Comparative Modeling and Simulation of Electric Vehicles (EV) using SIMULINK, QSS, and ADVISOR Toolboxes

Project synopsis submitted in partial fulfillment

for the Award of

CERTIFICATION OF COMPLETION

in

Certification Course in MATLAB-SIMULINK, QSS & Advisor Toolbox for EV Design

by

PRANAV RAJESH GHOLAP

Vasheel Kumar

DIY guru Education & Research Pvt. Ltd

(Empanelled by NEAT, AICTE, Ministry of Education, Gov. of India)

DATE: 16/07/2025

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CHAPTER 1

PROJECT DESCRIPTION

ABSTRACT

Electric Vehicles (**Ather Rizta**) are vital for reducing emissions and promoting sustainable transport. This study compares three popular tools—SIMULINK, QSS, and ADVISOR—for EV modelling and simulation. These tools help analyze key EV components like batteries, motors, and powertrains. The research evaluates their accuracy, speed, and usability, offering insights to engineers and researchers for selecting the best tool for EV design tasks.

INTRODUCTION

Electric Vehicles (EVs) are key to reducing pollution and dependence on fossil fuels. Designing EV systems involves understanding complex interactions between batteries, motors, and control systems. Simulation tools like SIMULINK, QSS, and ADVISOR simplify this process by predicting performance and optimizing designs.

Toolbox Introduction:

- **SIMULINK:** A powerful tool in MATLAB for building and simulating dynamic systems. It uses a block-based design, making it great for detailed EV modelling, like motors, batteries, and control systems.

- **QSS (Quantized State Systems):** A simpler and faster way to simulate EVs by focusing on steady-state behavior rather than detailed changes over time, saving computation time.

• **ADVISOR (Advanced Vehicle Simulator):** A ready-to-use tool for analyzing EVs. It has built-in models for key components like batteries and powertrains, making it easy to quickly test and optimize designs.

CHAPTER 2

REQUIRED INPUT PARAMETERS AND CALCULATIONS

Vehicle Specifications:

For consistency across toolboxes, the following standardized vehicle specifications are used in all models:

Vehicle Type: 2-Wheeler Electric Vehicle (Ather Rizta)

Kerb Weight: 119

Pay Load: 80

Total Weight:199

Battery Pack: 2.9 kWh

Battery Voltage: 5V

Battery Capacity: 60Ah

Frontal Area: 0.855 m^2

Tyres: 90/90 R12

Coefficient of Rolling Resistance: 0.02

Drag Coefficient: 1.5

Motor Type: Permanent Magnet Synchronous Motor (PMSM)

