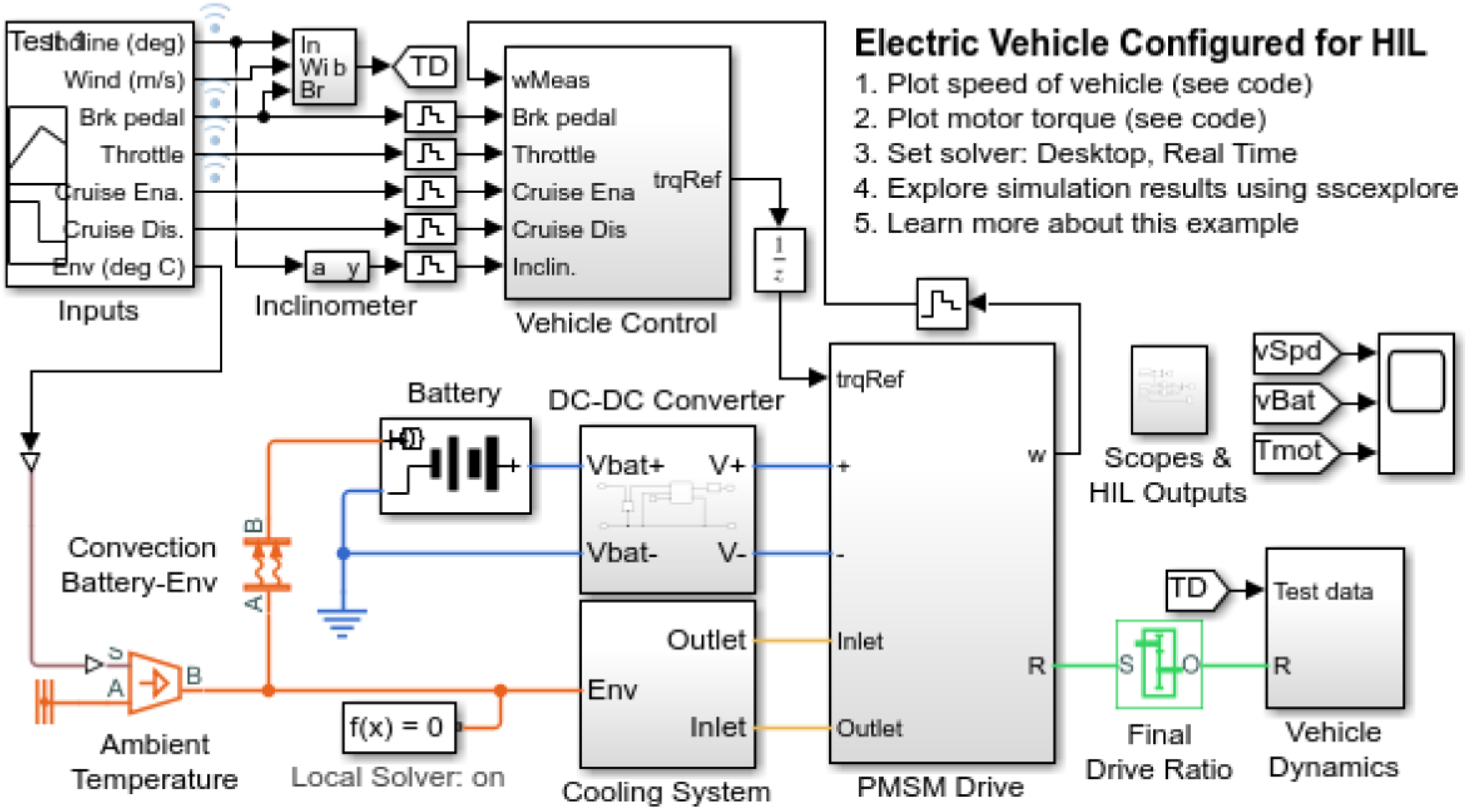
- The scope of a simulation covers a dynamic simulation of an electric vehicle.
- At this point we are familiar with Chapter 2 Vehicle Mechanics and Chapter 3 Vehicle Architectures and Design

Description

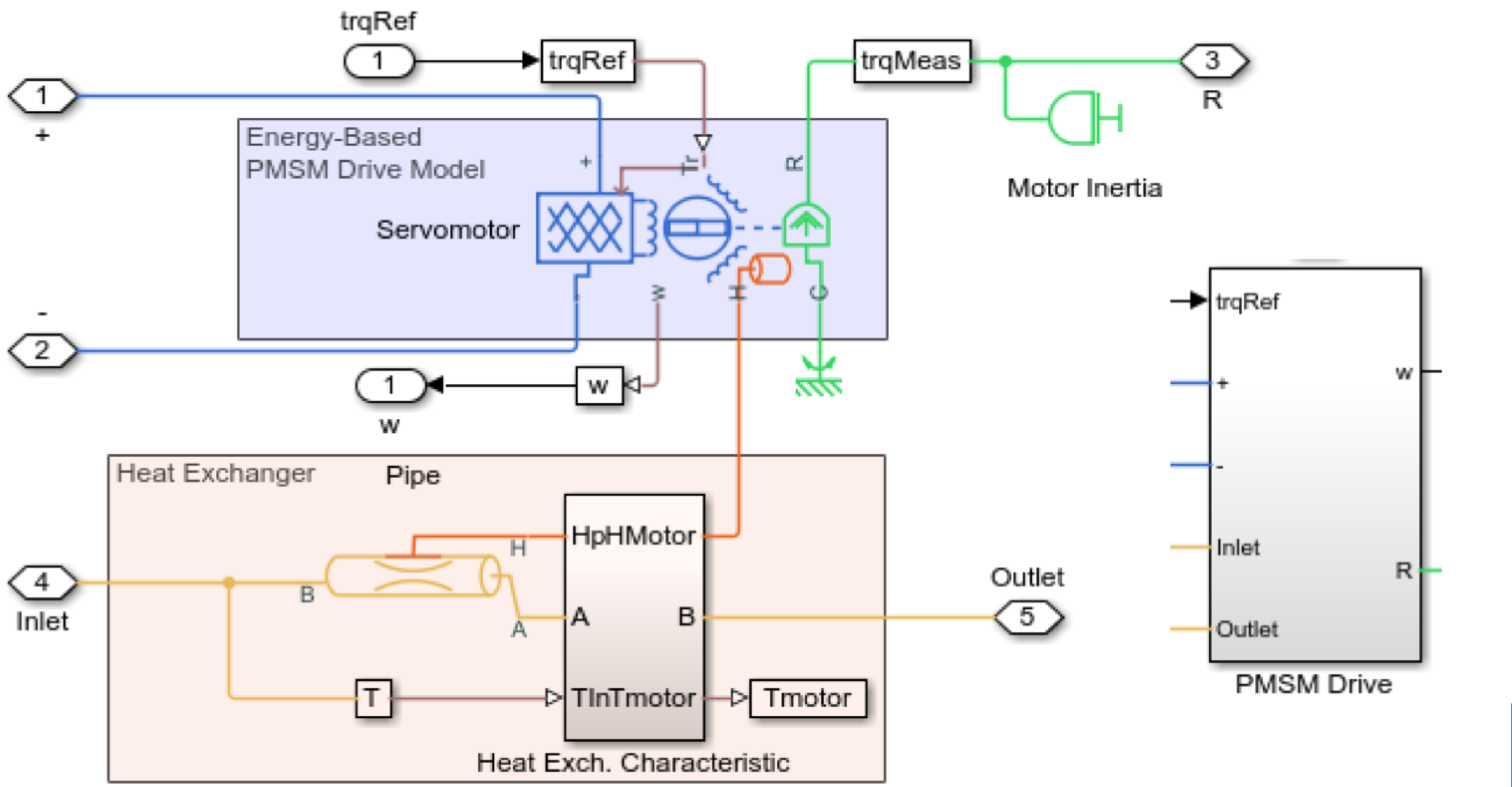
The EV simulation is divided into four important parts:

1. Vehicle Control
2. Permanent Magnet Synchronous Motor (PMSM) Drive
3. Vehicle Dynamics
4. Cooling System

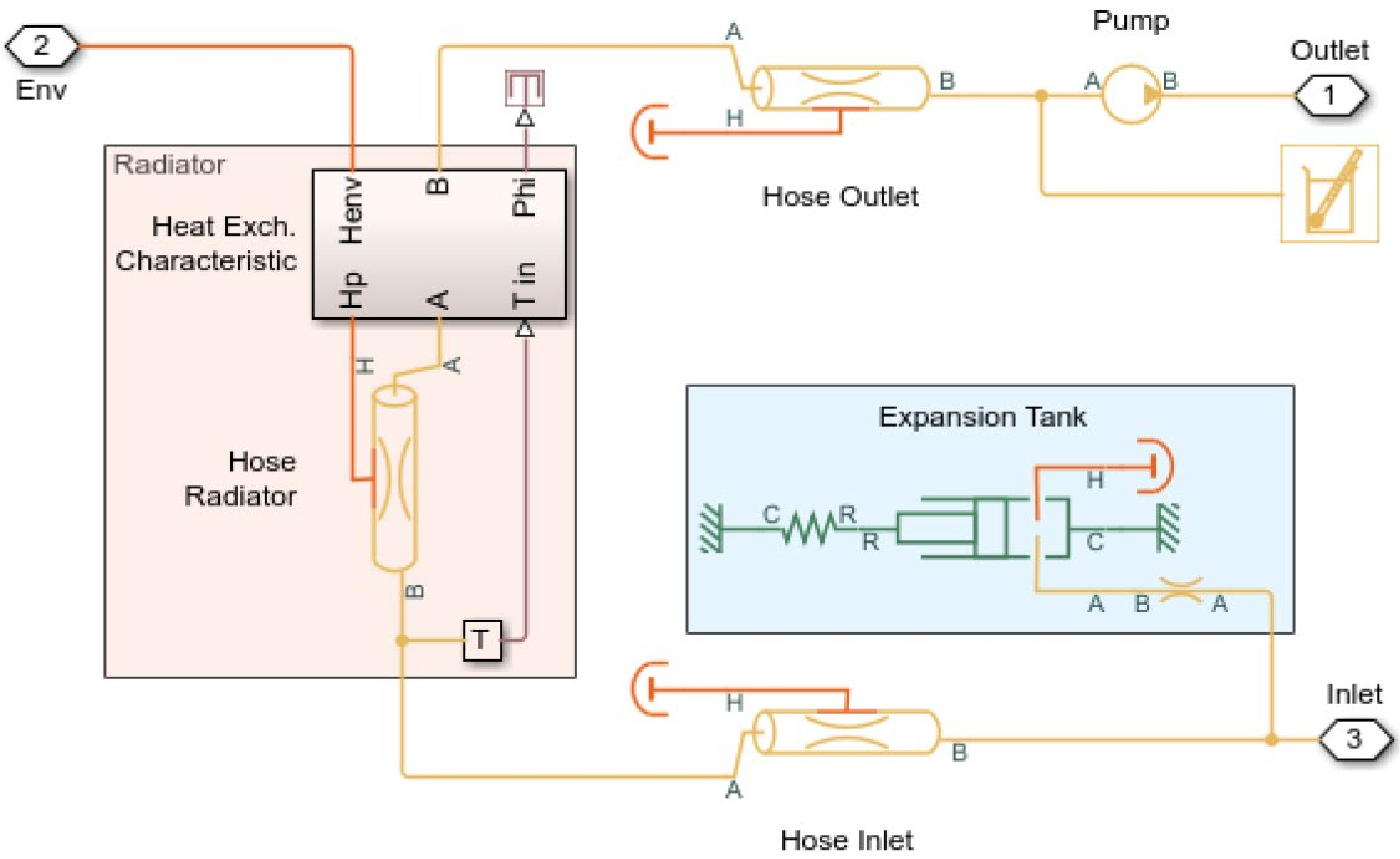
Model


Electric Vehicle Configured for HIL
1. Plot speed of vehicle (see code)
2. Plot motor torque (see code)
3. Set solver: Desktop, Real Time
4. Explore simulation results using sscexplore
5. Learn more about this example
Incline (deg)
Wind (m/s)
Brk pedal
Throttle
Cruise Ena.
Cruise Dis.
Env (deg C)
Inputs
In
Wi b
Br
TD
a y
Inclinometer
wMeas
Brk pedal
Throttle
Cruise Ena
Cruise Dis
Inclin.
trqRef
Vehicle Control
trqRef
w
PMSM Drive
Scopes &
HIL Outputs
vSpd
vBat
Tmot
Battery
DC-DC Converter
Vbat+
V+
Vbat-
V-
Convection
Battery-Env
Outlet
Env
Inlet
Inlet
Outlet
Cooling System
R
S
O
Final
Drive Ratio
TD
Test data
R
Vehicle
Dynamics
A
B
Ambient
Temperature
f(x) = 0
Local Solver: on

