

Topic:
E-Bike simulation

Presenter : Nguyen Duc Tai



INTRODUCTION

Overview of research situation

- Domestic:

- Vu, M. N., & Ta, M. C. (2015). A sliding mode algorithm for **antilock braking /traction control of EVs**. VNUHCM Journal of Science and Technology Development, 18(3), 174-182.
- Phan, T. T., Ngo, H. T., & Huynh, B. T. (2022). Application of pid method to **control traction** on the vehicles through controlling the brake moment at the two driving wheels. Tra vinh university journal of science.

- International

- Vecchio, C., Tanelli, M., Corno, M., Ferrara, A., & Savaresi, S. M. (2009, June). Second order sliding mode for **traction control** in ride-by-wire sport motorcycles. In 2009 American Control Conference.
- Cabrera, J. A., Castillo, J. J., Carabias, E., & Ortiz, A. (2014). Evolutionary optimization of a motorcycle **traction control** system based on fuzzy logic. IEEE Transactions on Fuzzy Systems
- Yuniarto, M. N., Wiratno, S. E., Nugraha, Y. U., Sidharta, I., & Nasruddin, A. (2022). **Modeling, Simulation, and Validation** of An Electric Scooter Energy Consumption Model: A Case Study of Indonesian Electric Scooter



BASIC THEORY

Types of electric motors

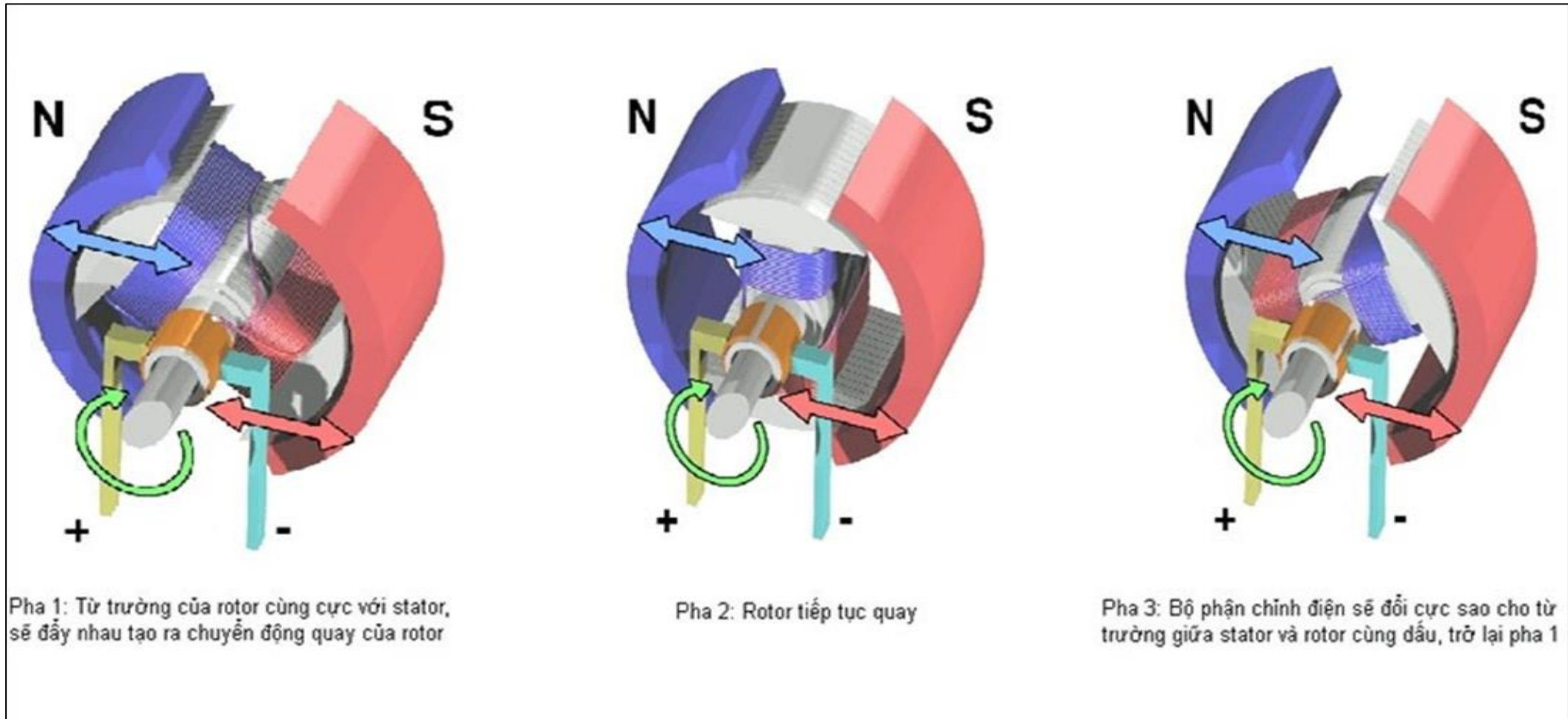
- **Five** main types of electric motors:
 - DC electric motor with DC carbon brush
 - Induction motor
 - Permanent magnet synchronous motor (PMSM)
 - Switched reluctance motor
 - Brushless DC motor (BLDC)
- **BLDC** motors and **permanent magnet** motors are more suitable, thanks to their advantages of **low pollution** and **fuel consumption**. Less and the power-to-mass ratio is higher.

DC Motor

- DC Motor (1-way electric motor with **carbon brush**):
 - DC motors (Direct Current Motors) are motors controlled by current with a **specific direction**. The output of this motor usually **consists of two wires**.
 - The **no-load** speed of a DC motor **without deceleration** can reach from 1000 RPM to 40 000 RPM.



DC Motor

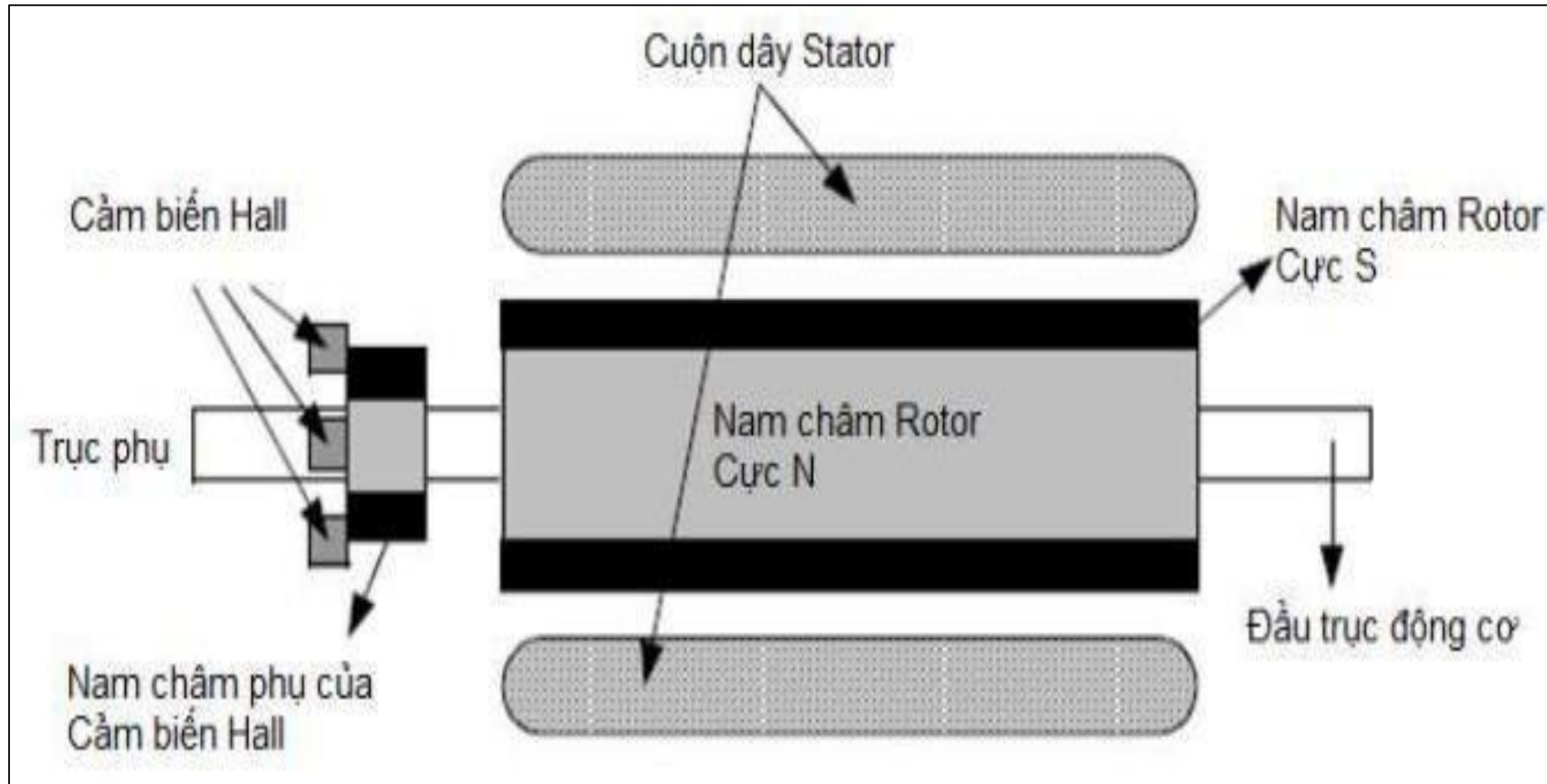


DC motor operating principle

BLDC Motor

- BLDC Motor (brushless motor):
 - BLDC motors are similar to DC motors but the functions of the **rotor and stator are reversed**.
 - The rotor is made up of a **set of permanent magnets**.
 - The stator is a **controlled electromagnet**.
 - **Vary the change** by **controlling the current** into the different coil wires to keep the rotor spinning.
- The **reversal of the current** through the winding wires is carried out by **power transistor** control according to the **position** of the rotor through sensors (**Hall**).