Motor Power (continuous): 4.3 kW

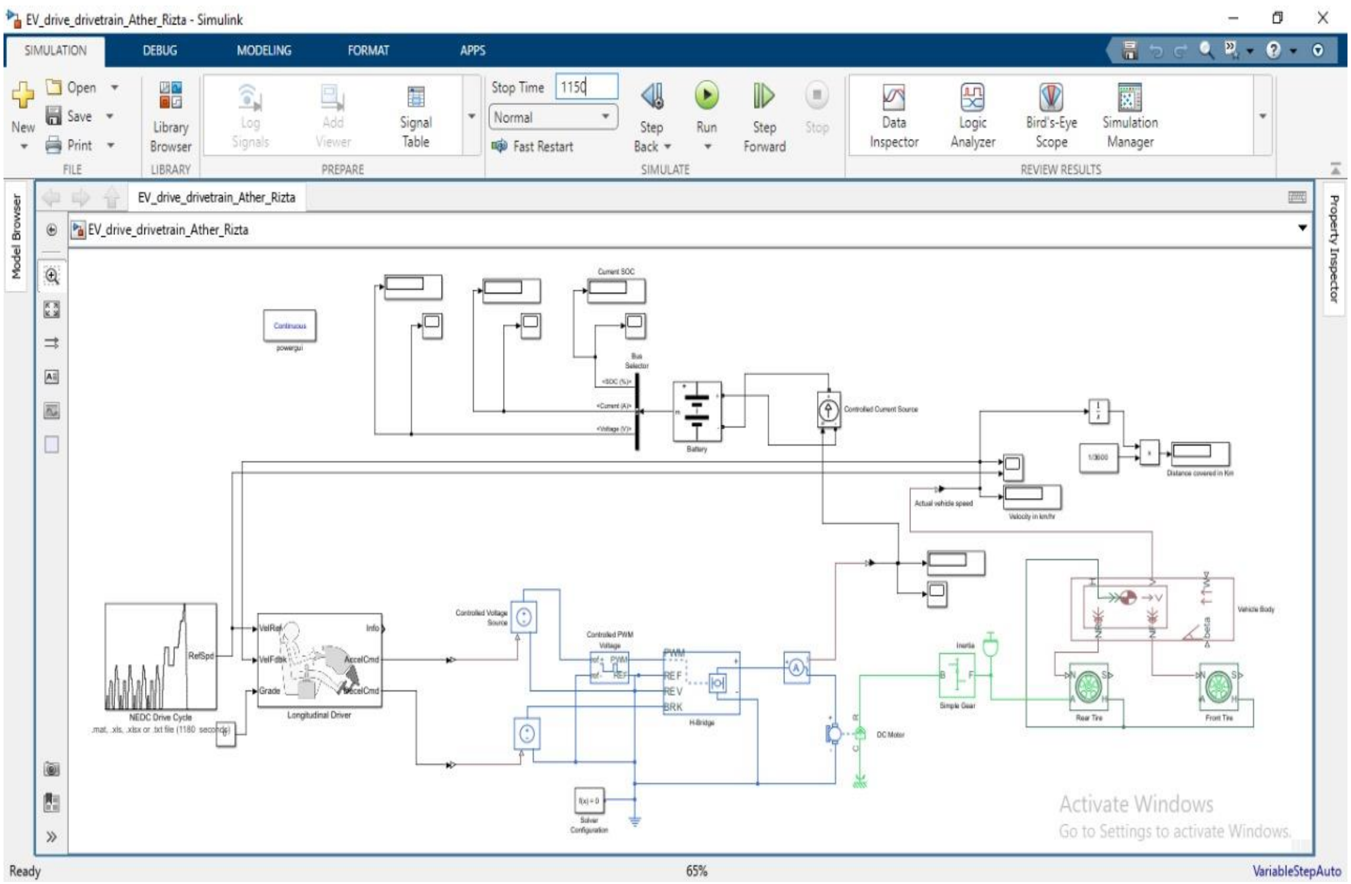
Motor RPM: 7176

Transmission/ Gear Ratio: 7.8:1

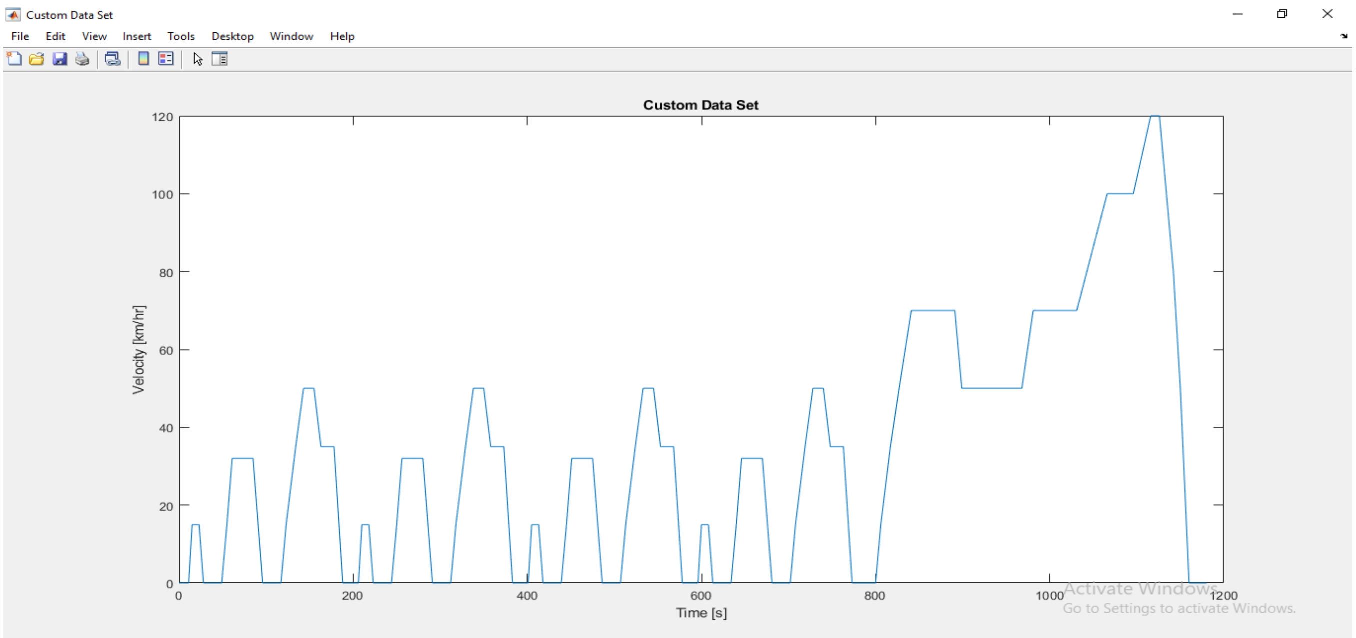
Drive Cycle: NEDC

These specifications help maintain consistency in model parameters across all three toolboxes, making it easier to compare performance outcomes.