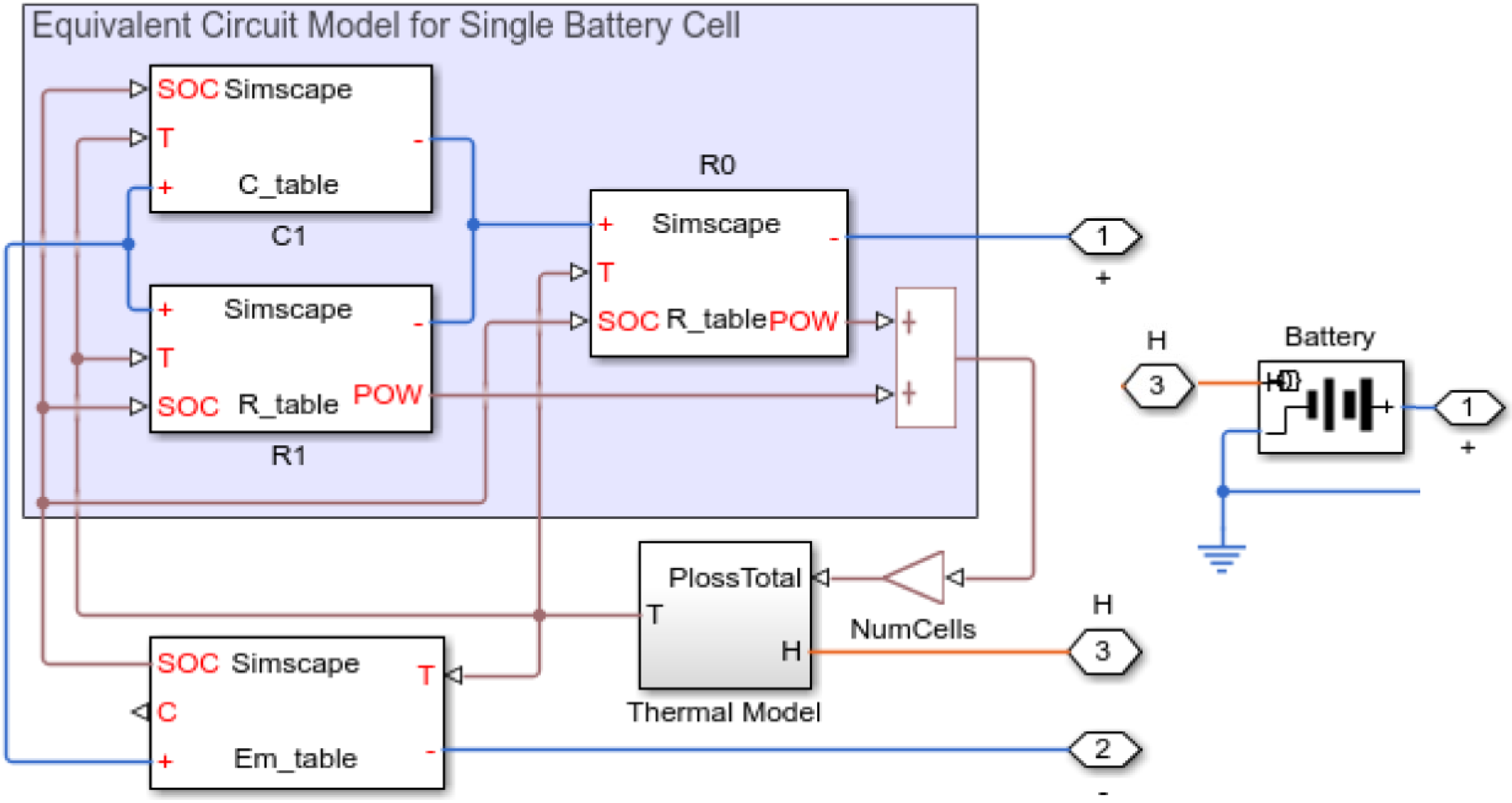
PMSM Drive Subsystem



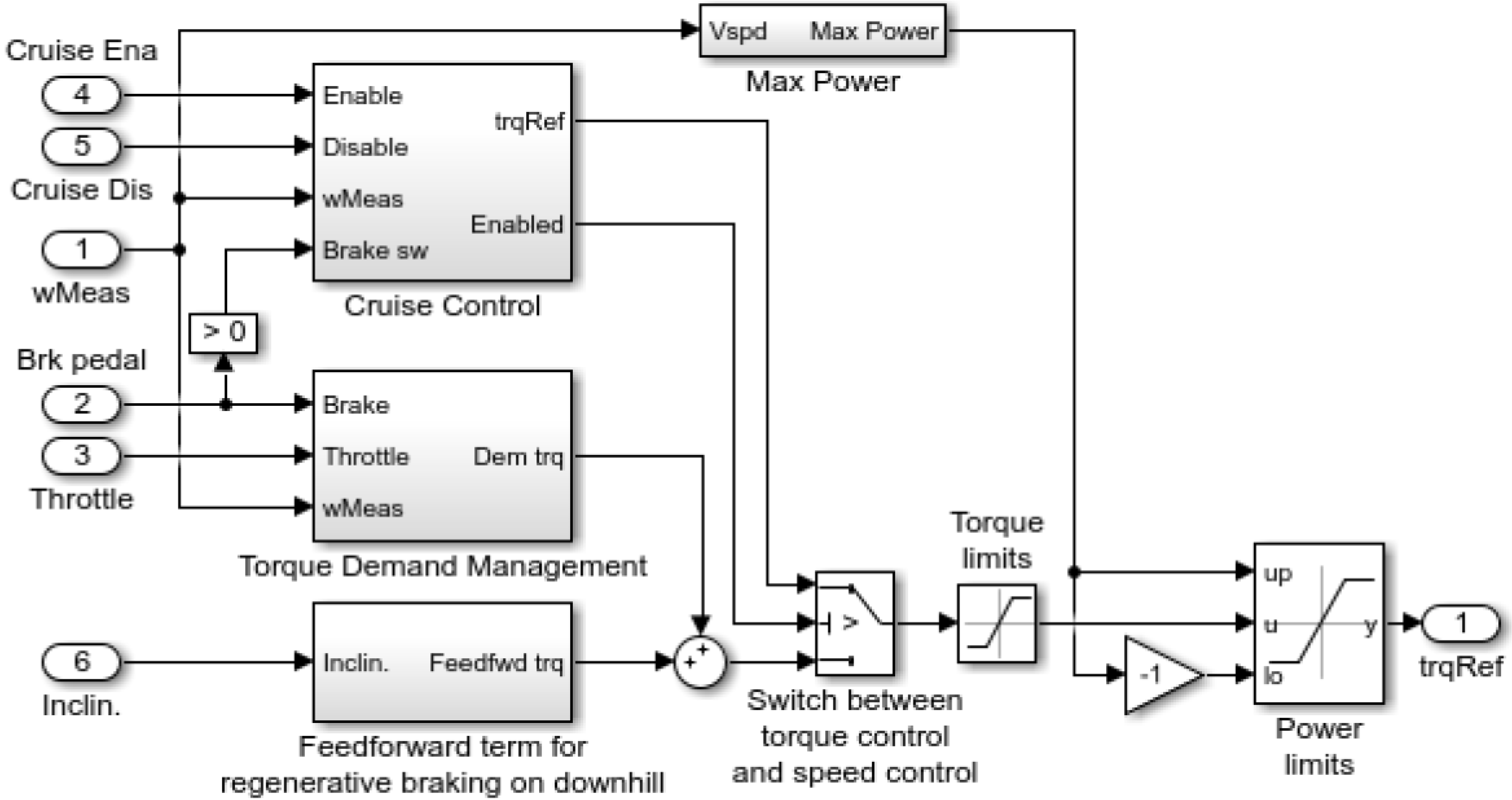
Cooling System Subsystem

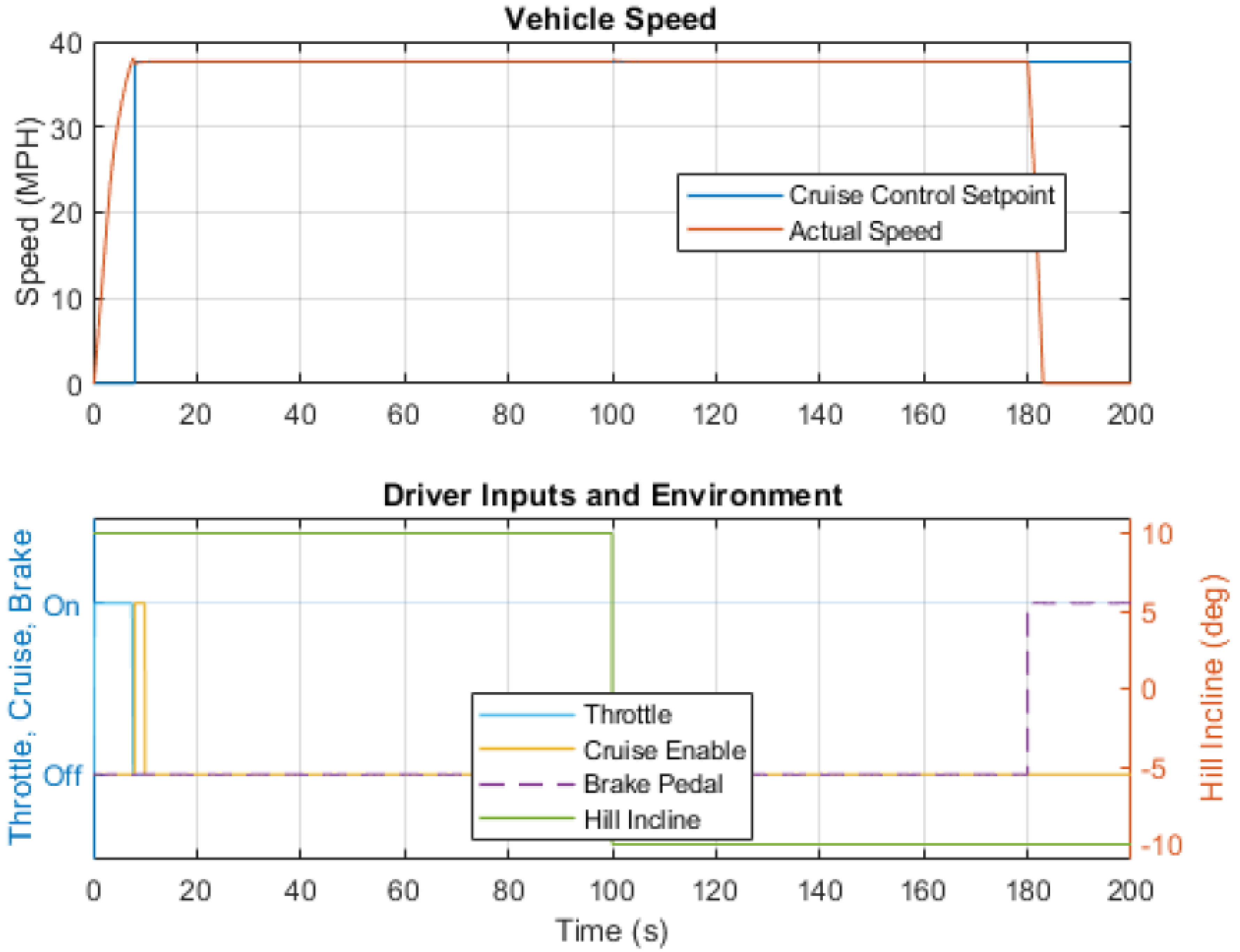


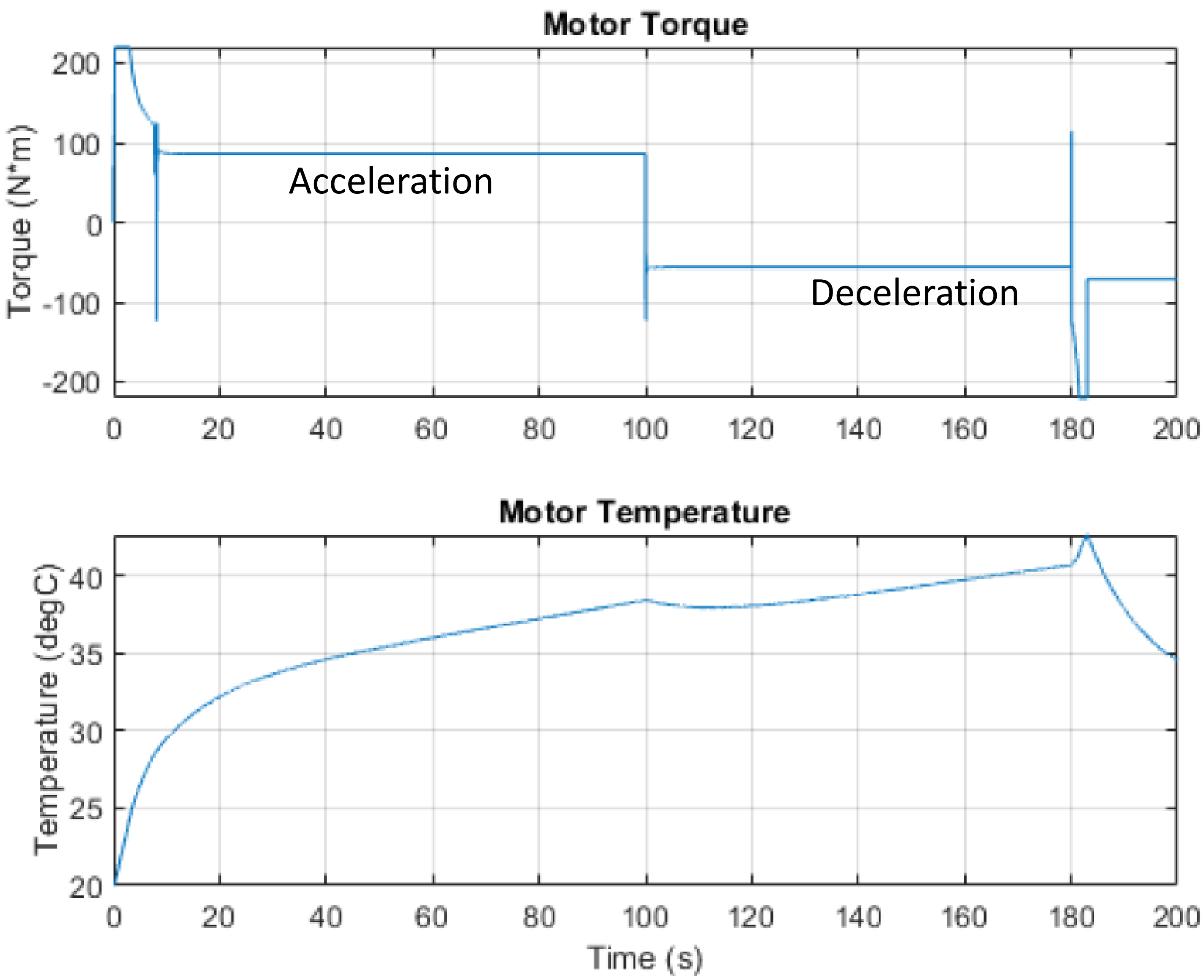