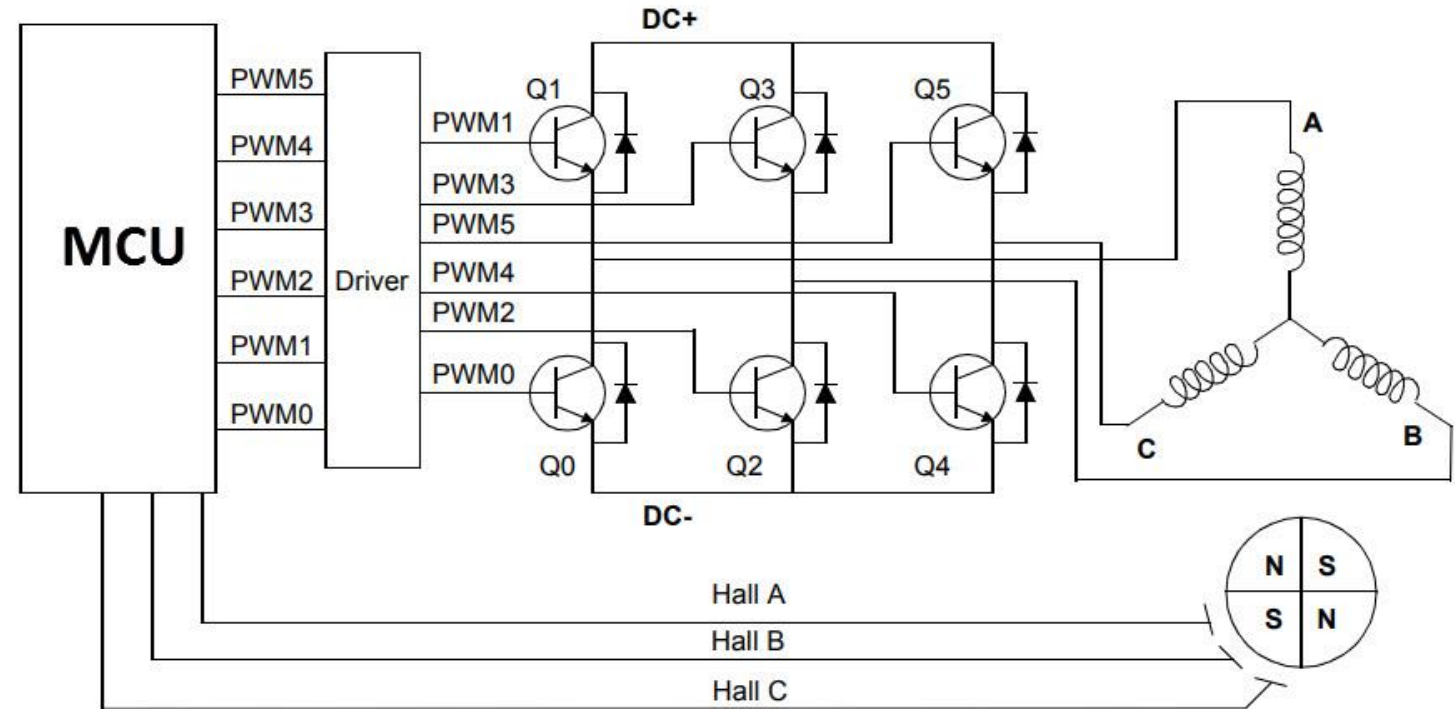
BLDC Motor

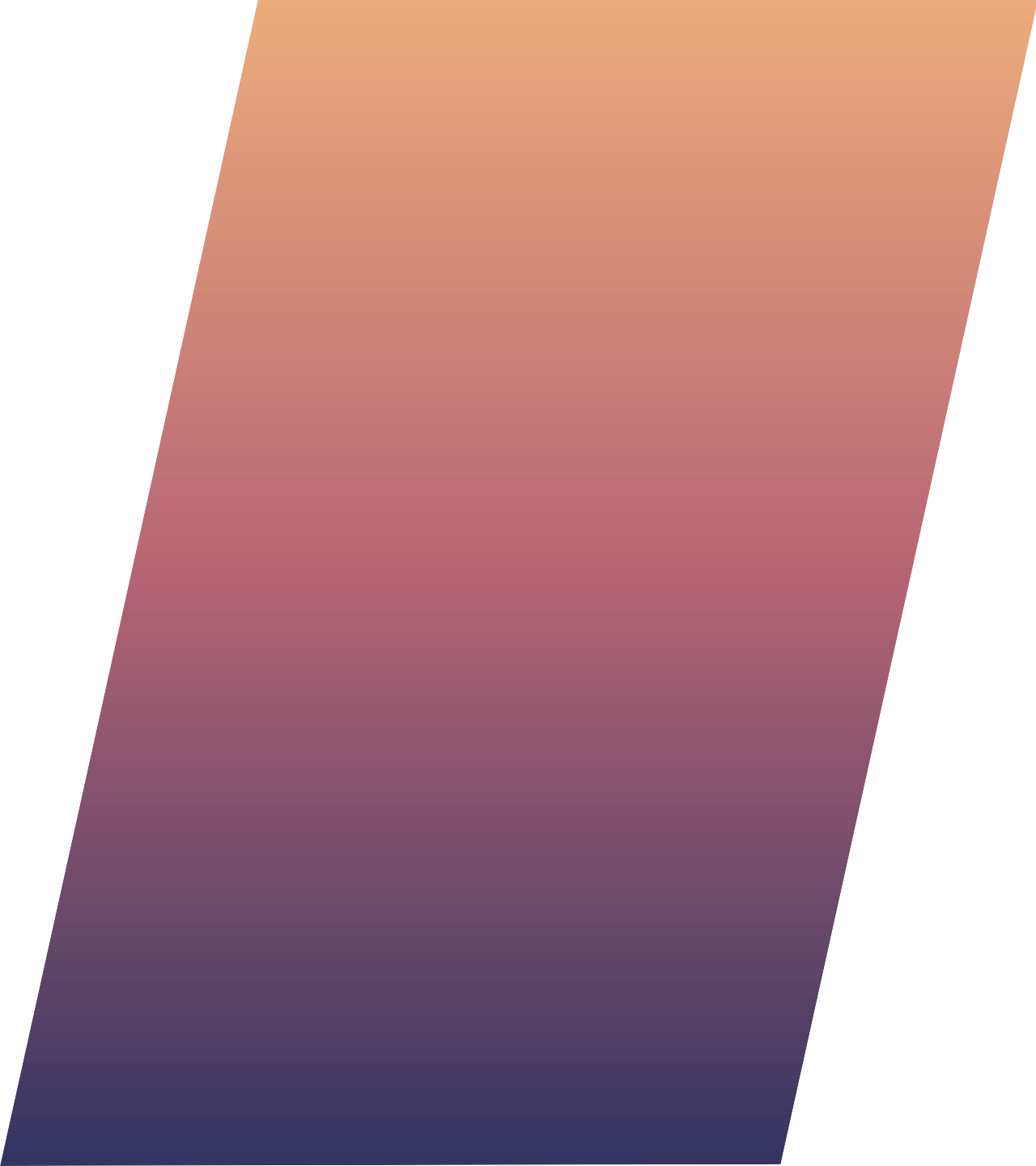


DC motor operating principle

BLDC Motor

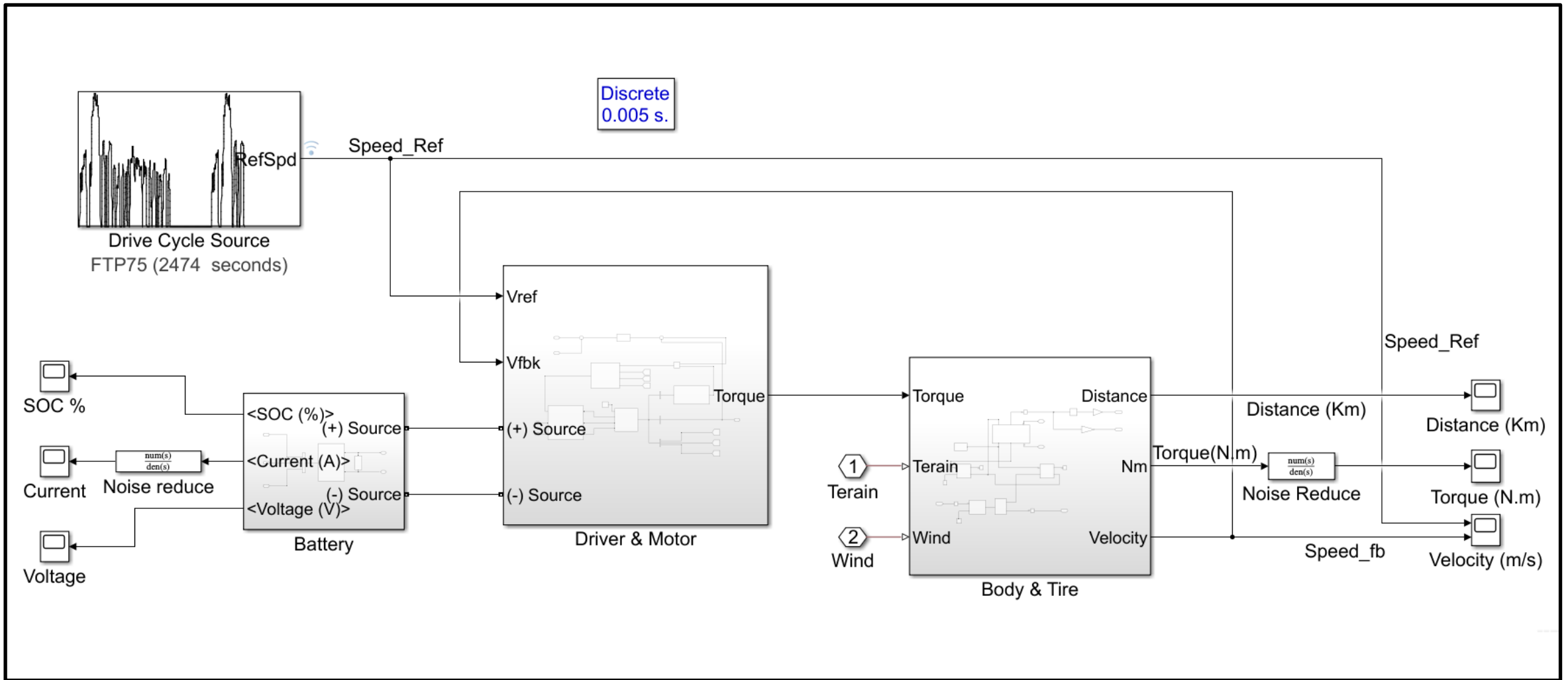
- Base on **position of the rotor**, the control system switches **on** and **off** the **transistors**. Each state:
 - 1 coil that is energized **positively**,
 - 1 coil that is energized **negatively**,
 - 1 coil that is **de-energized**.
- **Torque** is generated by the **interaction** between the magnetic field created by the **stator coils** and the **permanent magnet**.



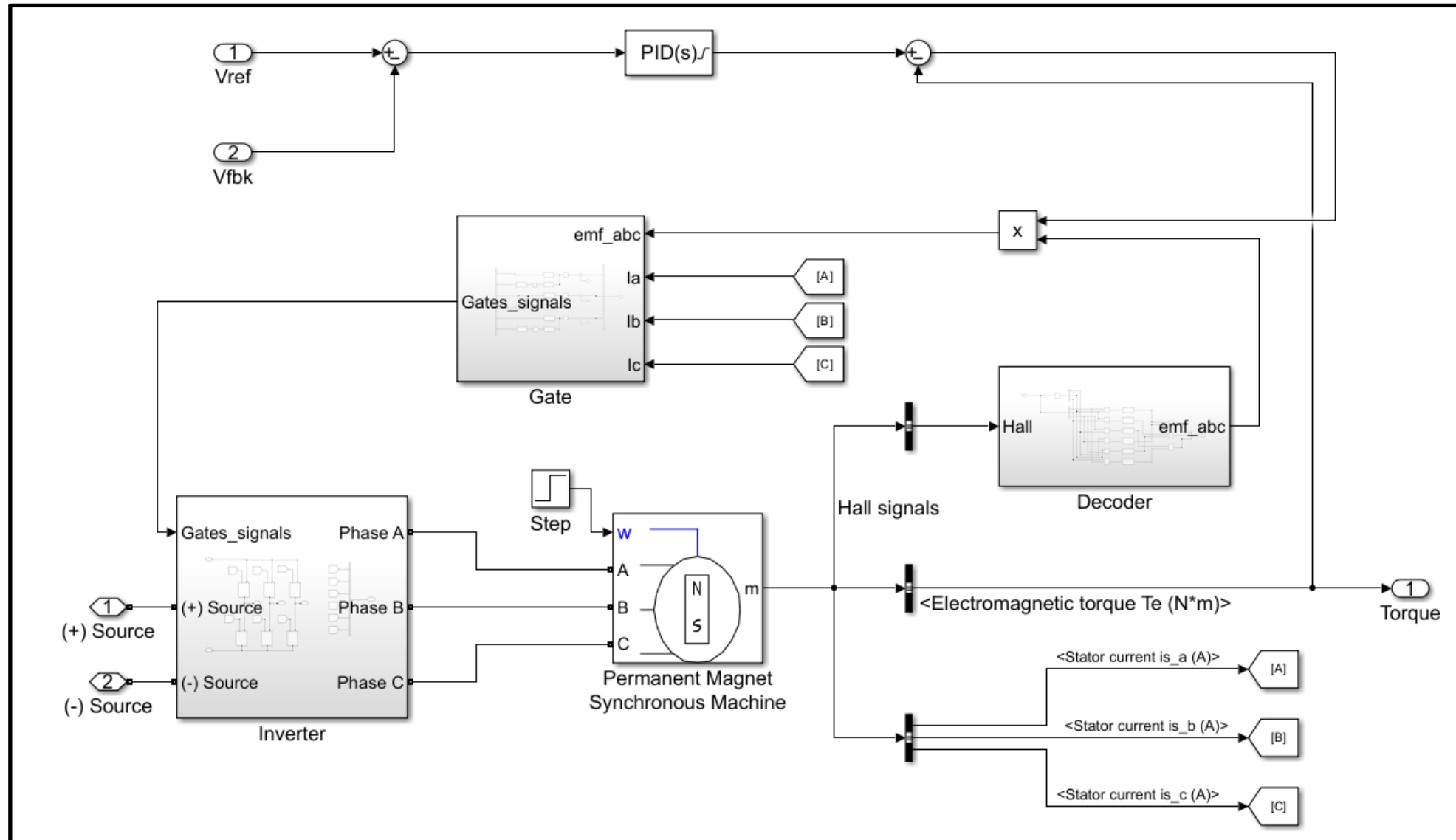
A decorative vertical bar on the left side of the slide, featuring a diagonal gradient from orange at the top to dark blue at the bottom.

E-BIKE MODELING

General



Driver & Motor



Motor configuration

Block Parameters: Permanent Magnet Synchronous Machine

Permanent Magnet Synchronous Machine (mask) (link)

Implements a three-phase or a five-phase permanent magnet synchronous machine. The stator windings are connected in wye to an internal neutral point.

The three-phase machine can have sinusoidal or trapezoidal back EMF waveform. The rotor can be round or salient-pole for the sinusoidal machine, it is round when the machine is trapezoidal. Preset models are available for the Sinusoidal back EMF machine.

The five-phase machine has a sinusoidal back EMF waveform and round rotor.

Configuration Parameters

Number of phases: 3

Back EMF waveform: Trapezoidal

Mechanical input: Speed ω

Measurement output

☐ Use signal names to identify bus labels

Configuration Parameters Advanced

Machine parameters

Compute from standard manufacturer specifications.

Stator phase resistance R_s (Ohm): 2.8750

Stator phase inductance L_s (H): 8.5e-3

Machine constant

Specify: Flux linkage established by magnets (V.s)

Flux linkage: 0.175

Back EMF flat area (degrees): 120

Pole pairs p (:): 4

Initial conditions [ω_m (rad/s) θ_{em} (deg) i_a, i_b (A)]: [0,0, 0,0]

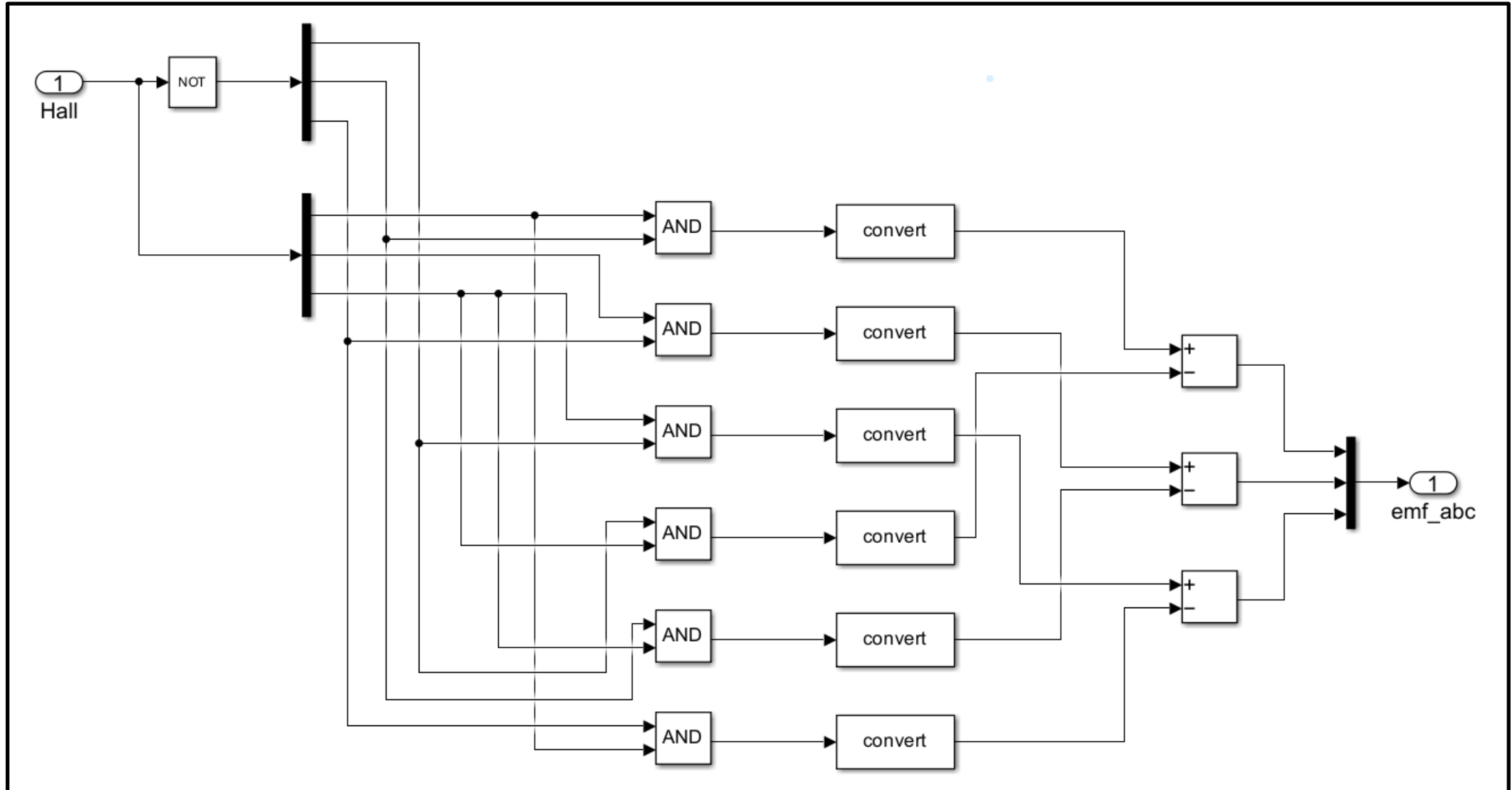
Rotor flux position when $\theta = 0$: 90 degrees behind phase A axis (modified Park)