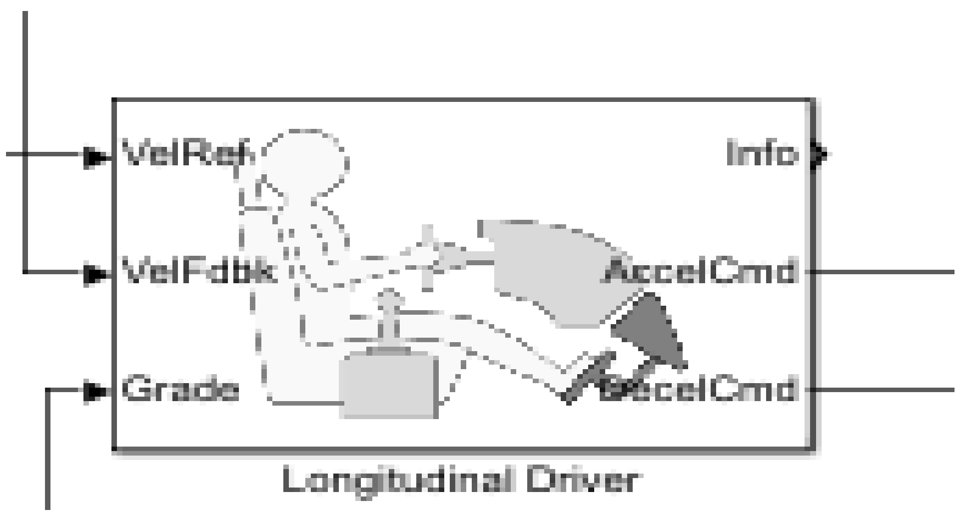
EV Modeling in SIMULINK

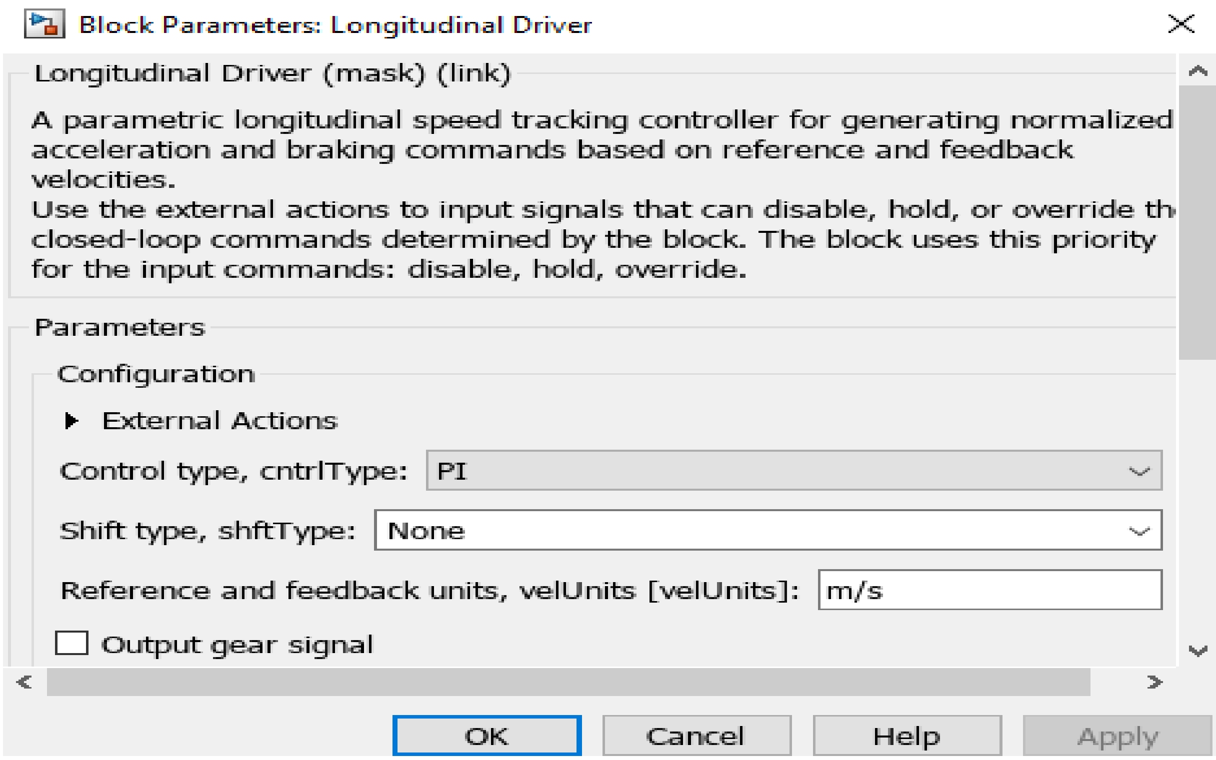


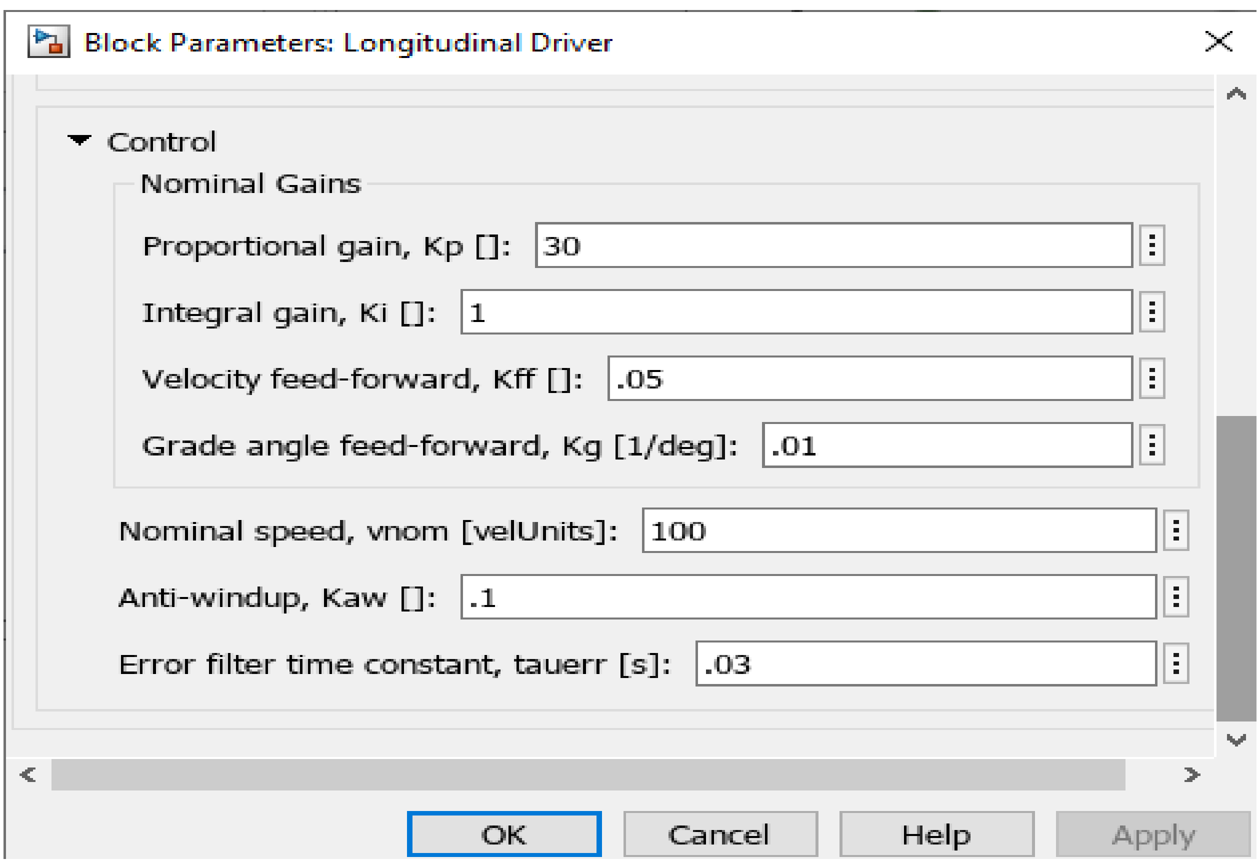
Selected Drive Cycle: NEDC (New European Driving Cycle)



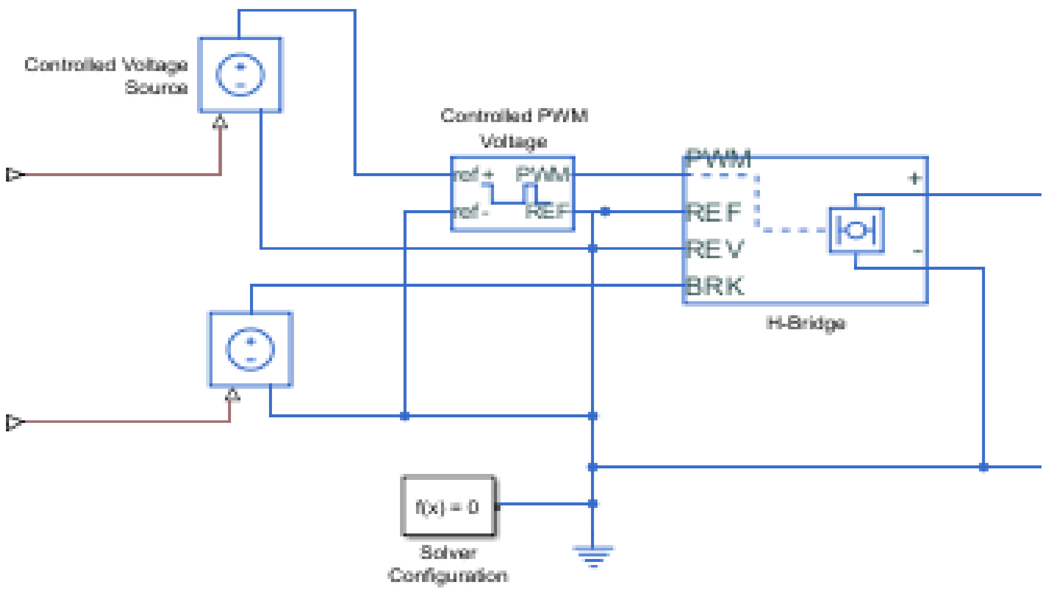
Throttle Parameters:




Block Parameters: Longitudinal Driver
Longitudinal Driver (mask) (link)
A parametric longitudinal speed tracking controller for generating normalized acceleration and braking commands based on reference and feedback velocities.
Use the external actions to input signals that can disable, hold, or override th closed-loop commands determined by the block. The block uses this priority for the input commands: disable, hold, override.
Parameters
Configuration
External Actions
Control type, cntrlType: PI
Shift type, shftType: None
Reference and feedback units, velUnits [velUnits]: m/s
Output gear signal
OK
Cancel
Help
Apply


Block Parameters: Longitudinal Driver
Control
Nominal Gains
Proportional gain, Kp []: 30
Integral gain, Ki []: 1
Velocity feed-forward, Kff []: .05
Grade angle feed-forward, Kg [1/deg]: .01
Nominal speed, vnom [velUnits]: 100
Anti-windup, Kaw []: .1
Error filter time constant, tauerr [s]: .03
OK
Cancel
Help
Apply

Motor Controller System:



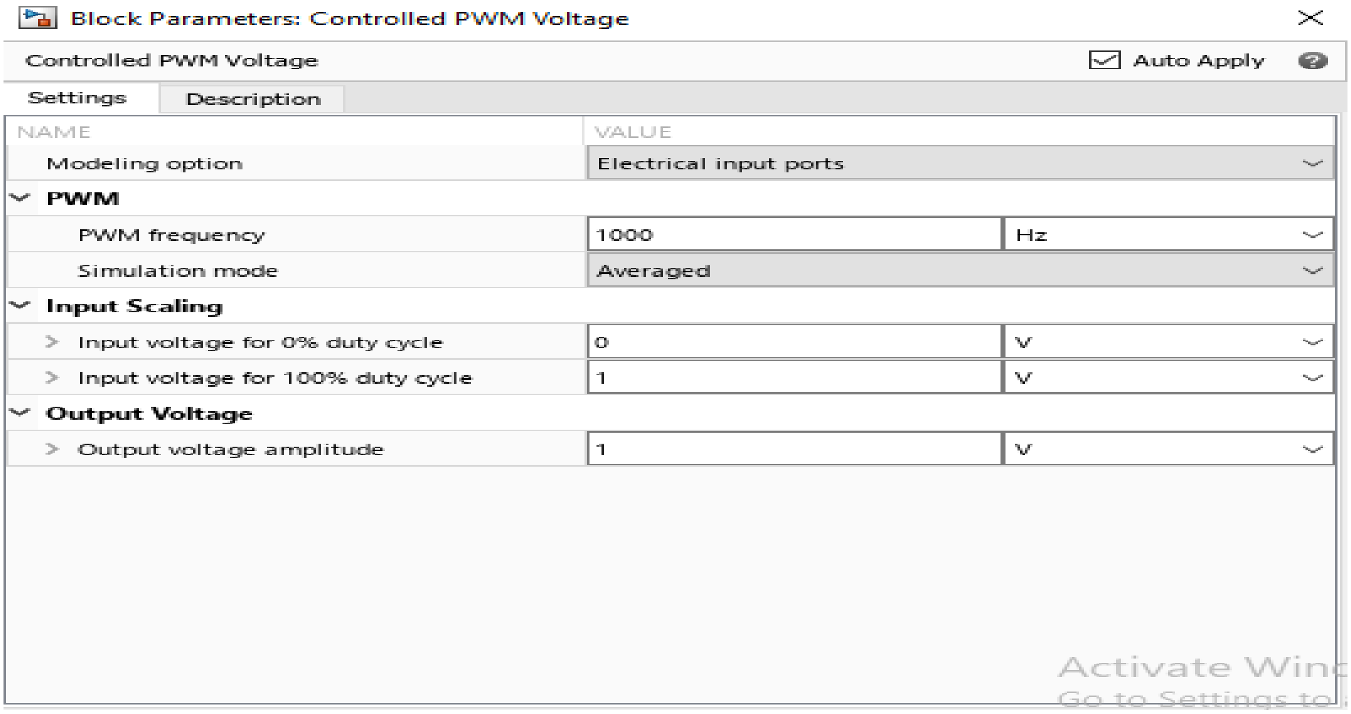
Controlled PWM Voltage:

Simulink provides an inbuilt Controlled PWM Voltage block. This block is used for providing the proper pulse inputs to the H-Bridge circuit.

This block creates a Pulse-Width Modulated (PWM) voltage across the PWM and REF ports. The output voltage is zero when the pulse is low, and is equal to the Output voltage amplitude parameter when high. Duty cycle is set by the input value.

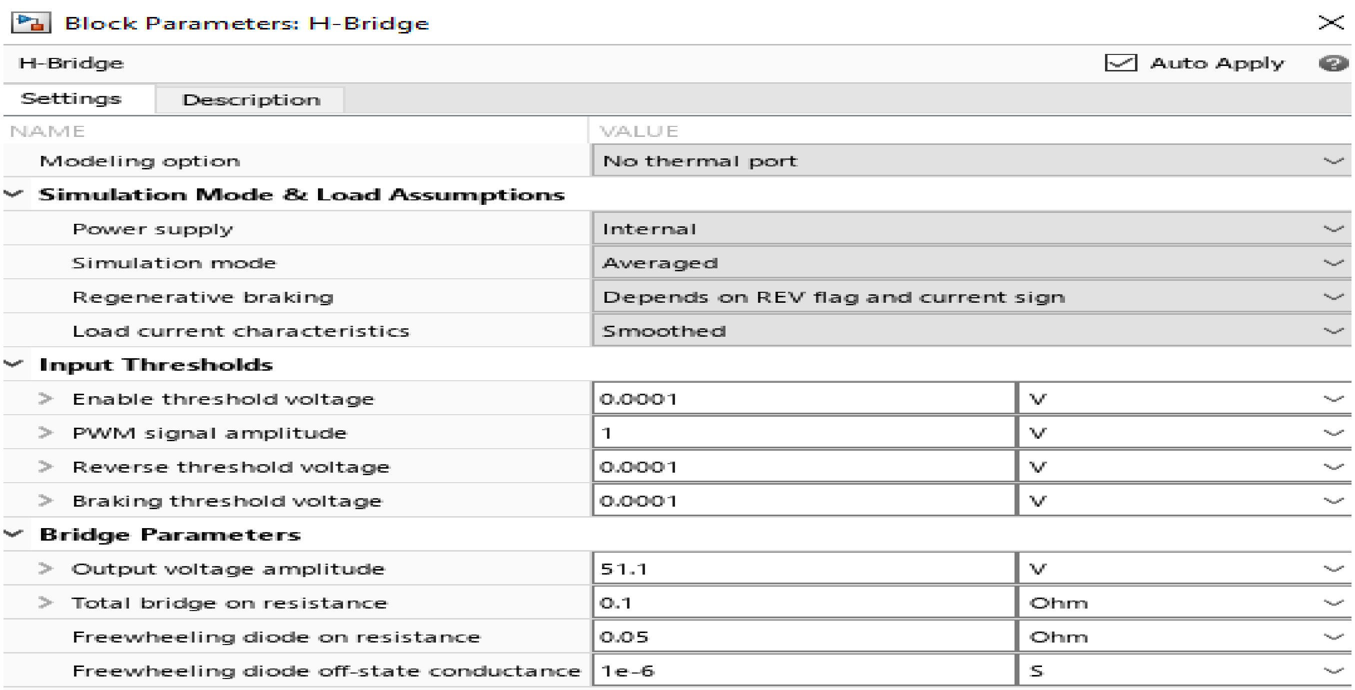
At time zero, the pulse is initialized as high unless the duty cycle is set to zero or the Pulse delay time is greater than zero. The Simulation mode can be set to PWM or Averaged.

In PWM mode, the output is a PWM signal. In Averaged mode, the output is constant with value equal to the averaged PWM signal.



The **PWM & REF** connections are for the corresponding ports on the H-Bridge circuit. The 2 reference inputs correspond to the throttle inputs given by the driver. The block generates corresponding pulse width as per the accelerations and brakes applied by the driver himself.

H-bridge: This block represents an H-bridge motor drive. The block can be driven by the Controlled PWM Voltage block in PWM or Averaged mode. In PWM mode, the motor is powered if the PWM port voltage is above the Enable threshold voltage. In Averaged mode, the PWM port voltage divided by the PWM signal amplitude parameter defines the ratio of the on-time to the PWM period. Using this ratio and assumptions about the load, the block applies an average voltage to the load that achieves the correct average load current. The Simulation mode parameter value must be the same for the Controlled PWM Voltage and H-Bridge blocks.



Connection **REF** is for the reference input. This combined with the PWM connected will form the pulse input for the H-Bridge. Here, the REF input is connected to the Electrical Reference (ground).