Electric and Thermal Model Subsystem

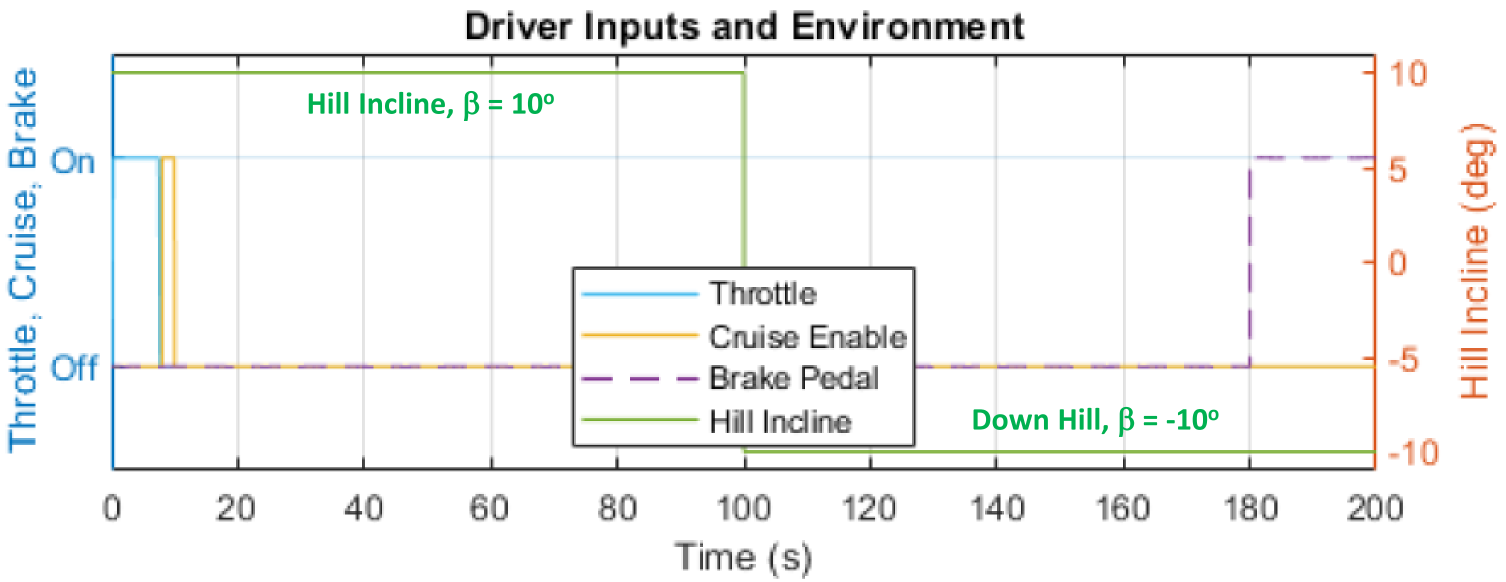


Vehicle Control Subsystem

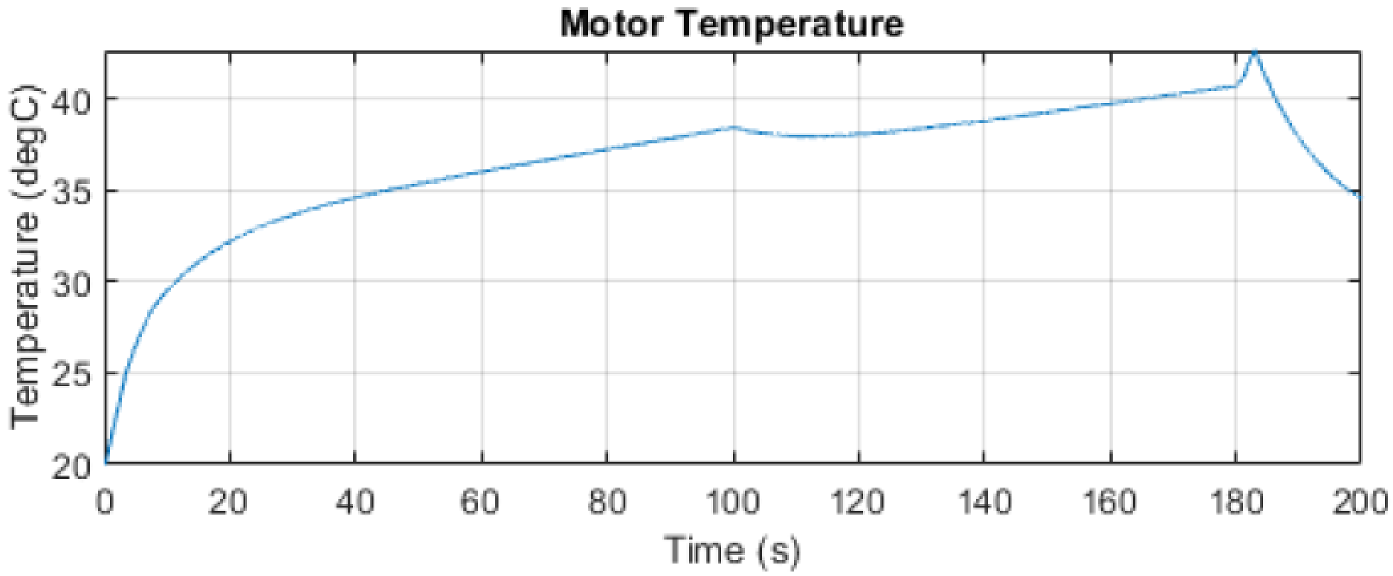



Vehicle Speed
Speed (MPH)
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180
200
Cruise Control Setpoint
Actual Speed
Driver Inputs and Environment
Throttle, Cruise, Brake
On
Off
Hill Incline (deg)
10
5
0
-5
-10
Throttle
Cruise Enable
Brake Pedal
Hill Incline
Time (s)