Hall signal solving

ha	hb	hc	$EMFa$	$EMFb$	$EMFc$
0	0	0	0	0	0
0	0	1	0	-1	+1
0	1	0	-1	+1	0
0	1	1	-1	0	+1
1	0	0	+1	0	-1
1	0	1	+1	-1	0
1	1	0	0	+1	-1
1	1	1	0	0	0



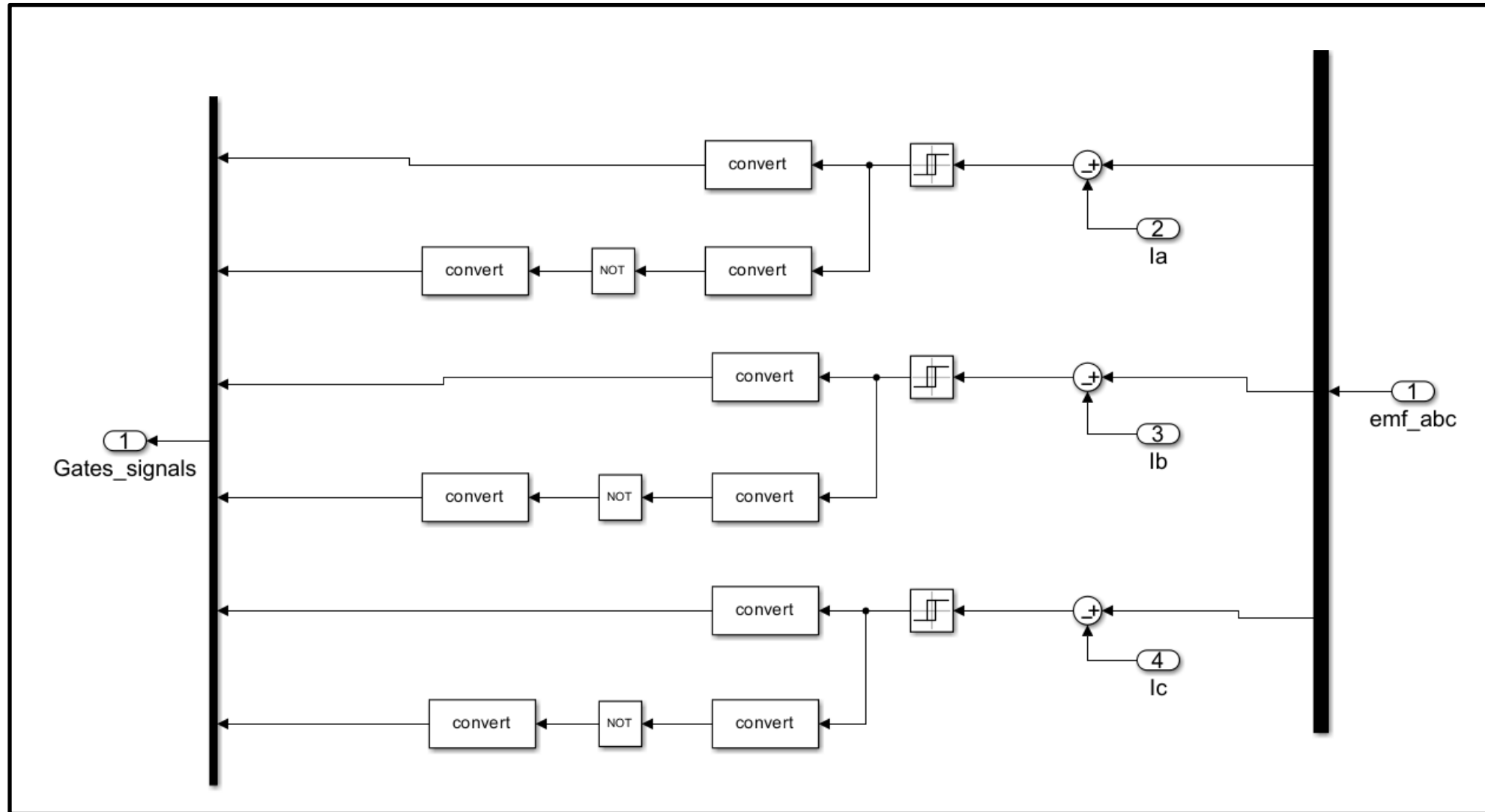
Hall decoder



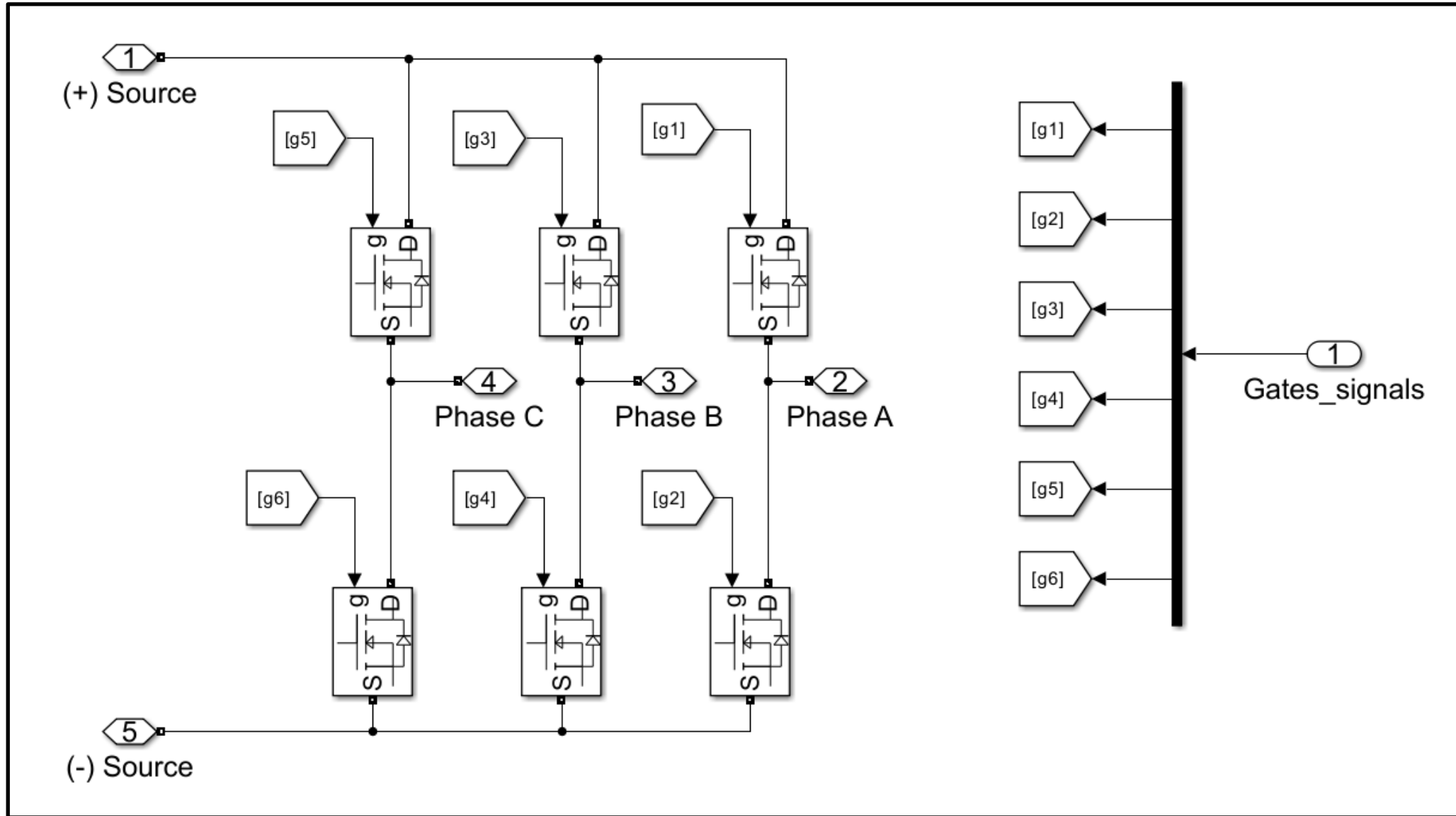
Convert EMF into phase signal

EMF_a	EMF_b	EMF_c		G_1	G_2	G_3	G_4	G_5	G_6
0	0	0		0	0	0	0	0	0
0	-1	+1		0	0	0	1	1	0
-1	+1	0		0	1	1	0	0	0
-1	0	+1		0	1	0	0	1	0
+1	0	-1		1	0	0	0	0	1
+1	-1	0		1	0	0	1	0	0
0	+1	-1		0	0	1	0	0	1
0	0	0		0	0	0	0	0	0

Gate signal



Inverter



PID controller configuration for motor

Block Parameters: PID Controller

PID 1dof (mask) (link)

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires Simulink Control Design).

Controller: PID Form: Parallel

Time domain:

☒ Continuous-time
☐ Discrete-time

Discrete-time settings

Sample time (-1 for inherited): -1

Compensator formula

$$P + I \frac{1}{s} + D \frac{N}{1 + N \frac{1}{s}}$$

Main Initialization Output Saturation Data Types State Attributes

Controller parameters

Source: internal

Proportional (P): 15

Integral (I): 0.01

Derivative (D): 0

☒ Use filtered derivative

Filter coefficient (N): 100

OK Cancel Help Apply

Block Parameters: PID Controller

PID 1dof (mask) (link)

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires Simulink Control Design).

Controller: PID Form: Parallel

Time domain:

☒ Continuous-time
☐ Discrete-time

Discrete-time settings

Sample time (-1 for inherited): -1

Compensator formula

$$P + I \frac{1}{s} + D \frac{N}{1 + N \frac{1}{s}}$$

Main Initialization Output Saturation Data Types State Attributes

Output saturation

☒ Limit output

Source: internal

Upper limit: 1000

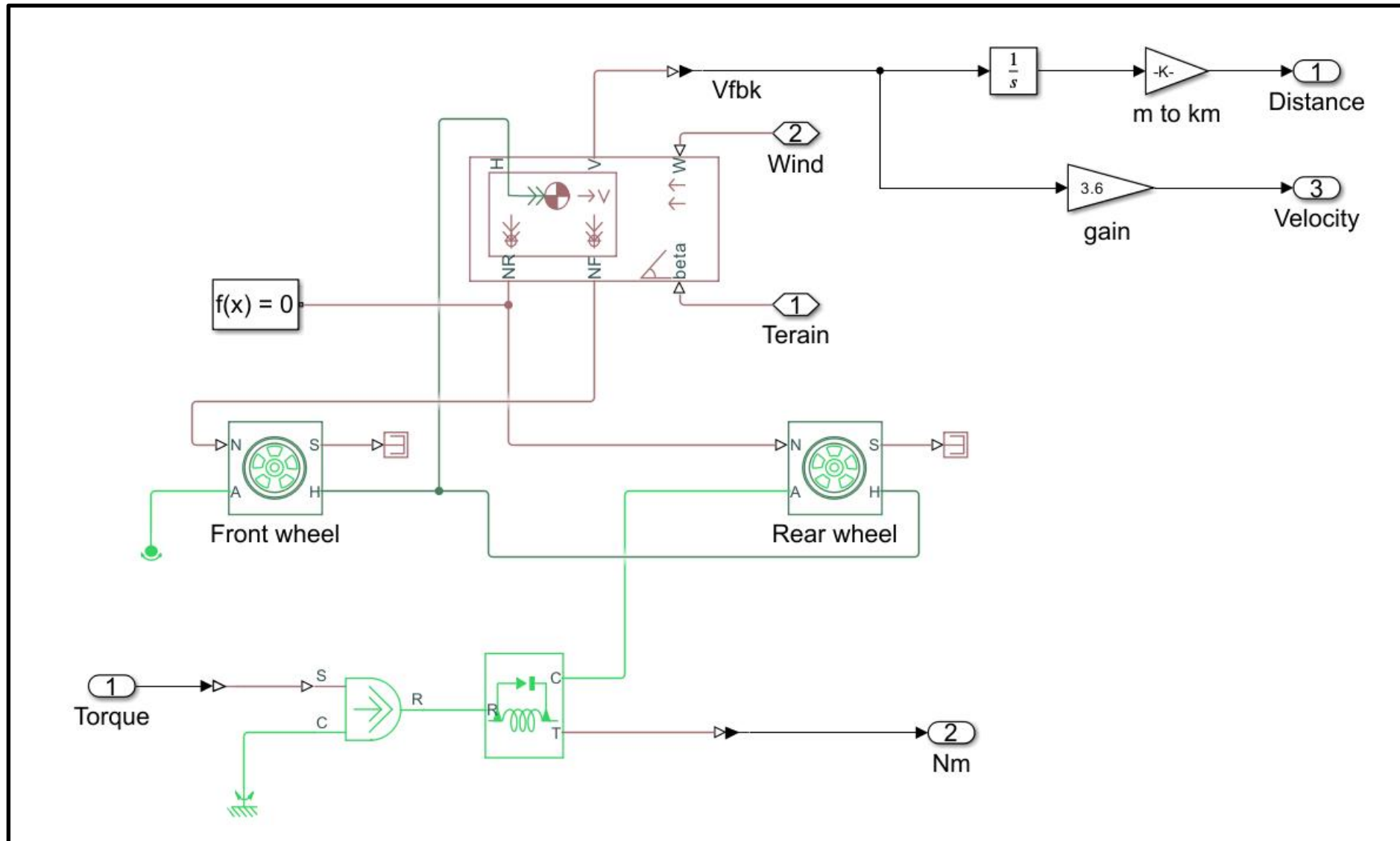
Lower limit: -1000

☒ Ignore saturation when linearizing

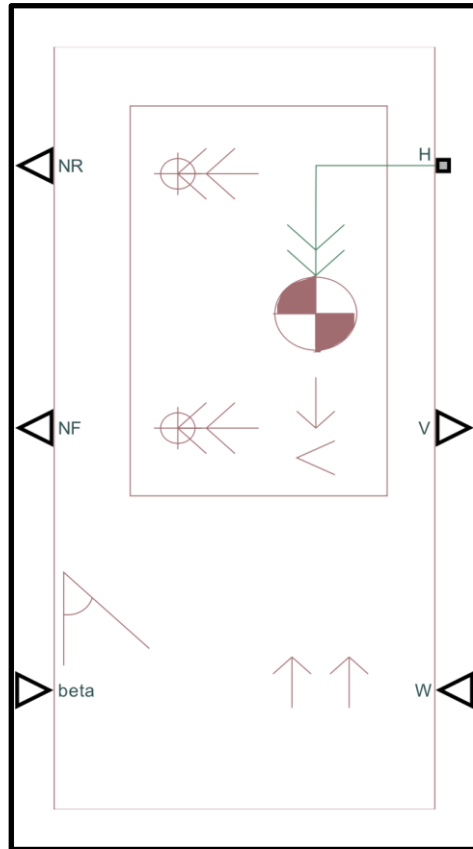
Anti-windup

OK Cancel Help Apply

Body & Tire



Body configuration



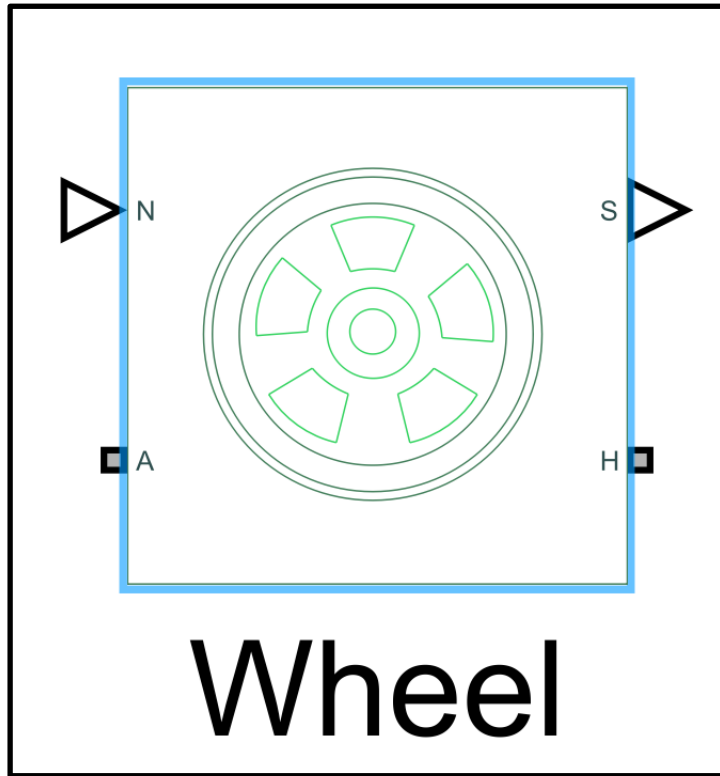
Block Parameters: Vehicle Body

Vehicle Body ☒ Auto Apply ?

Settings Description

NAME	VALUE
Main	
> Mass	135 kg
> Number of wheels per axle	1
> Horizontal distance from CG to front axle	0.6 m
> Horizontal distance from CG to rear axle	0.7 m
> CG height above ground	0.155 m
Externally-defined additional mass	Off
> Gravitational acceleration	9.81 m/s ²
Negative normal force warning	Off
Drag	
> Frontal area	0.76 m ²
> Drag coefficient	0.2
> Air density	1.18 kg/m ³

Wheel configuration



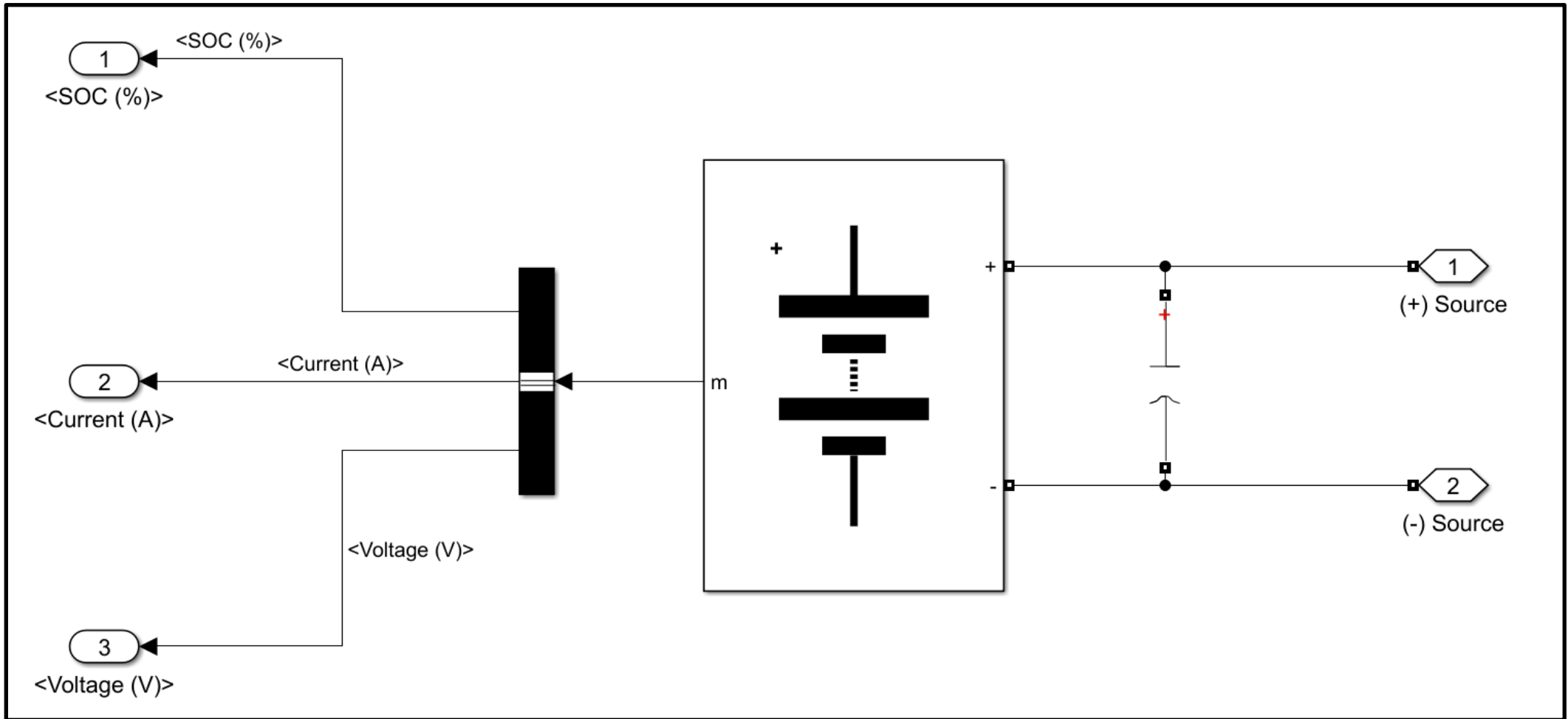
Block Parameters: Rear wheel

Tire (Magic Formula) ☒ Auto Apply

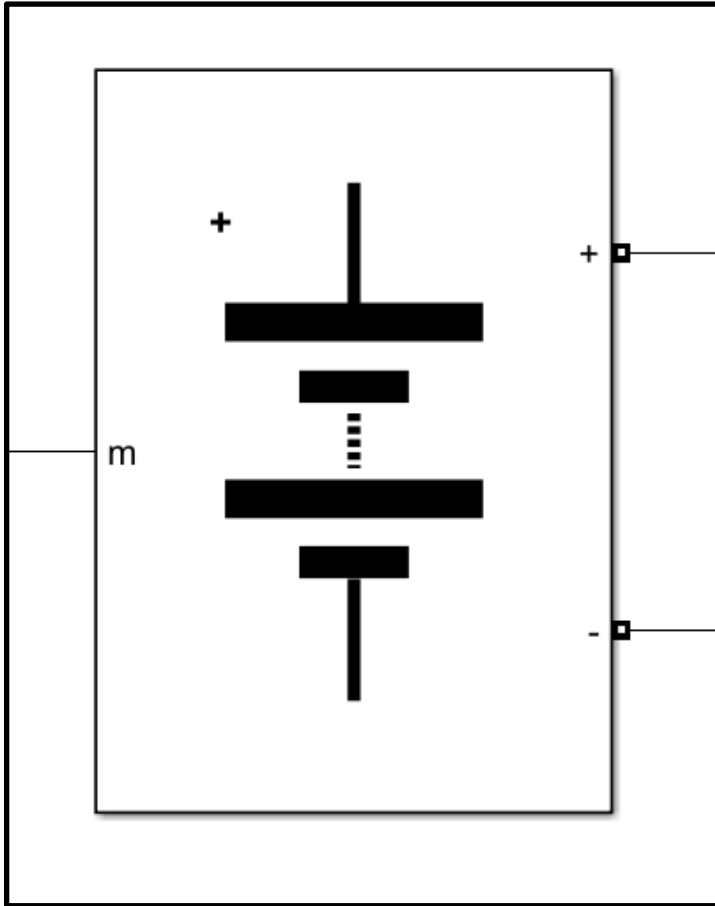
Settings Description

NAME	VALUE
Main	
Parameterize by	Peak longitudinal force and corresponding slip
> Rated vertical load	675 N
> Peak longitudinal force at rated load	337.5 N
> Slip at peak force at rated load (percent)	10
Geometry	
> Rolling radius	0.22 m
Rolling Resistance	
<input checked="" type="checkbox"/> Model rolling resistance	
Resistance model	Constant coefficient
> Constant coefficient	0.005
> Velocity threshold for rolling resistance	0.001 m/s