Connection **REV** corresponds to the reverse motion of the motor which essentially means, the backward motion of the vehicle. Here, the backward motion of the vehicle is not accounted for and so, the port is connected to the electrical reference.

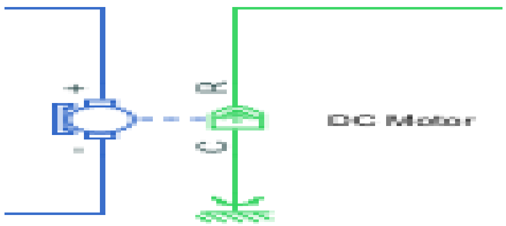
Connection **BRK** is for the braking of the vehicle. Since, the PWM mode results in a huge amount of simulation time, Averaged mode is selected for this simulation. Load current characteristics are considered to be smoothed here.

Also, the **Regenerative Braking** is an abled for the simulation. This means, when the vehicle starts decelerating, corresponding amount of charge will be fed back to the battery.

Accordingly, the **BRK** input is connected to a Controlled Voltage Source. This will generate emf corresponding to the intensity of brakes applied and fed the power back to the battery.
The Output Voltage Amplitude of the H-Bridge circuit is given the same value as the rated DC supply voltage of the DC motor.

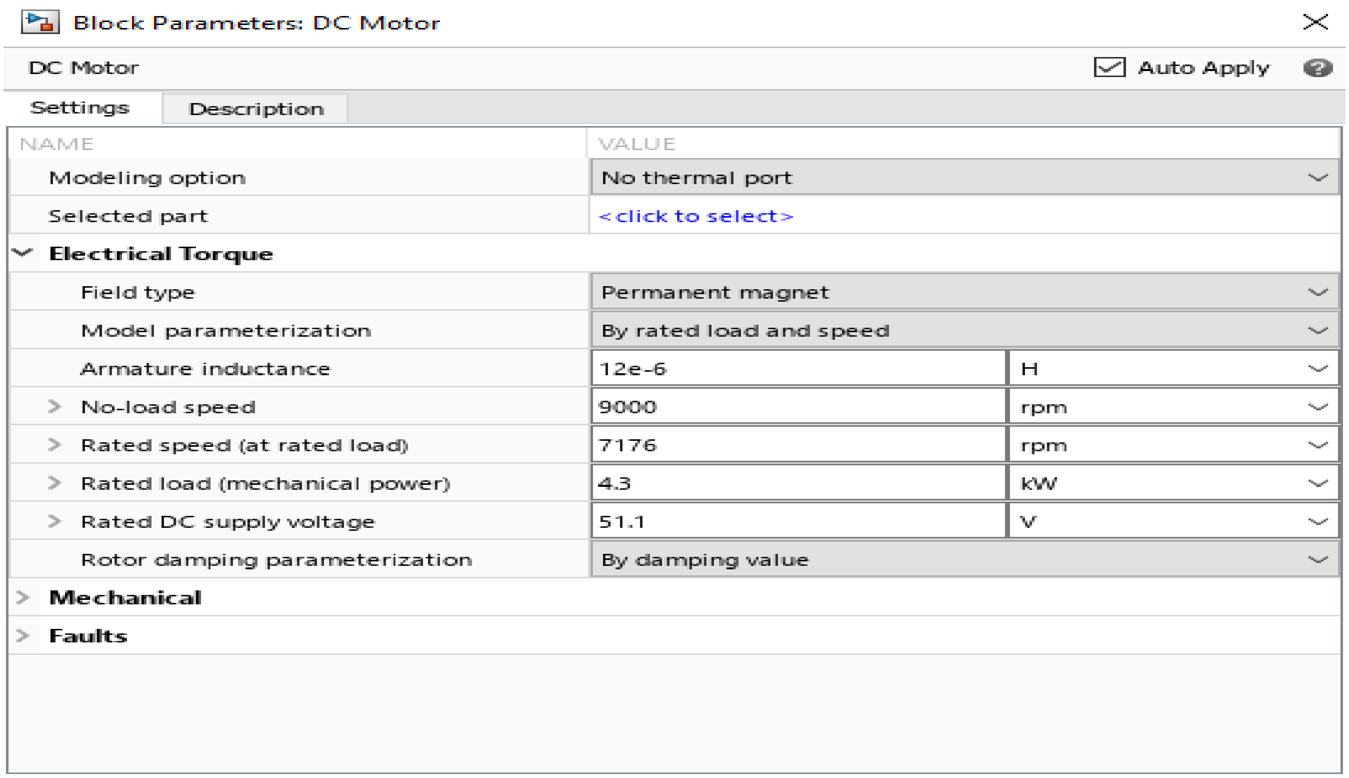
<u>Motor System:</u>

<u>DC Motor:</u>



This block represents the electrical and torque characteristics of a DC motor. The block assumes that no electromagnetic energy is lost, and hence the back-emf and torque constants have the same numerical value when in SI units. Motor parameters can either be specified directly, or derived from no-load speed and stall torque. If no information is available on armature inductance, this parameter can be set to some small non-zero value. When a positive current flow from the electrical + to - ports, a positive torque acts from the mechanical **C to R ports**. Motor torque direction can be changed by altering the sign of the back-emf or torque constants.
Simulink provides an inbuilt model block for DC motor which converts electrical input into mechanical rotational output.

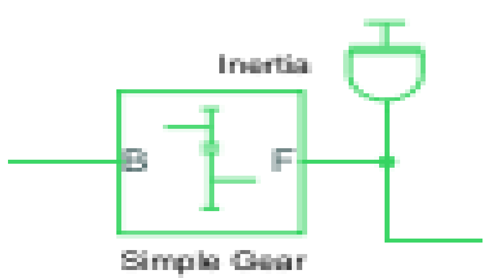
Note: Here, the blue color corresponds to the electrical side of the motor and the green color corresponds to the mechanical side. Here, the motor field type is kept as Permanent magnet and the model parameterization is done by rated load and speed. The armature inductance and the mechanical parameters are given their default values.