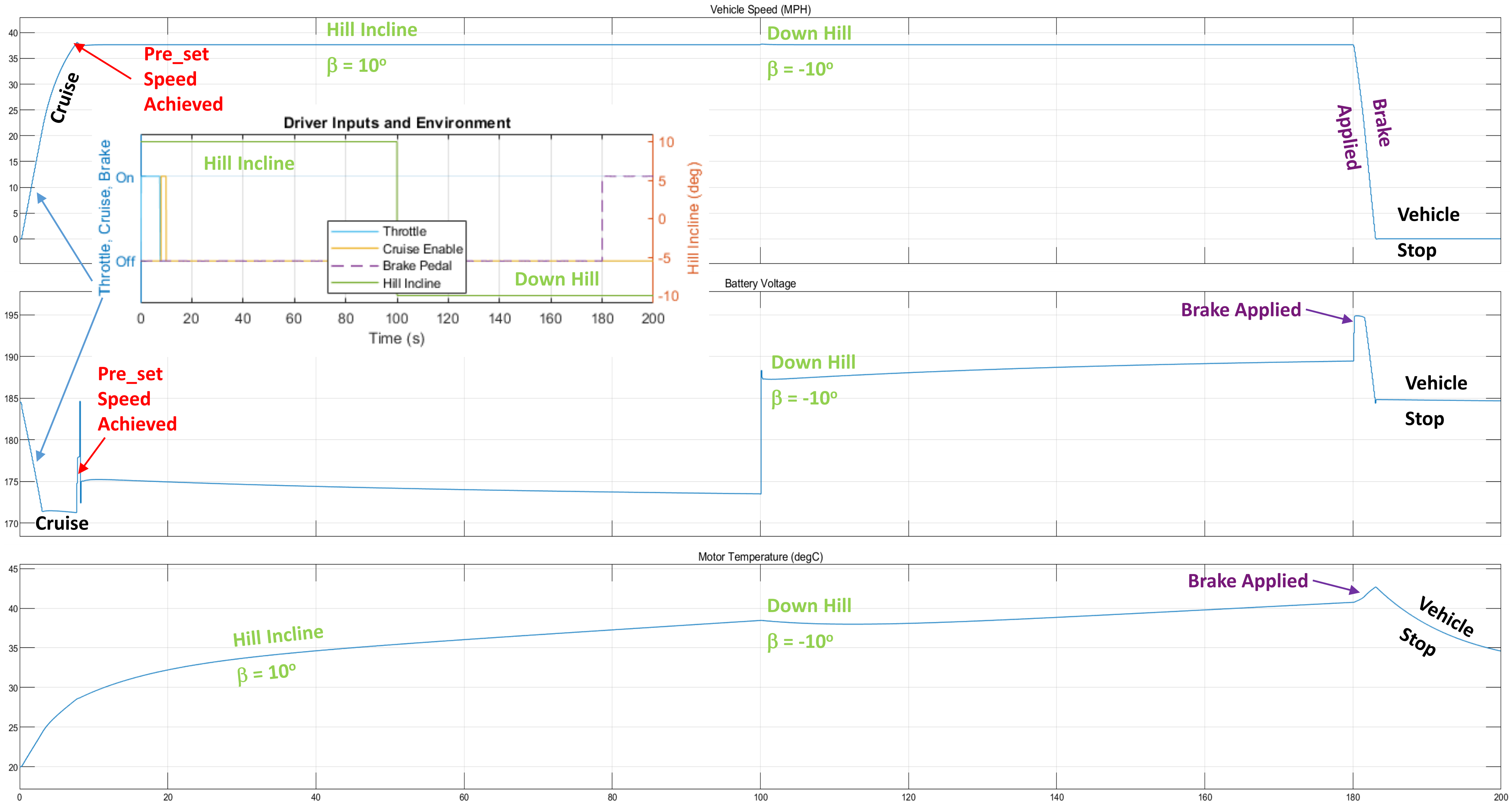

Motor Torque
Torque (N*m)
200
100
0
-100
-200
Acceleration
Deceleration
0
20
40
60
80
100
120
140
160
180
200
Motor Temperature
Temperature (degC)
40
35
30
25
20
Time (s)



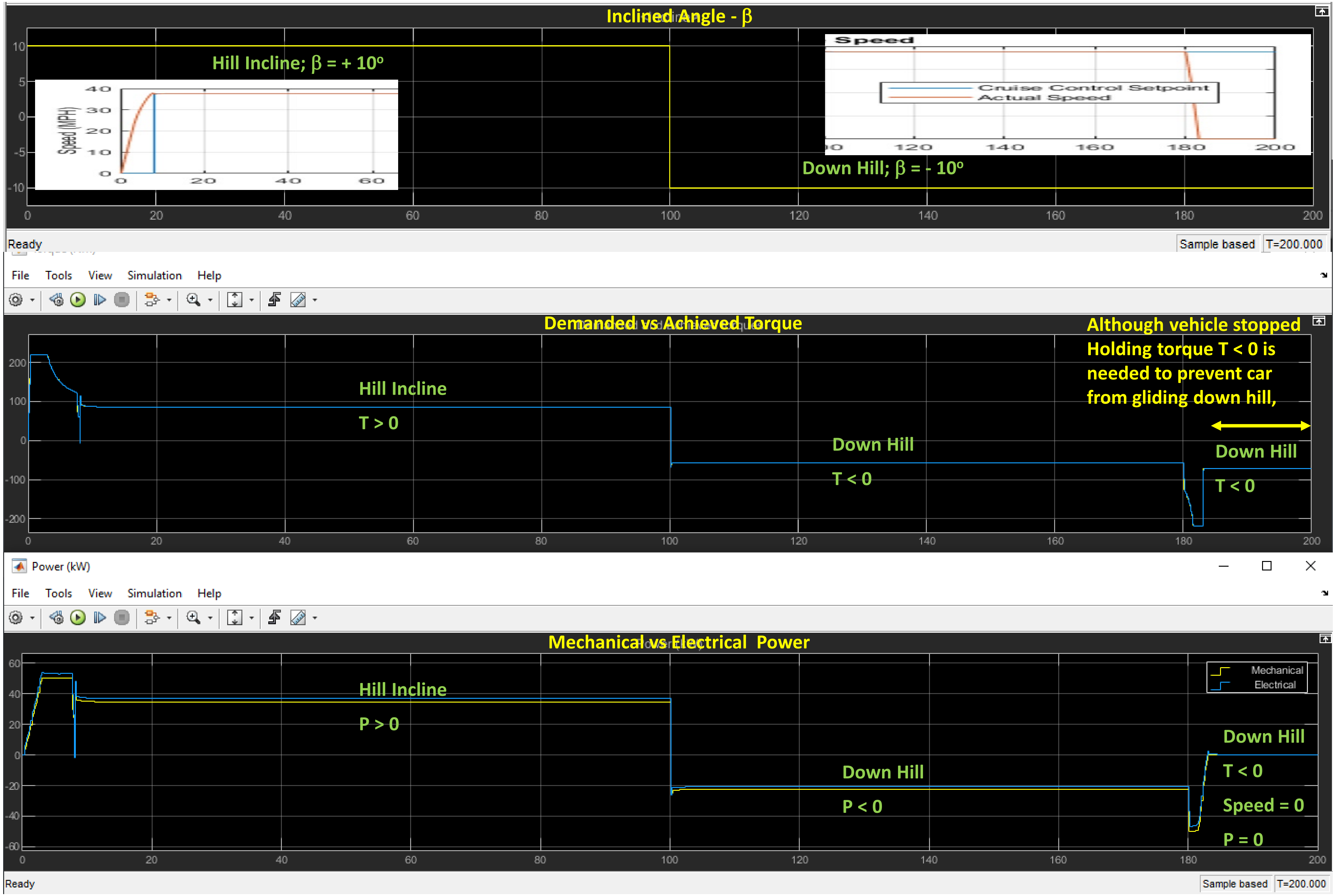
Driver Inputs and Environment
Hill Incline, β = 10º
Down Hill, β = -10º
Throttle
Cruise Enable
Brake Pedal
Hill Incline
Throttle, Cruise, Brake
On
Off
Hill Incline (deg)
10
5
0
-5
-10
0
20
40
60
80
100
120
140
160
180
200
Time (s)