Battery



Battery



Block Parameters: Battery1

Parameters Discharge

Type: Lithium-Ion

Temperature

☐ Simulate temperature effects

Aging

☐ Simulate aging effects

Nominal voltage (V) 50.4

Rated capacity (Ah) 22

Initial state-of-charge (%) 100

Battery response time (s) 30

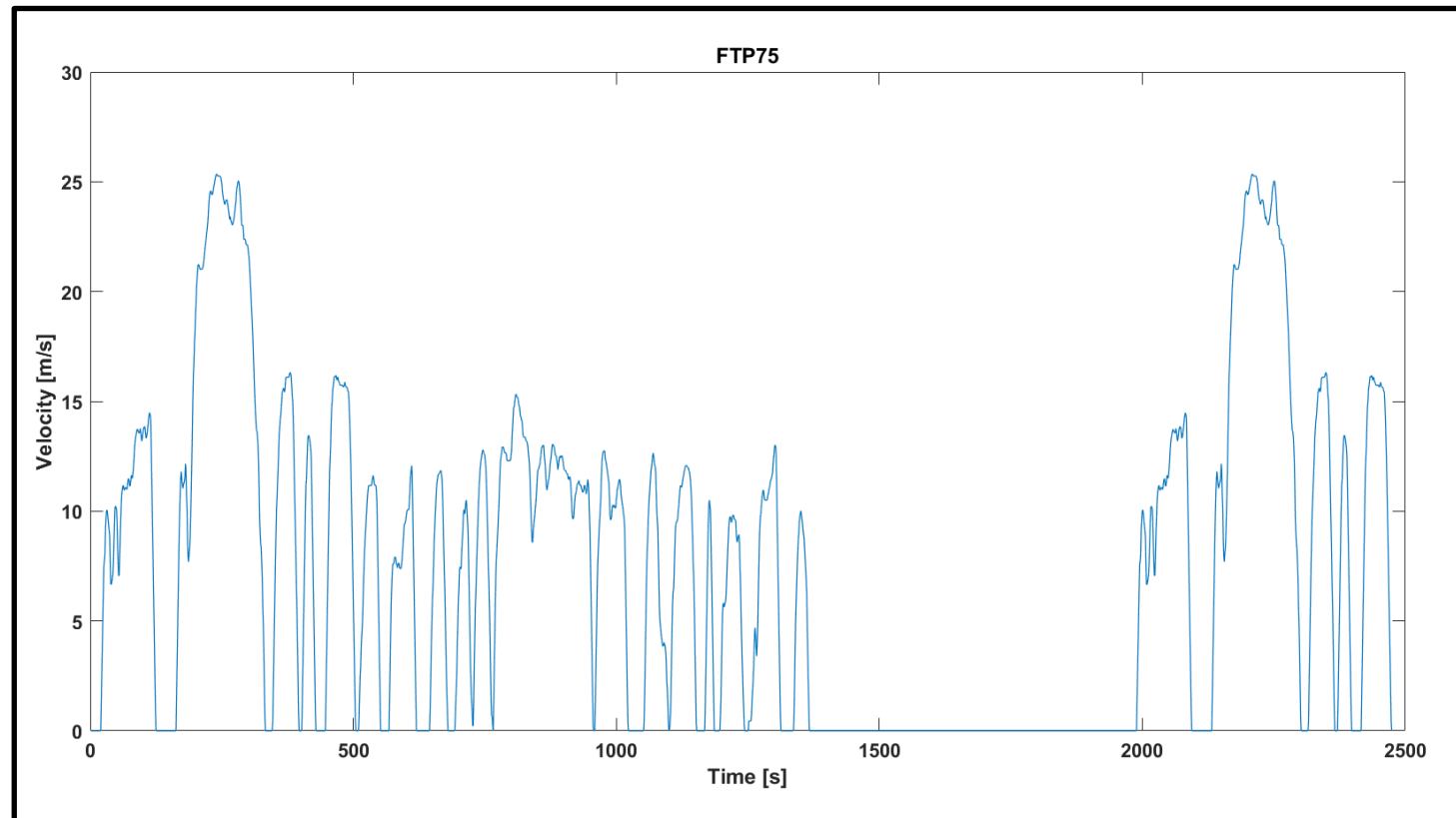
OK Cancel Help Apply



SIMULATION

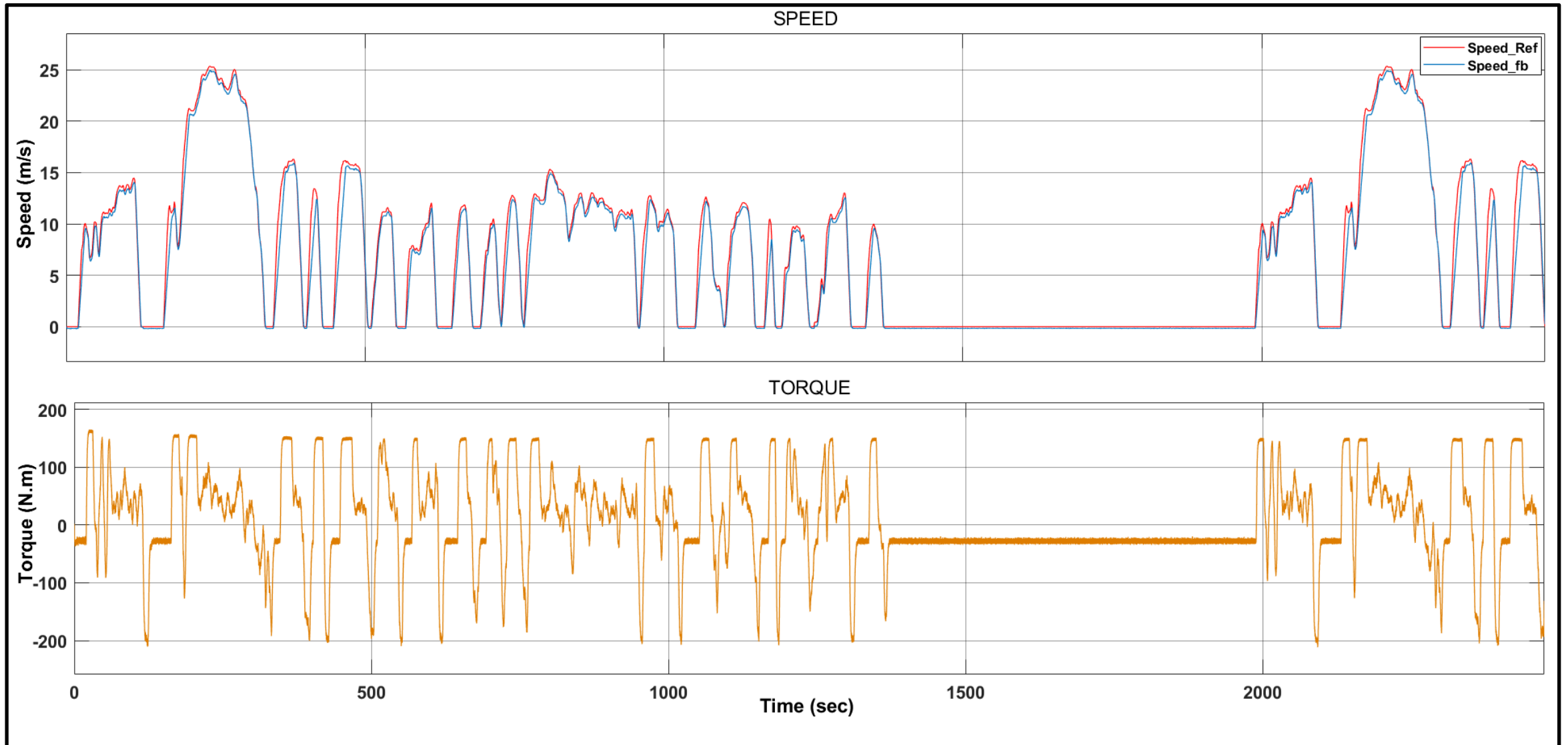
FTP-75 Cycle

- FTP-75 cycle is a standard for testing **fuel economy** and **emissions** used by the USA Environmental Protection Agency (EPA). This cycle simulates **low-speed city driving** conditions in **31 mins**, **12km**, average speed at **32km/h**.



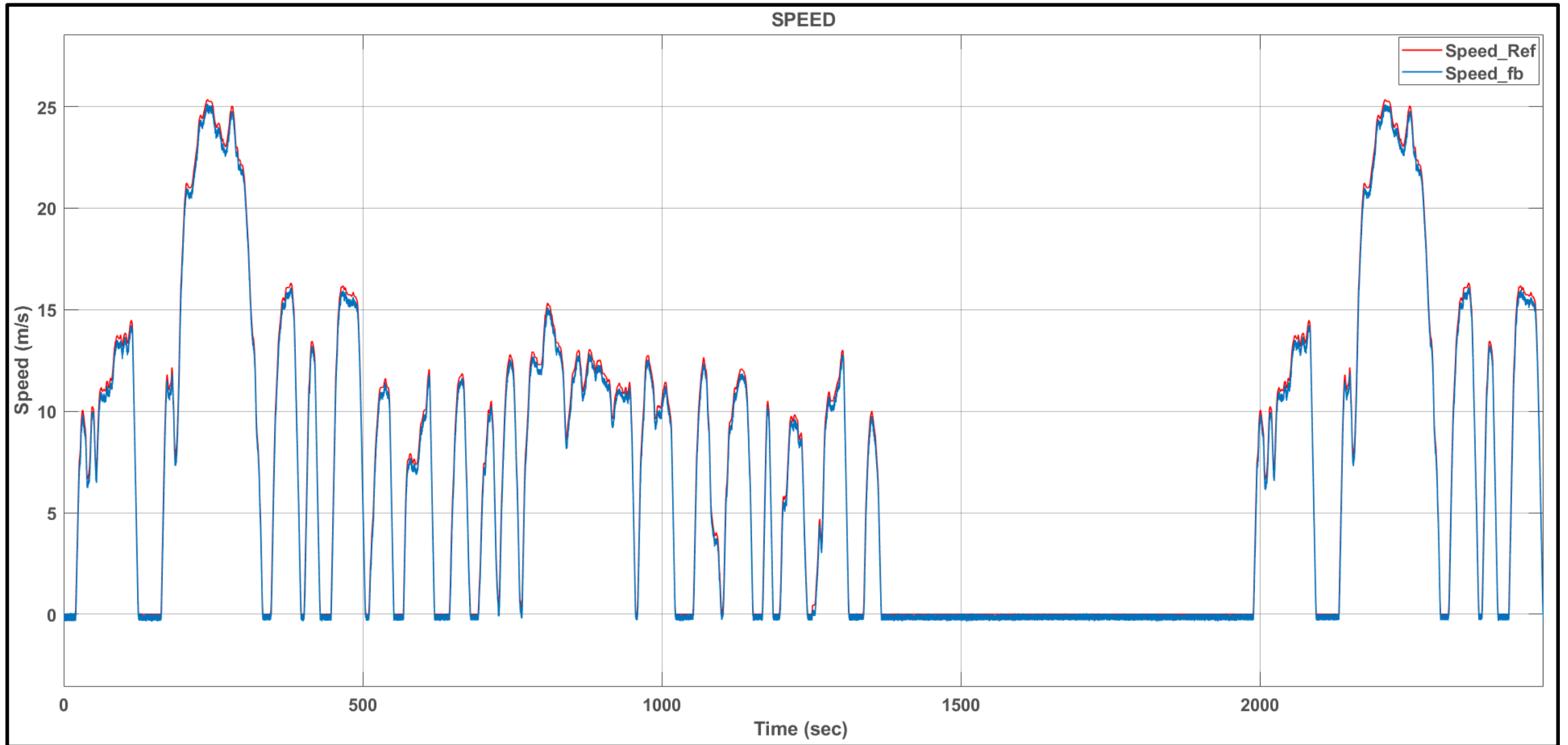


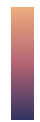
Testing result (FTP-75)



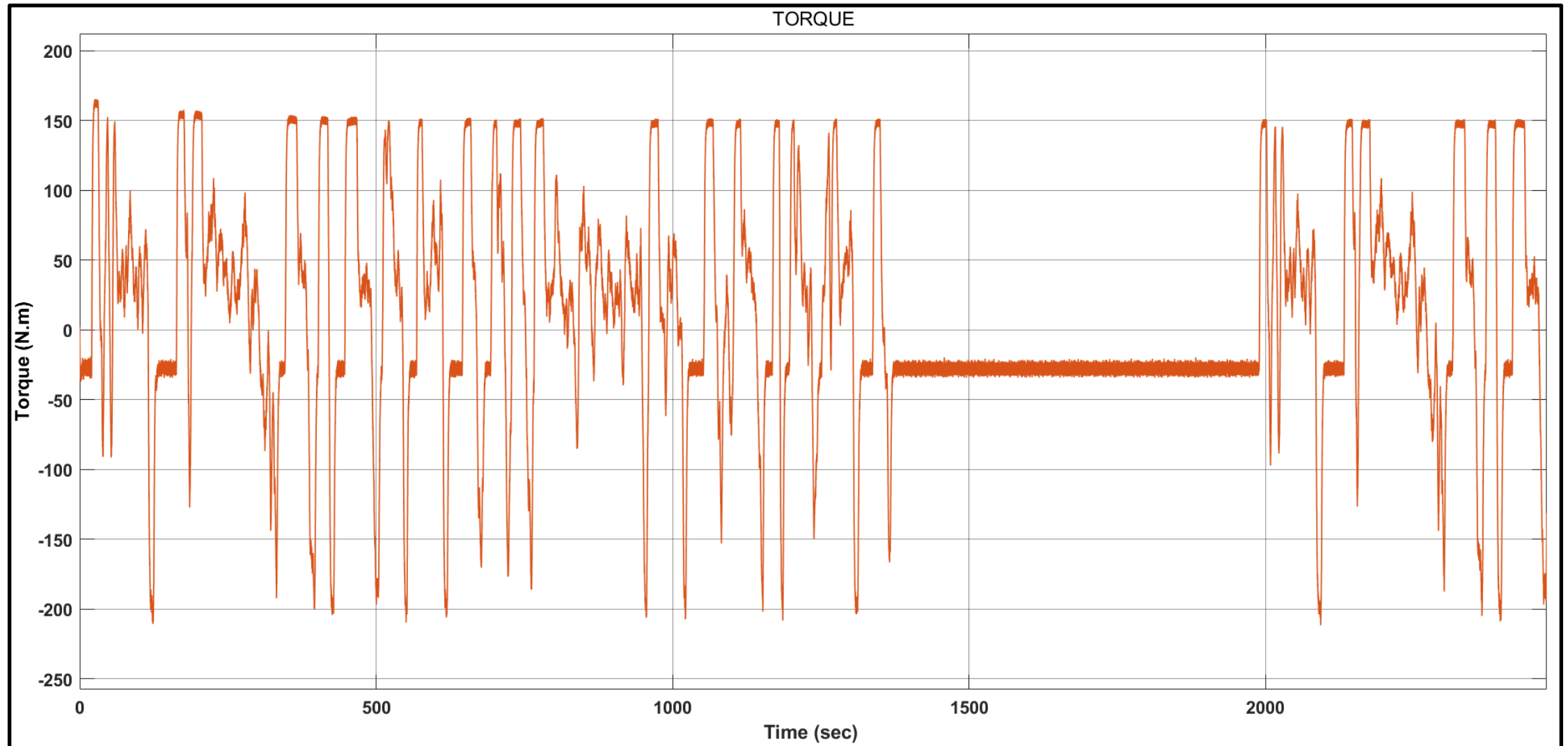


Speed result (FTP-75)

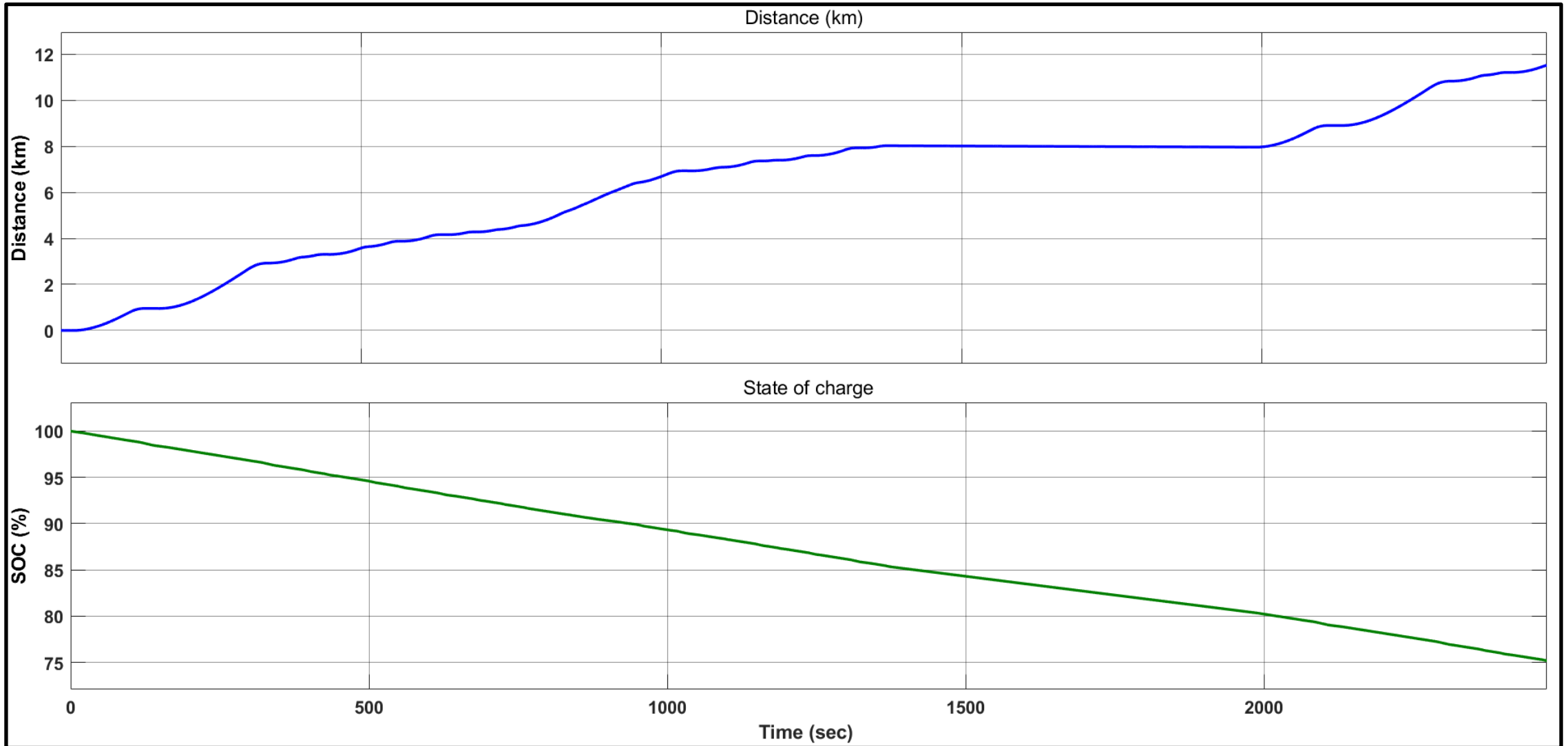




Torque result (FTP-75)