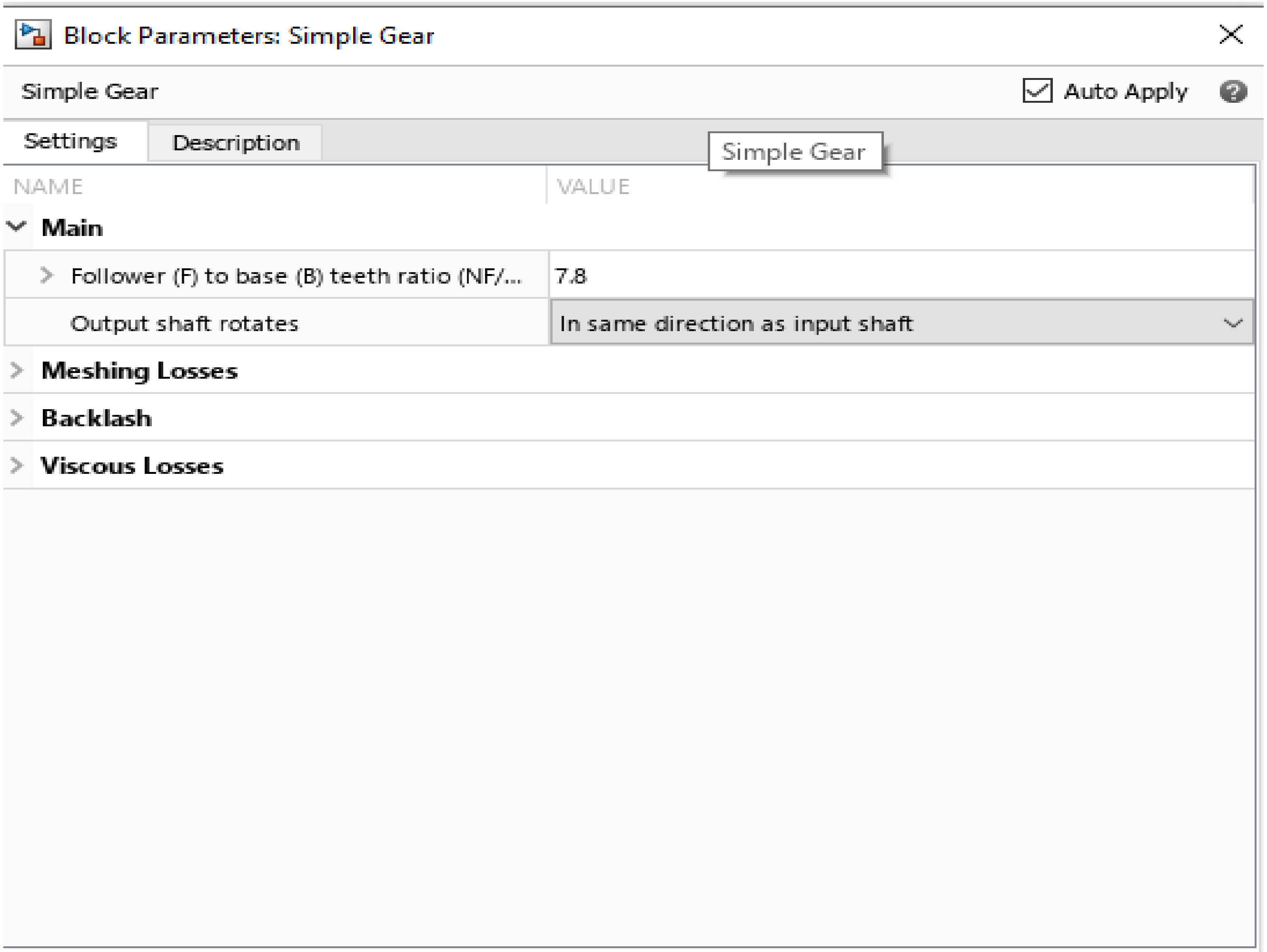
The **connection R** represents the Rotor (rotational output) while the connection **C** is for the Casing (stationary). Thus, the R port is connected to the input of the vehicle subsystem created earlier. The C port is connected to a **mechanical rotational reference**.

The + and - terminals of the motor are connected to the motor controller. If these terminals are directly connected to a battery, the required DC motor will run on the rated capacity of the battery. This will eventually result into no control over the DC motor and the vehicle will run at top speed throughout the simulation. Thus, a motor controller is very much needed.

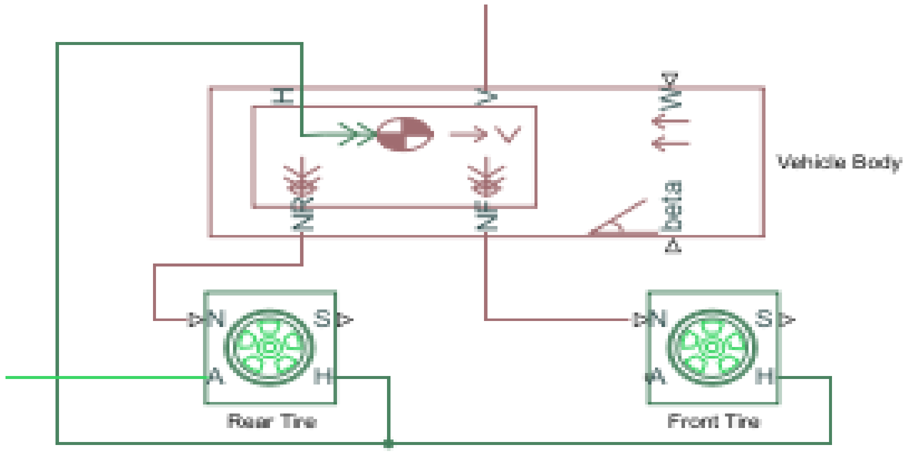
<u>Simple Gear:</u>



The input for this subsystem is taken as the Rotational speed of the motor. This input is fed to the front axle through a Simple Gear representing the **Final Drive Ratio of 7.8**. Here, the rotational direction of the output shaft is kept the same as that of the input shaft. Also, no meshing losses are considered for the simulation.