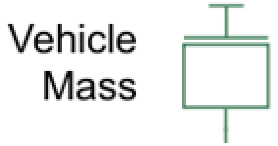
Motor Temperature
Temperature (degC)
40
35
30
25
20
0
20
40
60
80
100
120
140
160
180
200
Time (s)



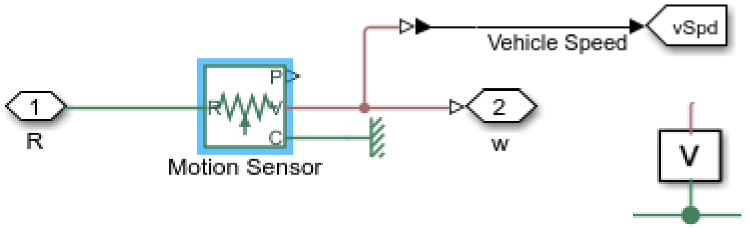
Vehicle Speed (MPH)
Hill Incline
β = 10º
Down Hill
β = -10º
Cruise
Pre_set
Speed
Achieved
Brake
Applied
Vehicle
Stop
Driver Inputs and Environment
Throttle, Cruise, Brake
On
Off
Throttle
Cruise Enable
Brake Pedal
Hill Incline
Hill Incline (deg)
Time (s)
Battery Voltage
Brake Applied
Motor Temperature (degC)

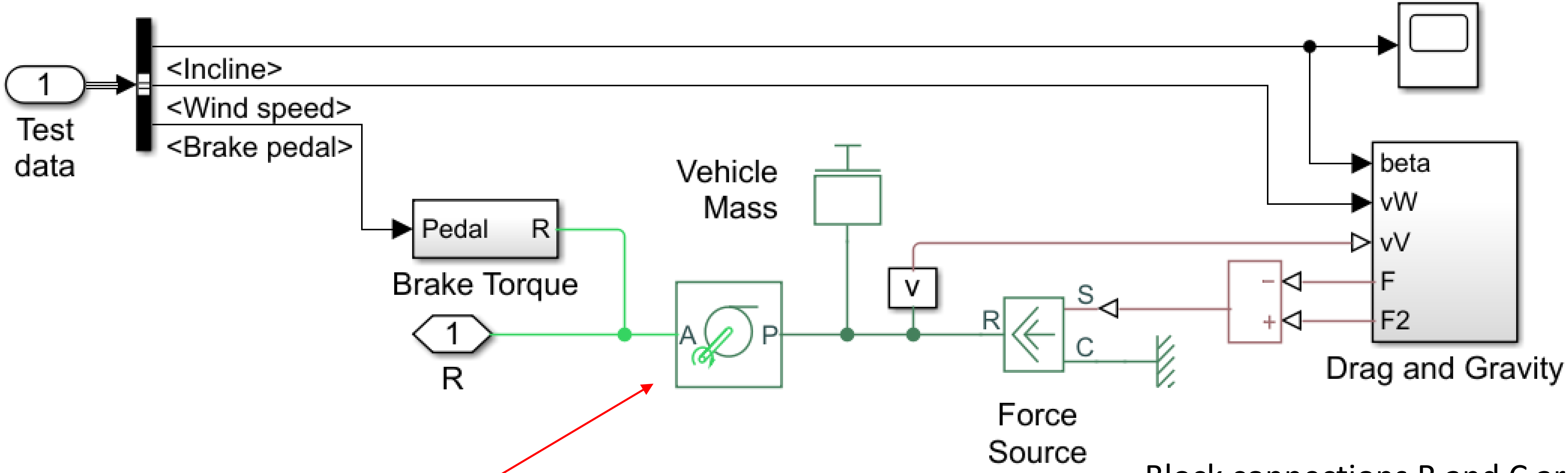


Inclined Angle - β
Hill Incline; β = + 10º
Speed
Cruise Control Setpoint
Actual Speed
Speed (MPH)
Down Hill; β = - 10º
Ready
Sample based
T=200.000
File Tools View Simulation Help
Demanded vs Achieved Torque
Hill Incline
T > 0
Down Hill
T < 0
Although vehicle stopped
Holding torque T < 0 is
needed to prevent car
from gliding down hill,
Down Hill
T < 0
Power (kW)
File Tools View Simulation Help
Mechanical vs Electrical Power
Mechanical
Electrical
Hill Incline
P > 0
Down Hill
P < 0
Down Hill
T < 0
Speed = 0
P = 0
Ready
Sample based
T=200.000



The block represents an ideal mechanical translational mass. The block has one or two mechanical translational conserving ports. The difference is purely graphical, as the ports are rigidly linked. The block positive direction is from its port to the reference point. This means that the inertia force is positive if mass is accelerated in positive direction.