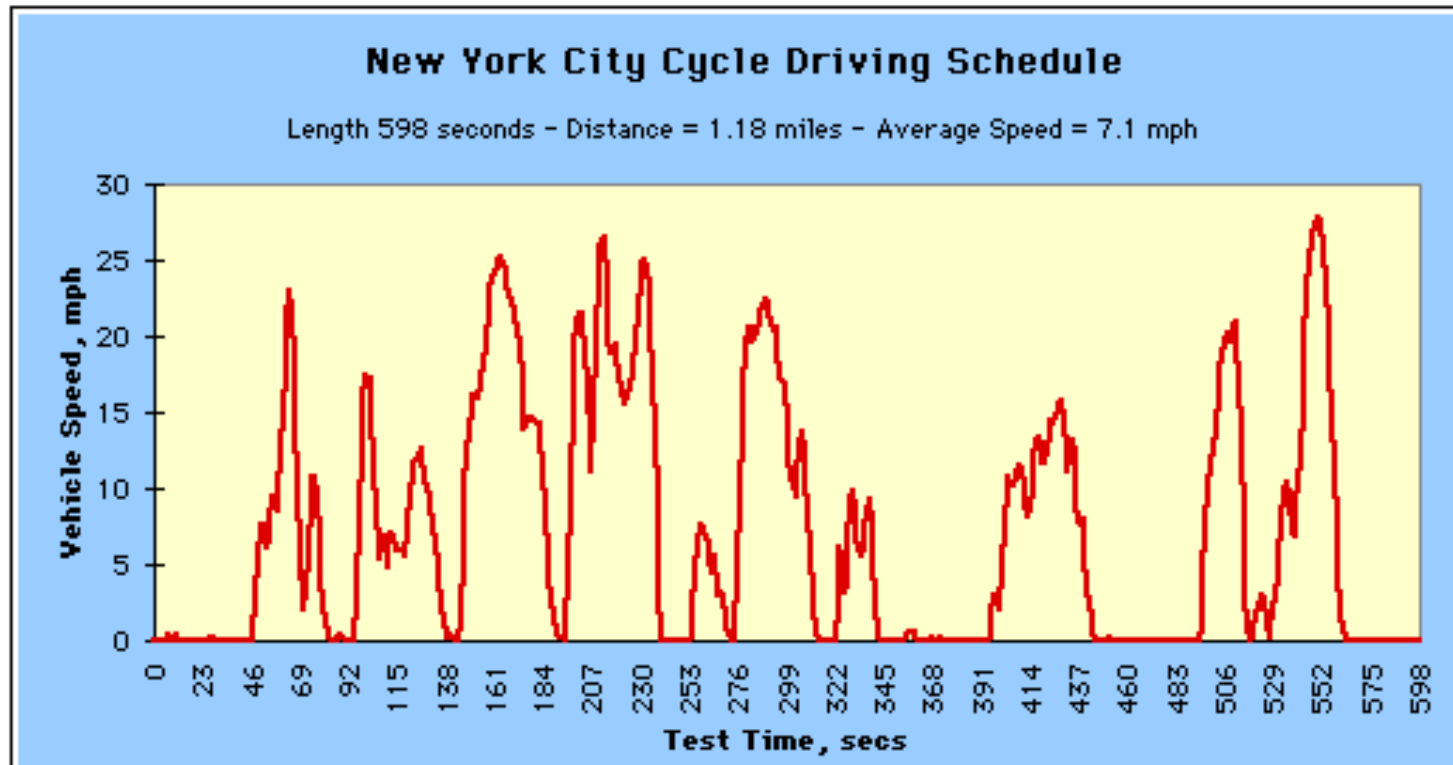


Distance and SOC (FTP-75)



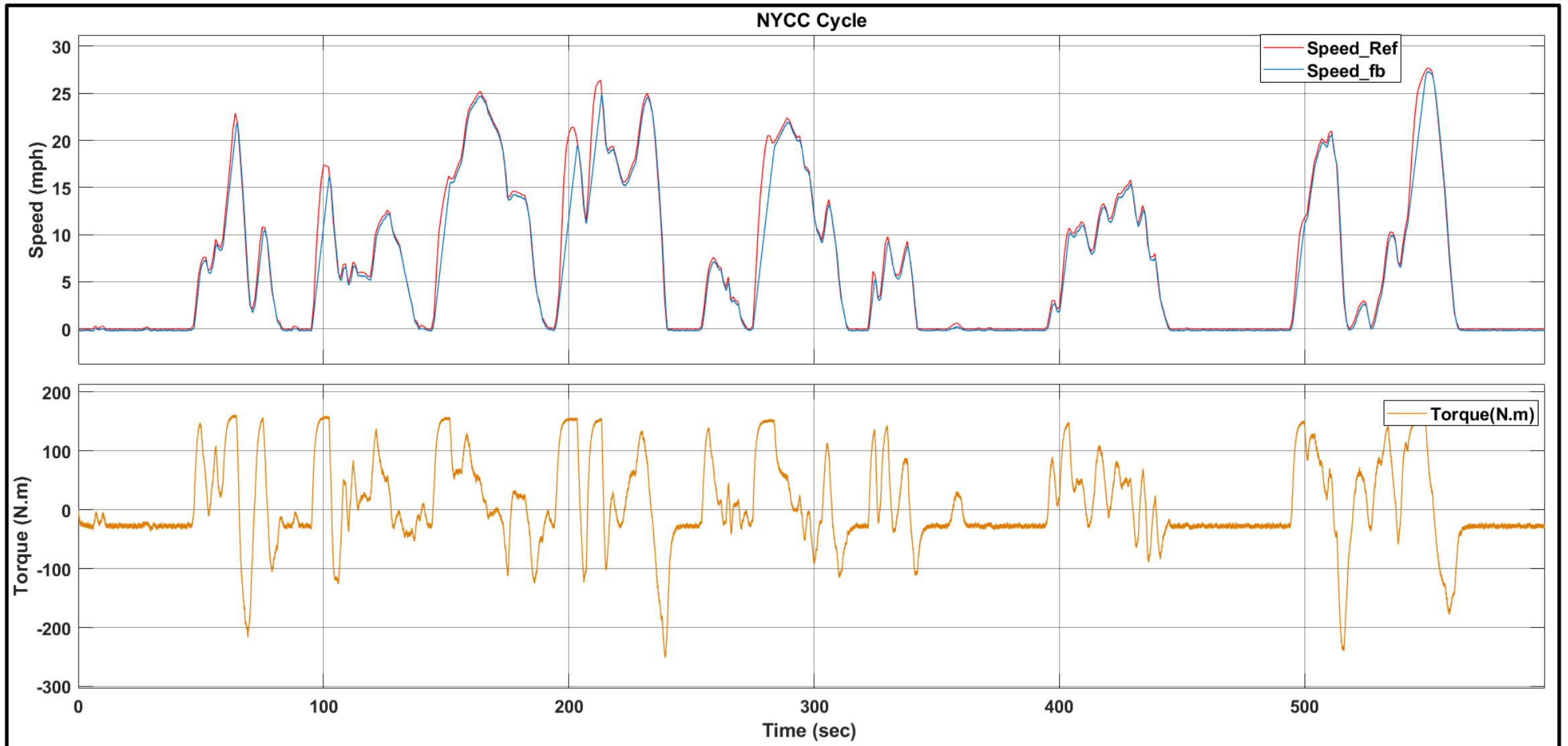
The New York City Cycle (NYCC)

- NYCC cycle is designed to simulate typical stop-and-go traffic conditions in a densely populated urban environment. This cycle simulates **low-speed** conditions, lasts **10mins**, **1.9km**, average speed at **11km/h**.

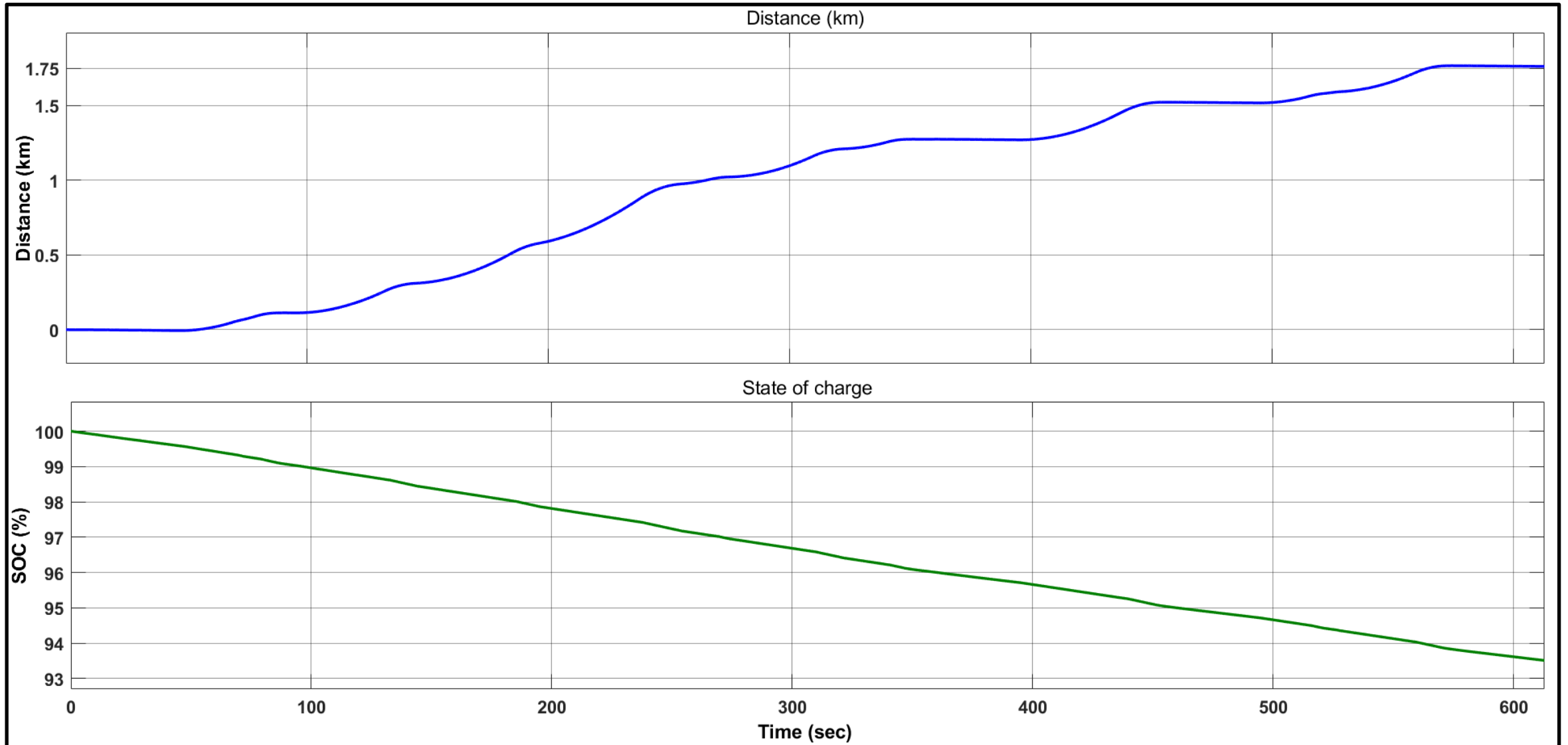




Testing result (NYCC)

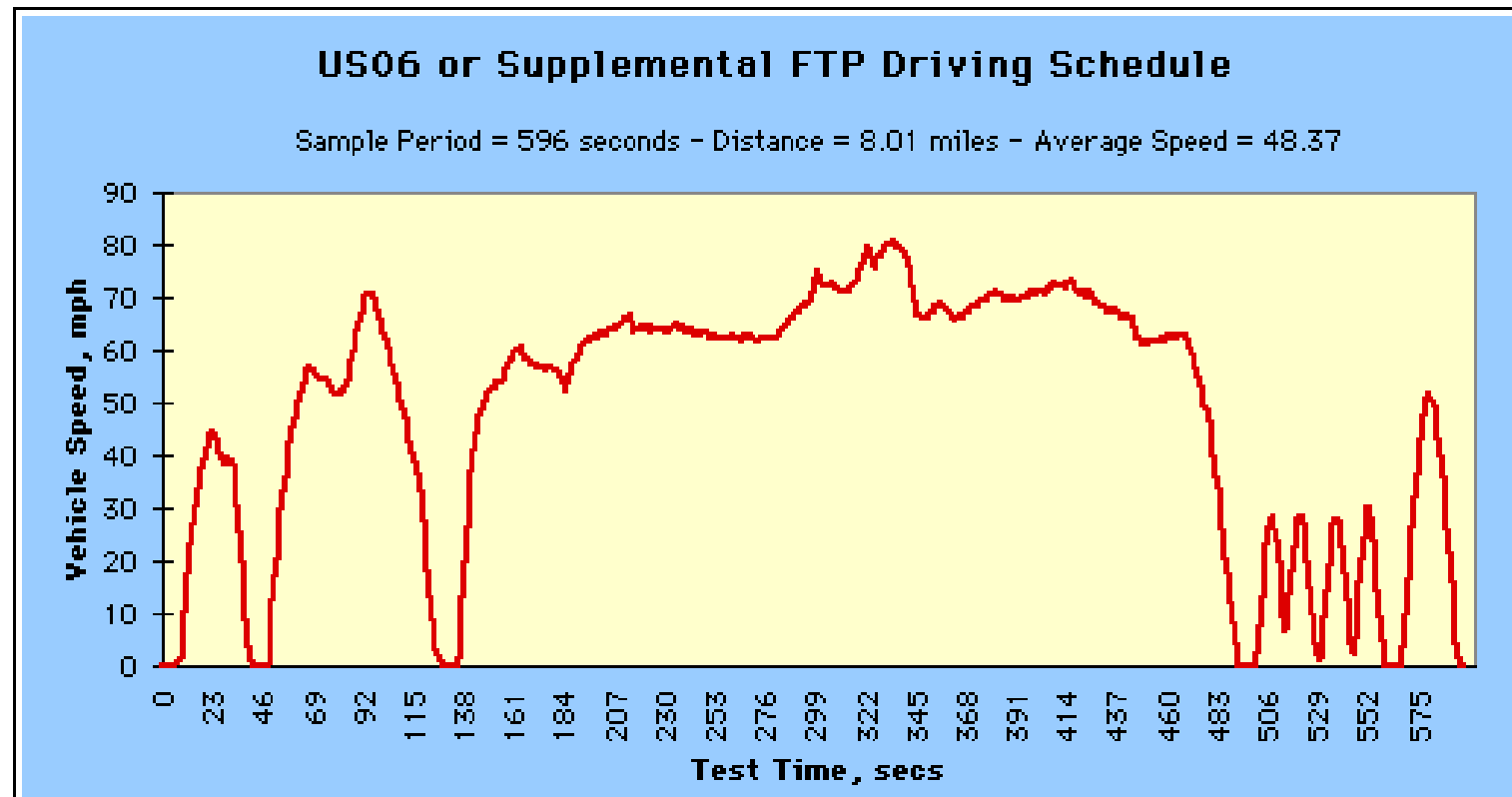


Distance and SOC (NYCC)