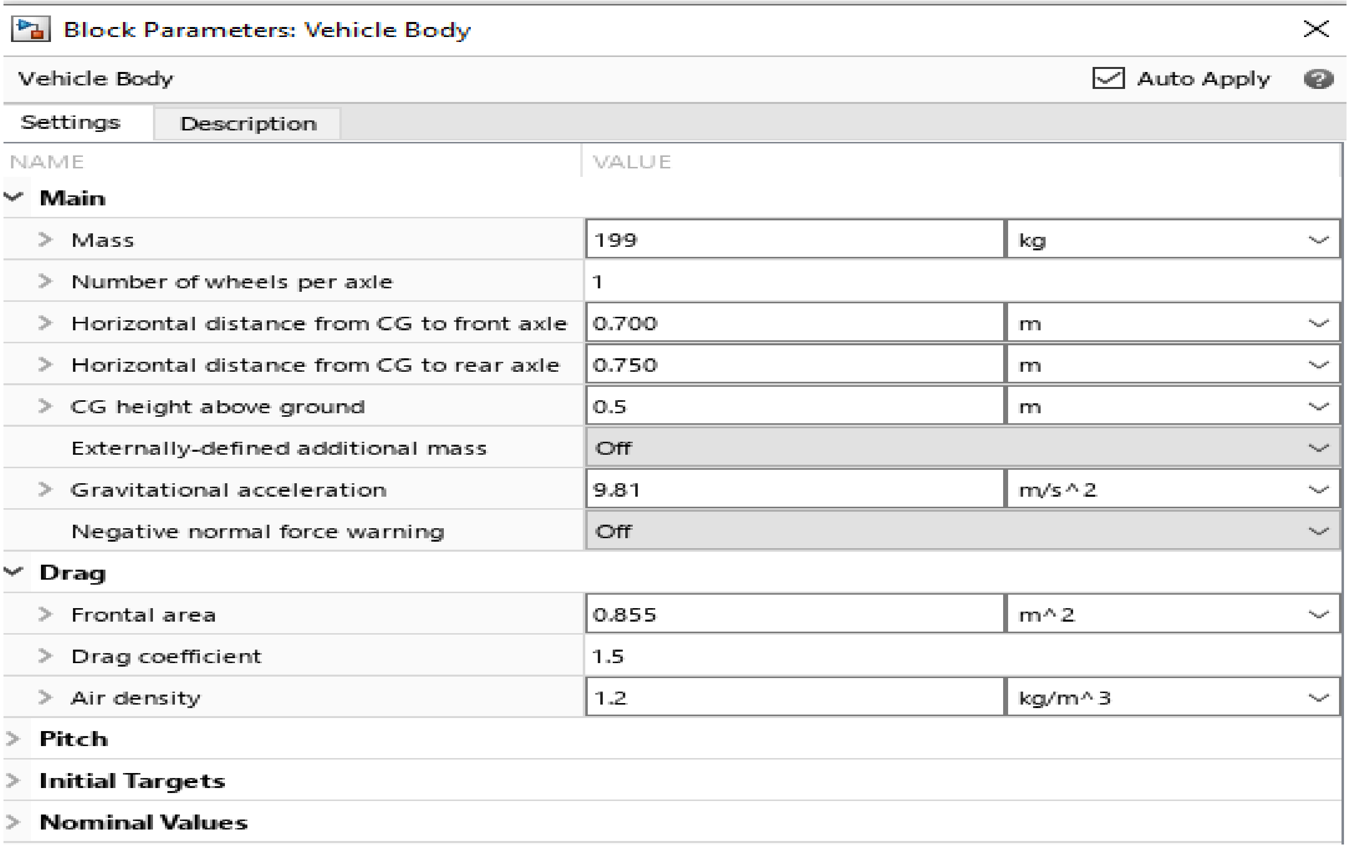
<u>Vehicle System:</u>



The **Vehicle Body** block basically represents a two-axle vehicle body in longitudinal motion.

The block accounts for body mass, aerodynamic drag, road incline, weight distribution between axles due to acceleration road profile.

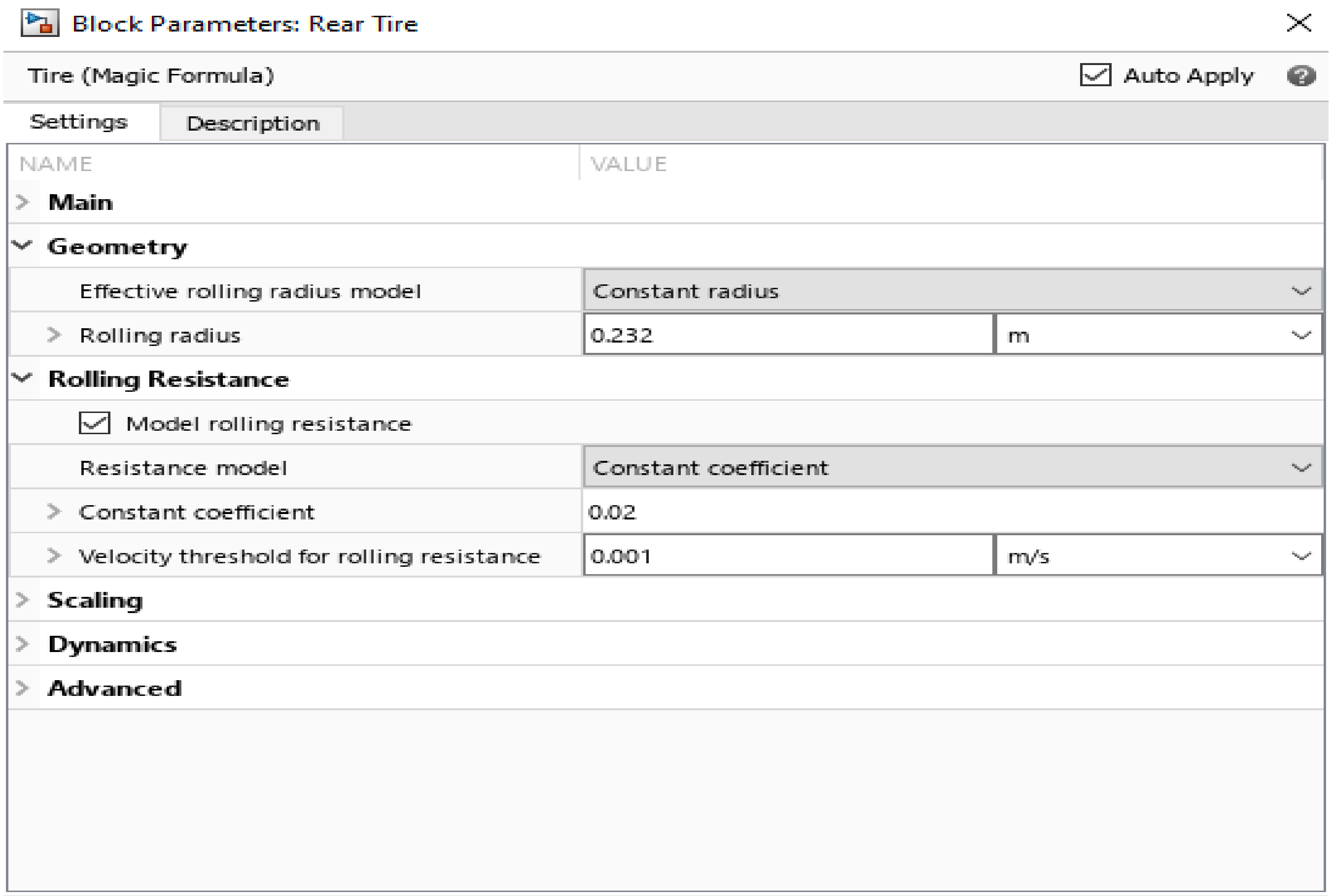
Here, the connection **H** is the mechanical translational conserving port hub**. NF & NR** correspond to the output ports for normal reaction forces on front axle and rear axle wheels respectively. Connection **V** represents the actual output translational velocity of the vehicle. **beta** is the road inclination angle & **W** corresponds to the headwind speed (headwind - direction opposite to that of vehicle). The gross weight is given to be **199** kg.



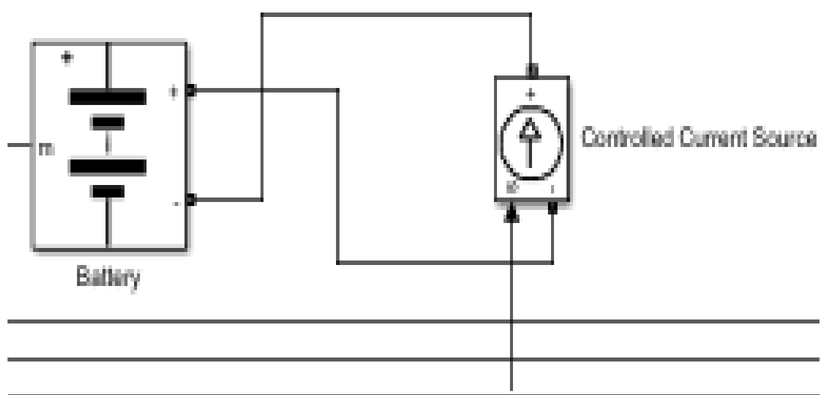
The tires are parameterized by Peak longitudinal force and corresponding slip. The other block parameters such as - rated vertical load, peak longitudinal force at rated load and slip at peak force at rated load - are kept with their default values.

The **tire radius** is given as **0.232 m**.