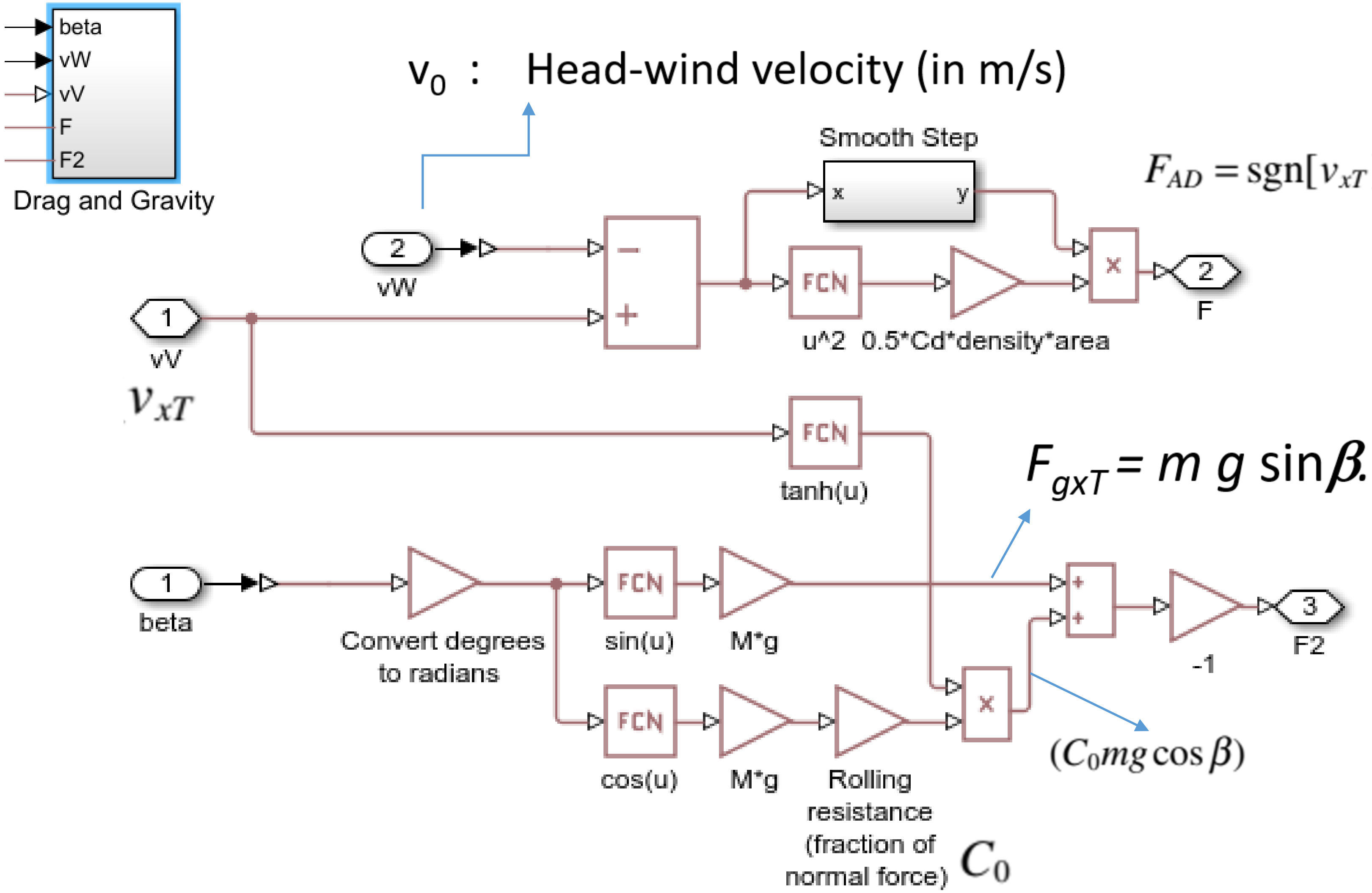


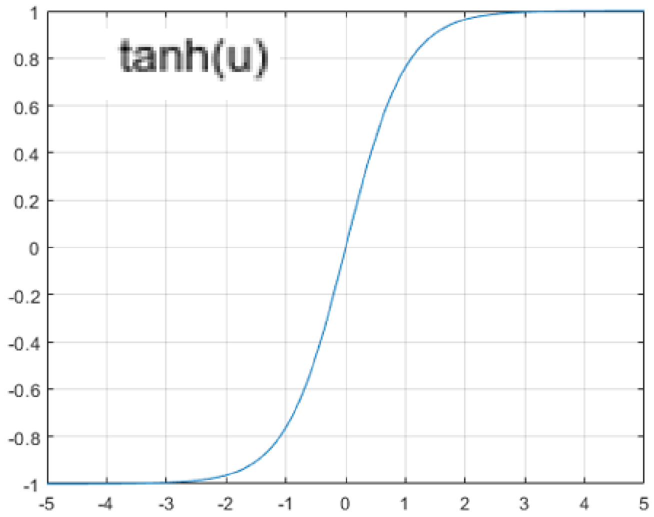


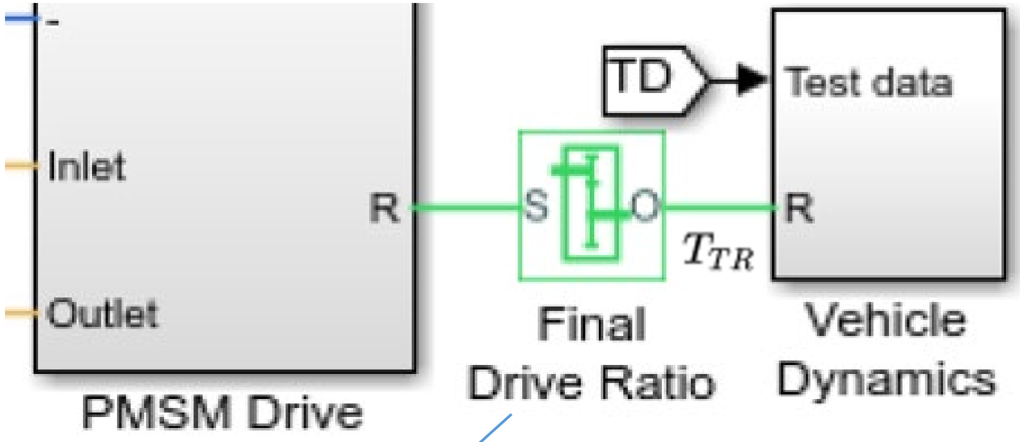
The block represents the wheel and axle mechanism as an ideal converter between mechanical rotational and mechanical translational motions. The mechanism has two connections: port A corresponds to the axle and is a mechanical rotational conserving port; port P corresponds to the wheel periphery and is a mechanical translational conserving port.

Block connections R and C are mechanical translational conserving ports. Port S is the physical signal port, through which control signal that drives the source is applied. Positive signal at port S generates force acting from C to R.

Drag and Gravity







The block represents an ideal, non-planetary, fixed gear ratio gear box. The gear box is characterized by its only parameter, Gear ratio, which can be positive or negative. Connections S and O are mechanical rotational conserving ports associated with the box input and output shaft, respectively. The gear ratio is determined as the ratio of the input shaft angular velocity to that of the output shaft.

The block generates torque in positive direction if a positive torque is applied to the input shaft and the ratio is assigned a positive value.