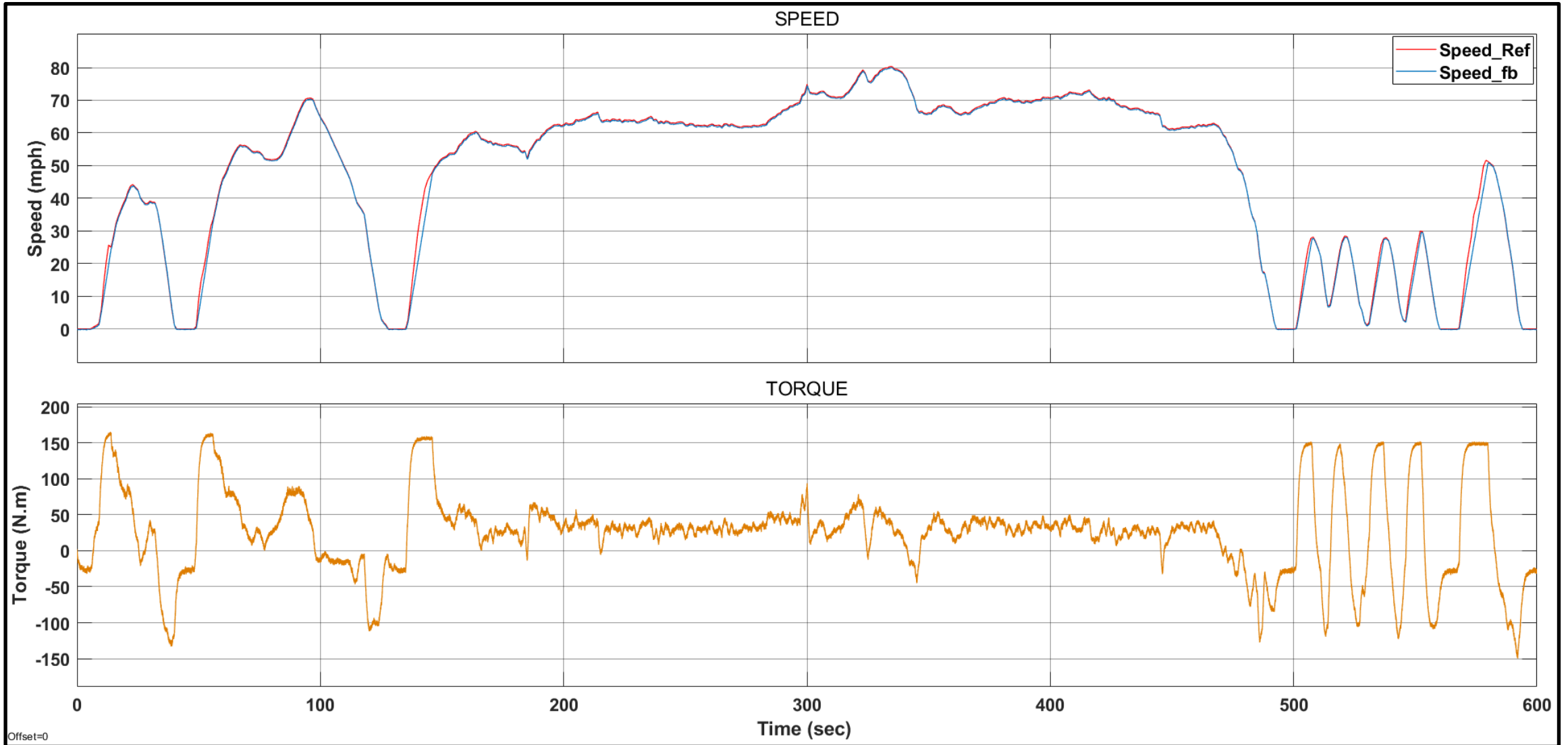


US06 - Supplemental FTP

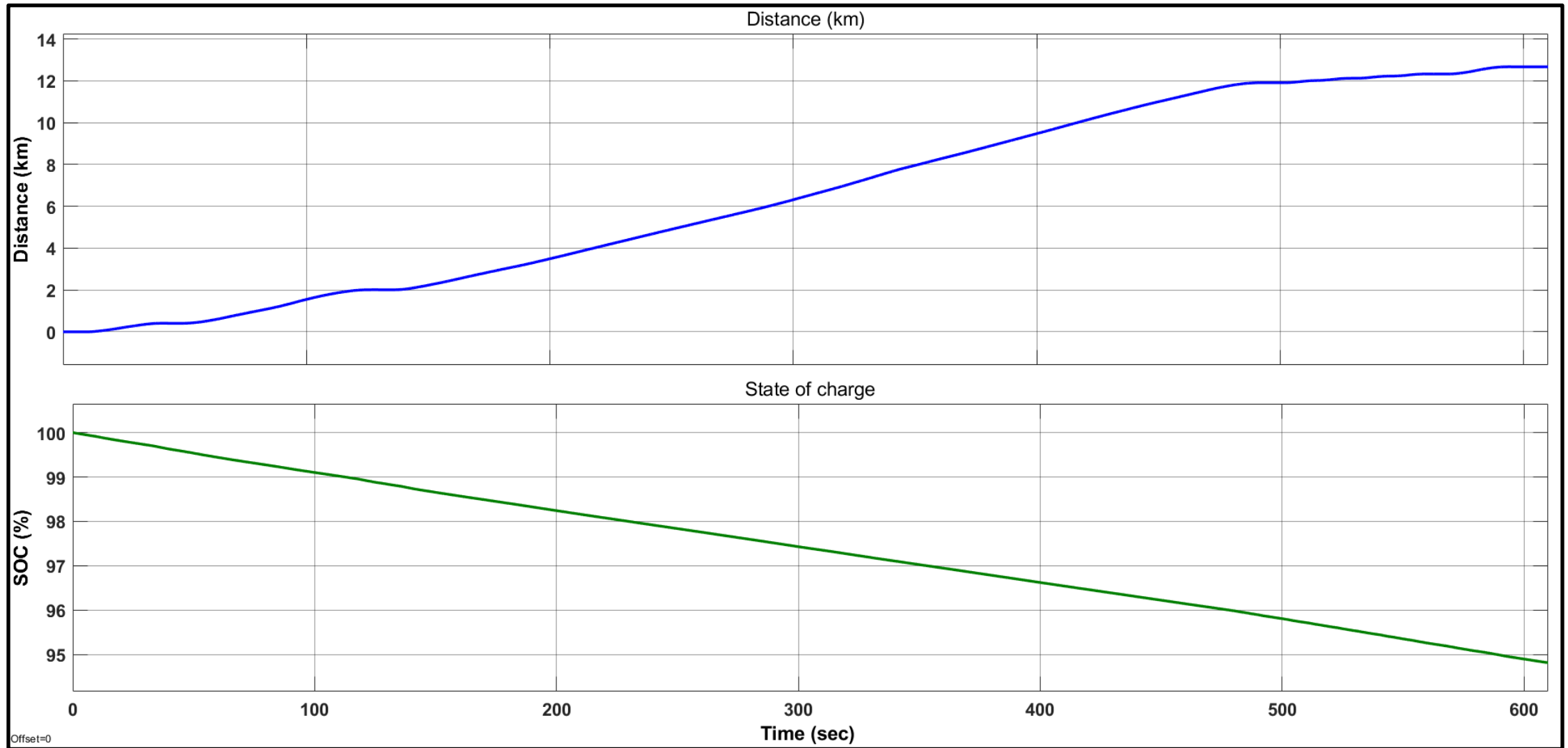
- US06 cycle is designed to represent **aggressive driving** conditions. This cycle simulates **higher speeds** and **acceleration rates** conditions, lasts **10mins**, **12.8km**, average speed at **48km/h**, peak speed **128km/h**.



Testing result (US06)



Distance and SOC (US06)



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BIKESIM MODEL

General

BikeSim Run Control; { Simulink } Ebike

File Edit Datasets Libraries Tools View Help

Back Forward Home Previous Next New Delete Lib Tool Save Undo Redo Parsfile Run258.par 11-05-2024 15:41:02

Sidebar Refresh Help Lock

Notes Linked Data

You can write notes here for this dataset.

Vehicle

Vehicle code: fixed_caster

Ebike

Events and Procedures

Events and Procedures:

Environment & Miscellaneous Data

Road/wind/misc.: 3D road

Flat

Road/wind/misc.:

Road/wind/misc.:

☒ **Override Some Controls**

Initial speed (open-loop control) 0.36 km/h

{No dataset selected}

Braking:

Shifting control:

Steering:

Run Control with Simulink

Run from Here Send to Simulink

Ebike

Stop run at specified time

Time (sec)	Road station (m)
Start: 0	0
Stop: 200	Road forward

Output variables: Write Channels

Basic outputs

Time step (sec)	Freq. (Hz)
Math model: 0.005	200
Output file: 0.005	200

☐ More

Results (Post Processing)

Animate

Front View, Wide

Plot ☒ Multiple Plots

Vx – longitudinal speed

Drive torque

{No dataset selected}

{No dataset selected}

{No dataset selected}

{No dataset selected}

{No dataset selected}

{No dataset selected}

☐ Overlay Other Runs

Mechanical Simulation

View Echo file with initial conditions

Save Revert

Wheels

Model Option: Magic Formula for Fx, Fy, and Mz (BikeSim 1.0)

Vertical Force

Effective rolling radius: 220 mm

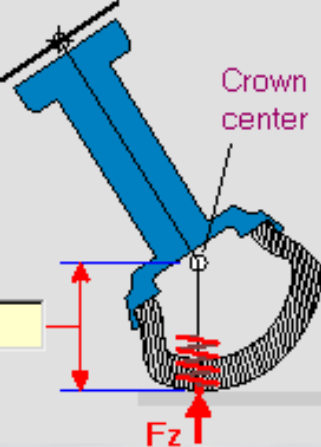
Spring rate: 130 N/mm

Maximum allowed force: 3000 N

Wheel mass: 10 kg

Un-deflected crown radius (mm): 50

Shear Forces and Moments



Crown center

F_z

Front tire

Model Option: Magic Formula for Fx, Fy, and Mz (BikeSim 1.0)

Vertical Force

Effective rolling radius: 220 mm

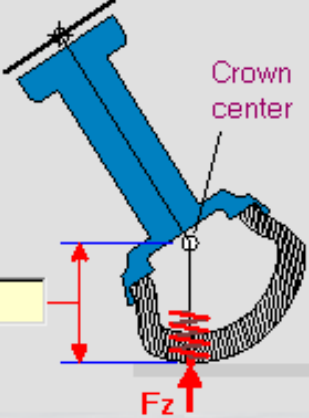
Spring rate: 141 N/mm

Maximum allowed force: 3000 N

Wheel mass: 10 kg

Un-deflected crown radius (mm): 50

Shear Forces and Moments

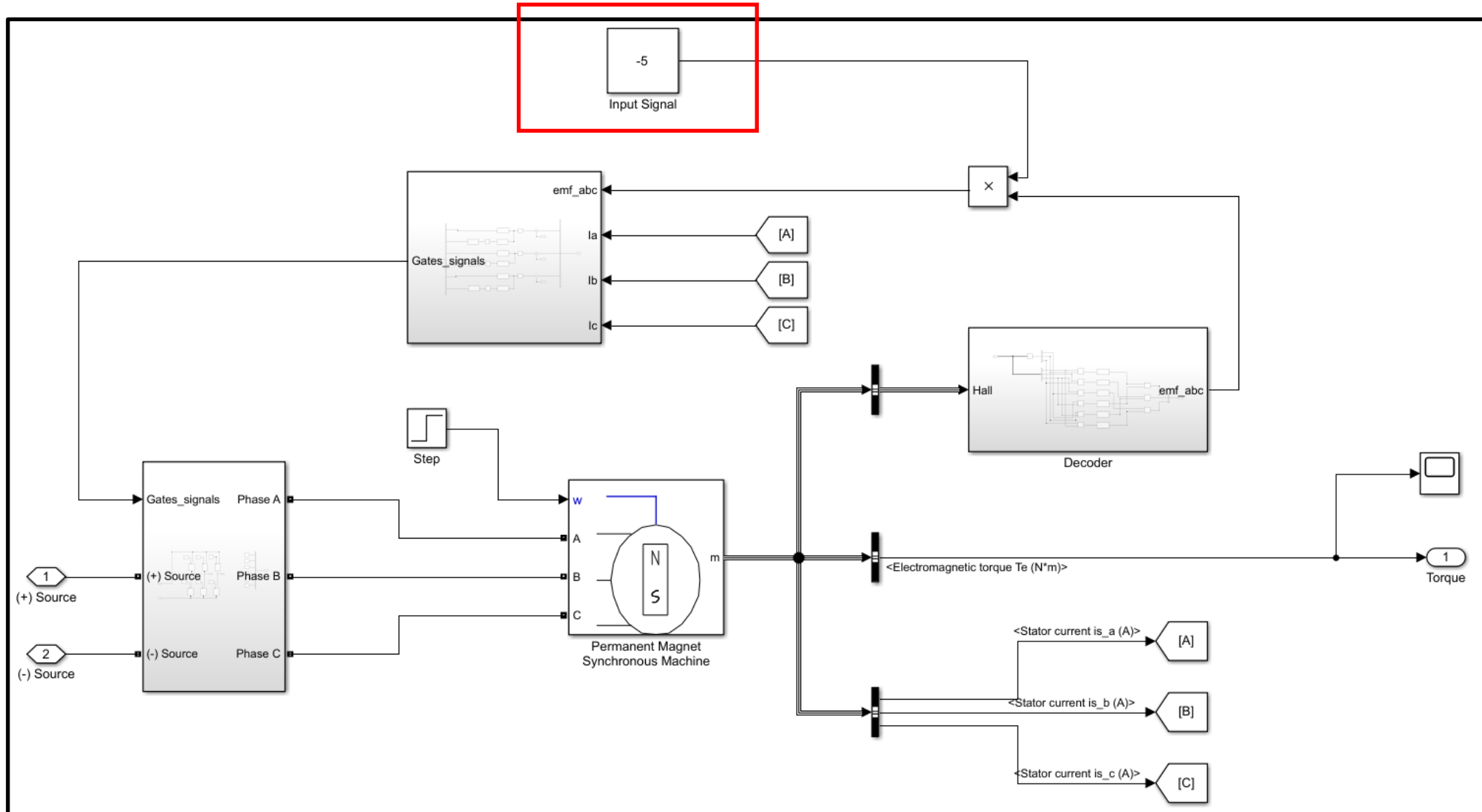


Crown center

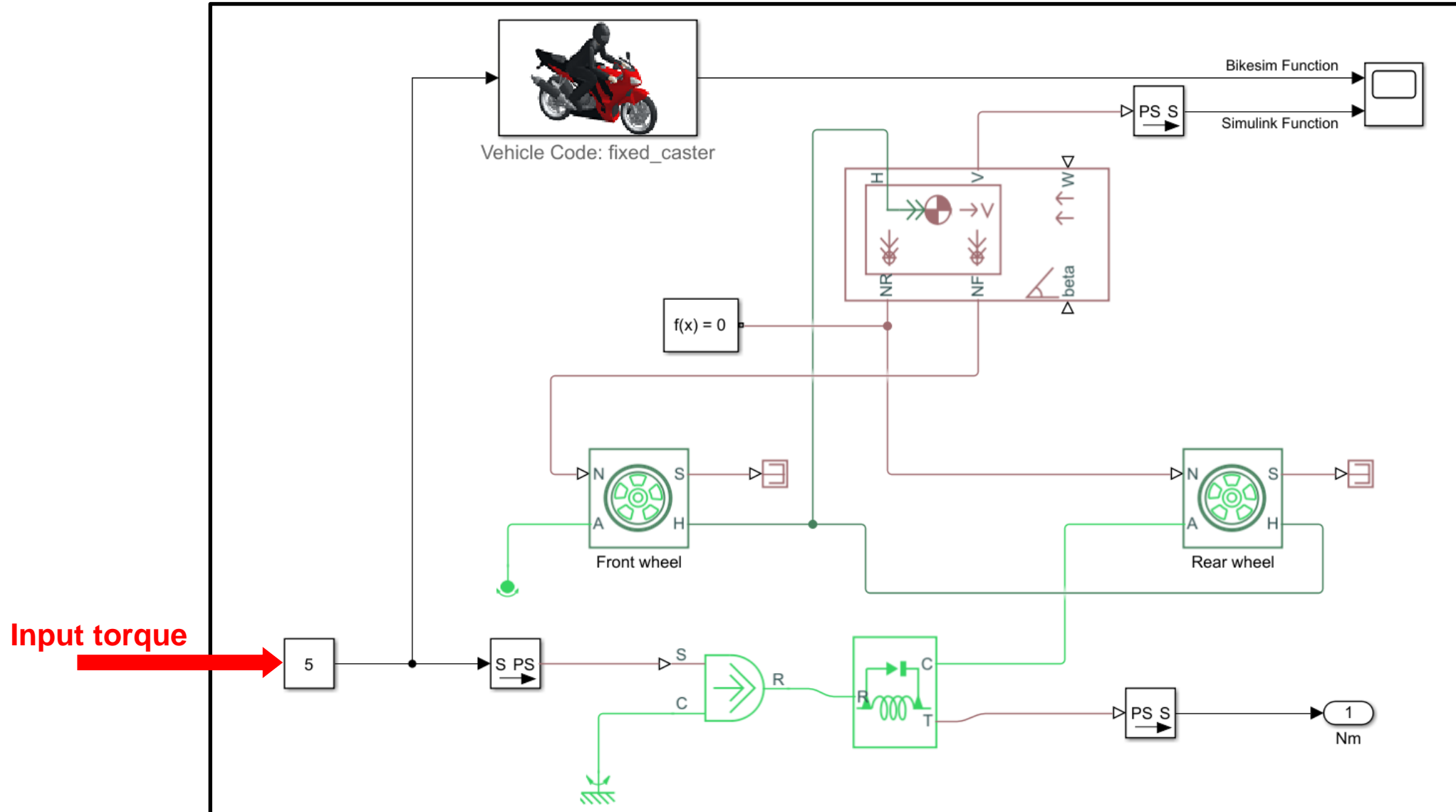
F_z

Rear tire

Driver & Motor testing block

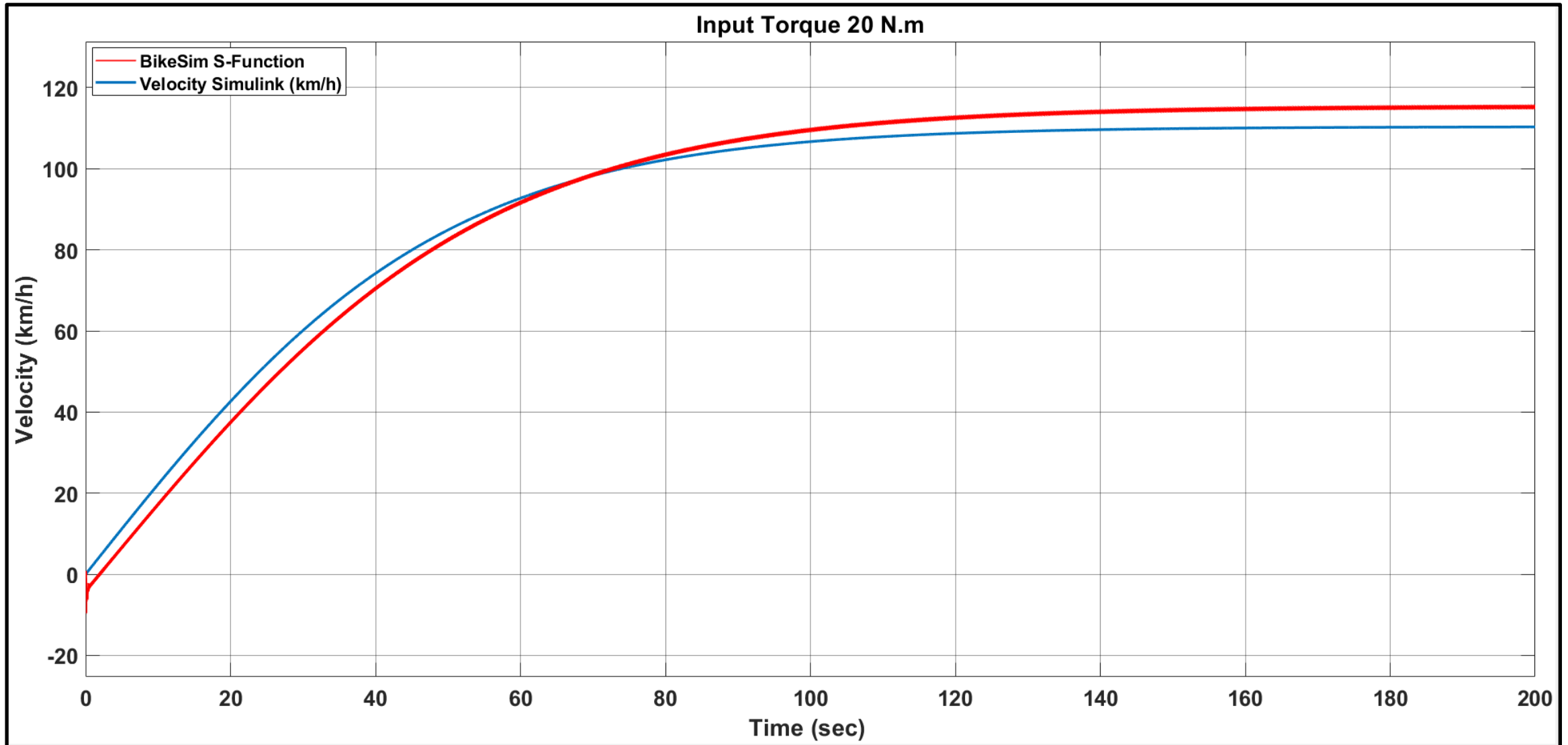


Simulink body vs Bikesim body



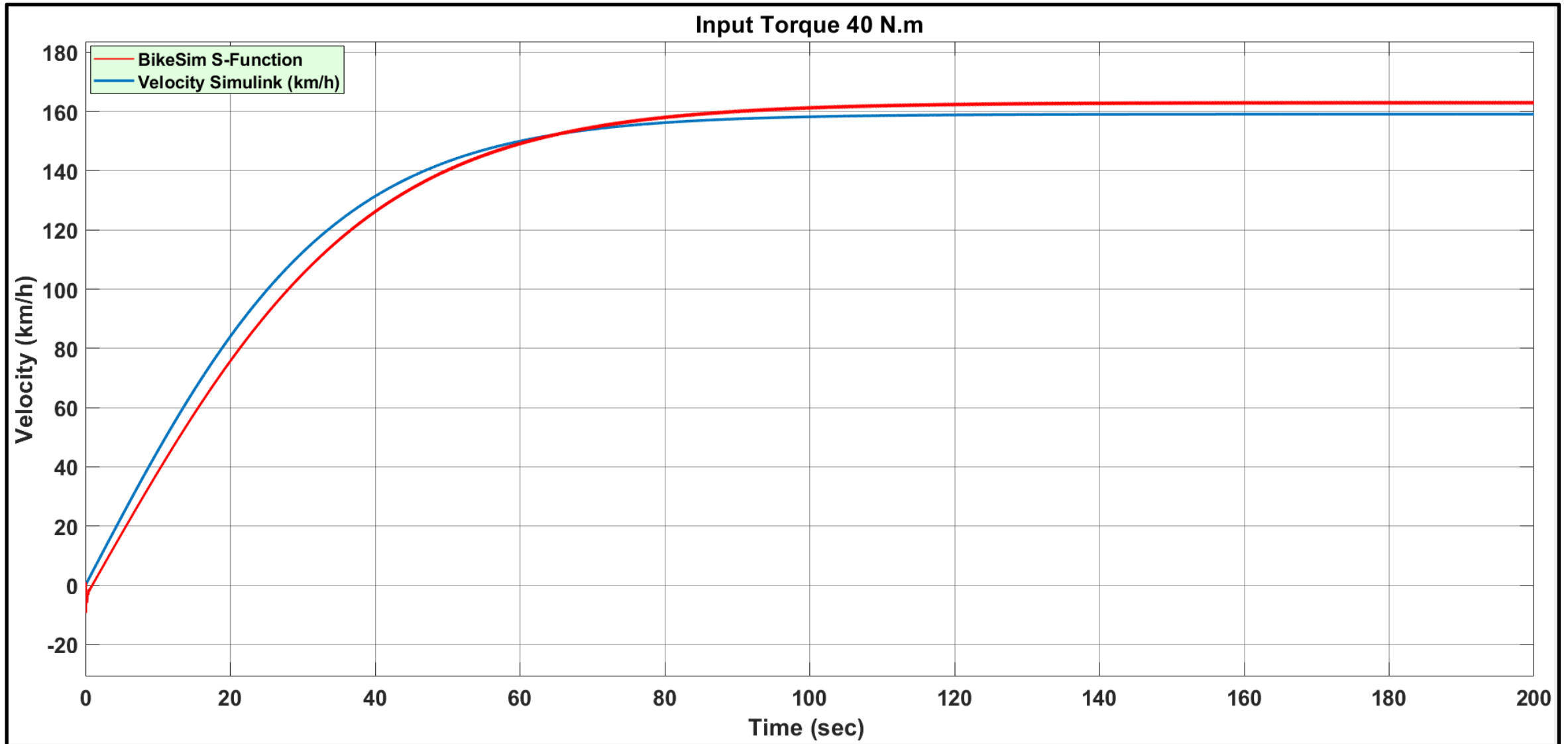


Input torque at 20 N.m



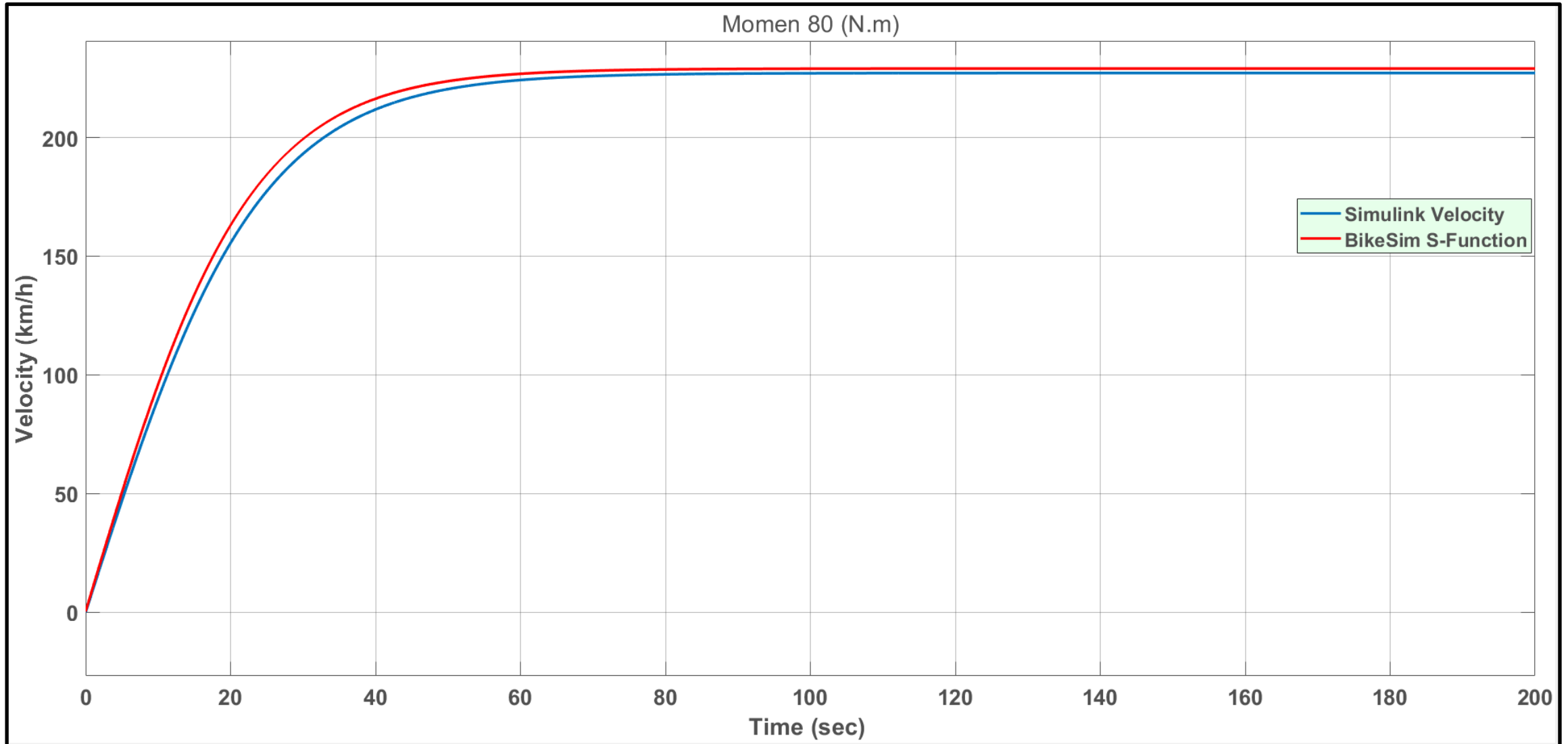


Input torque at 40 N.m





Input torque at 80 N.m



Thank you

For your attention



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