The **tire inertia** is kept as **1e-3 kg-m^2**. Also, the **rolling resistance** is given with a constant coefficient of **0.001m/s.**

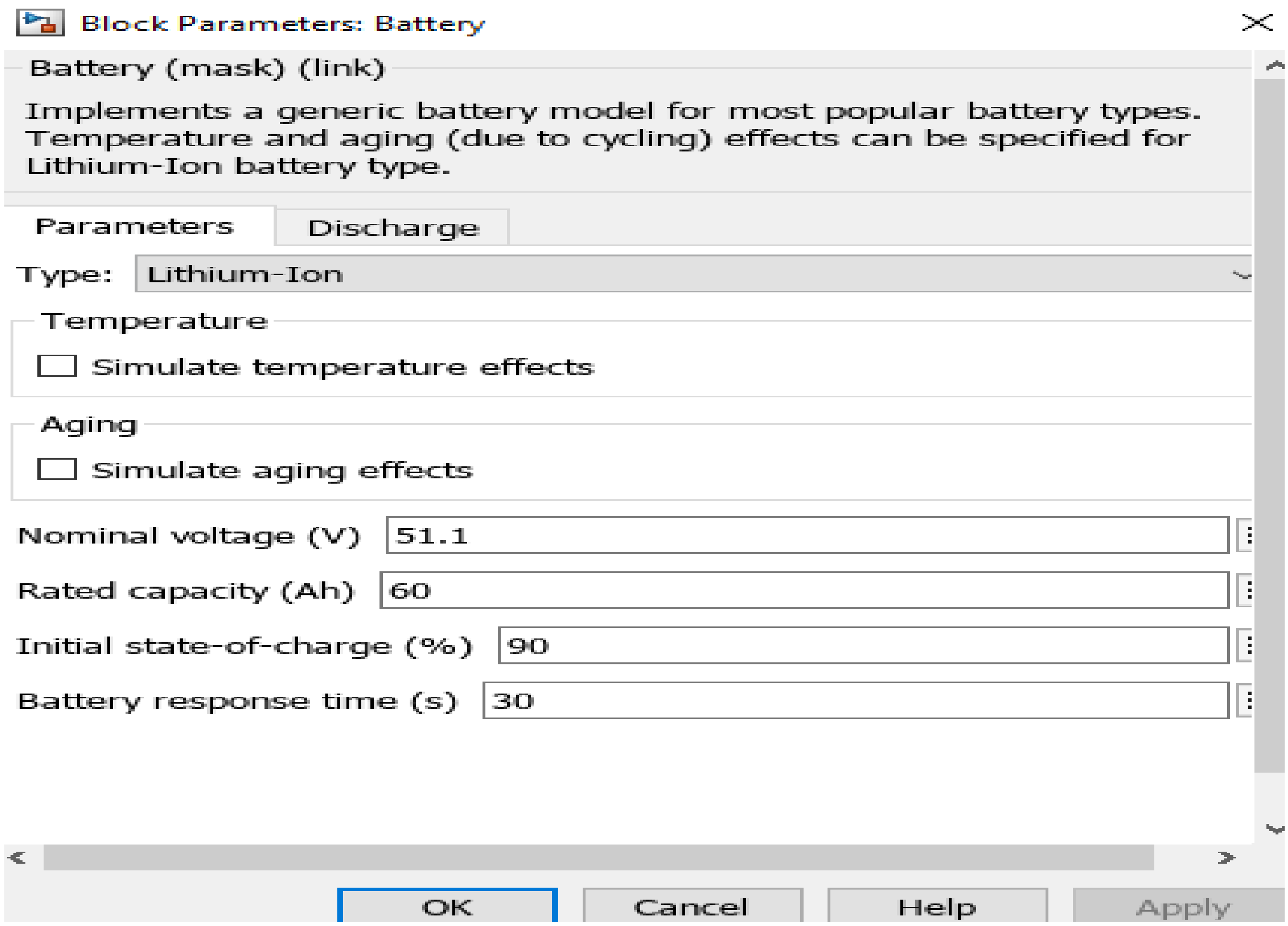


<u>Battery System:</u>



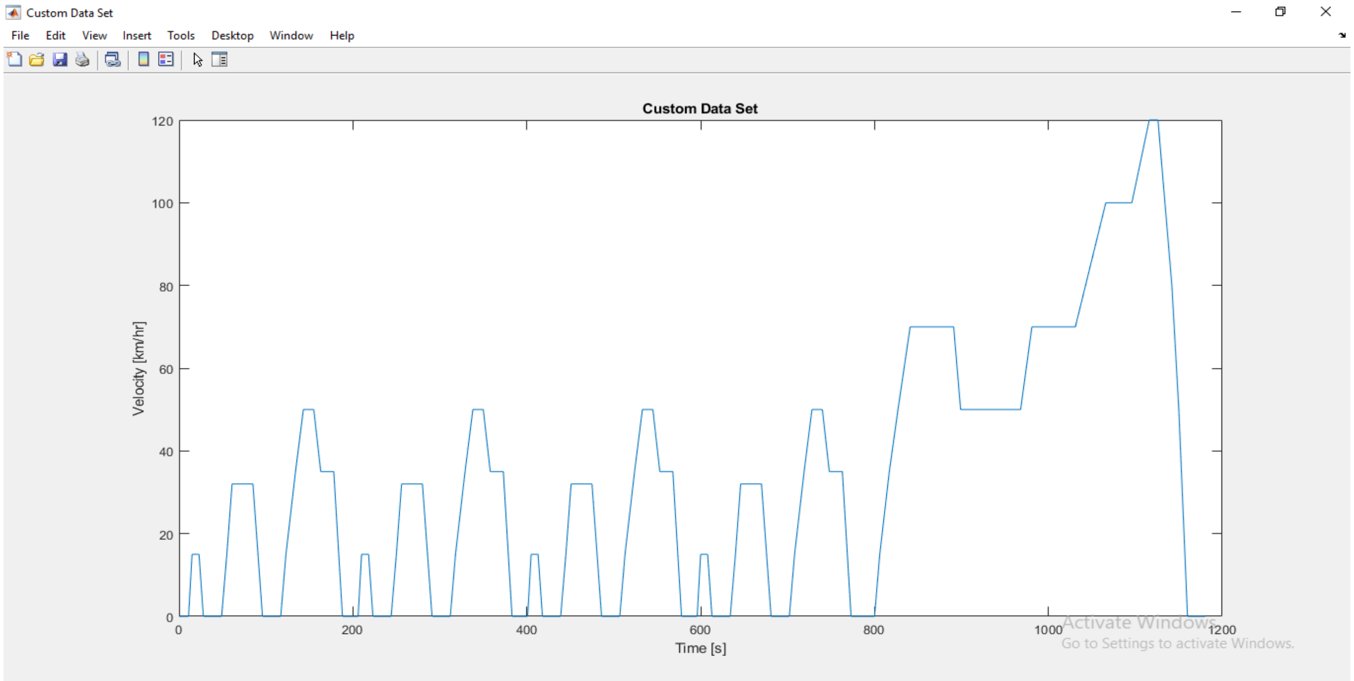
To ensure the battery supplies current as per the requirements of the motor controller and not the rated current, a **Current Sensor & Controlled Current Source** pair is connected.

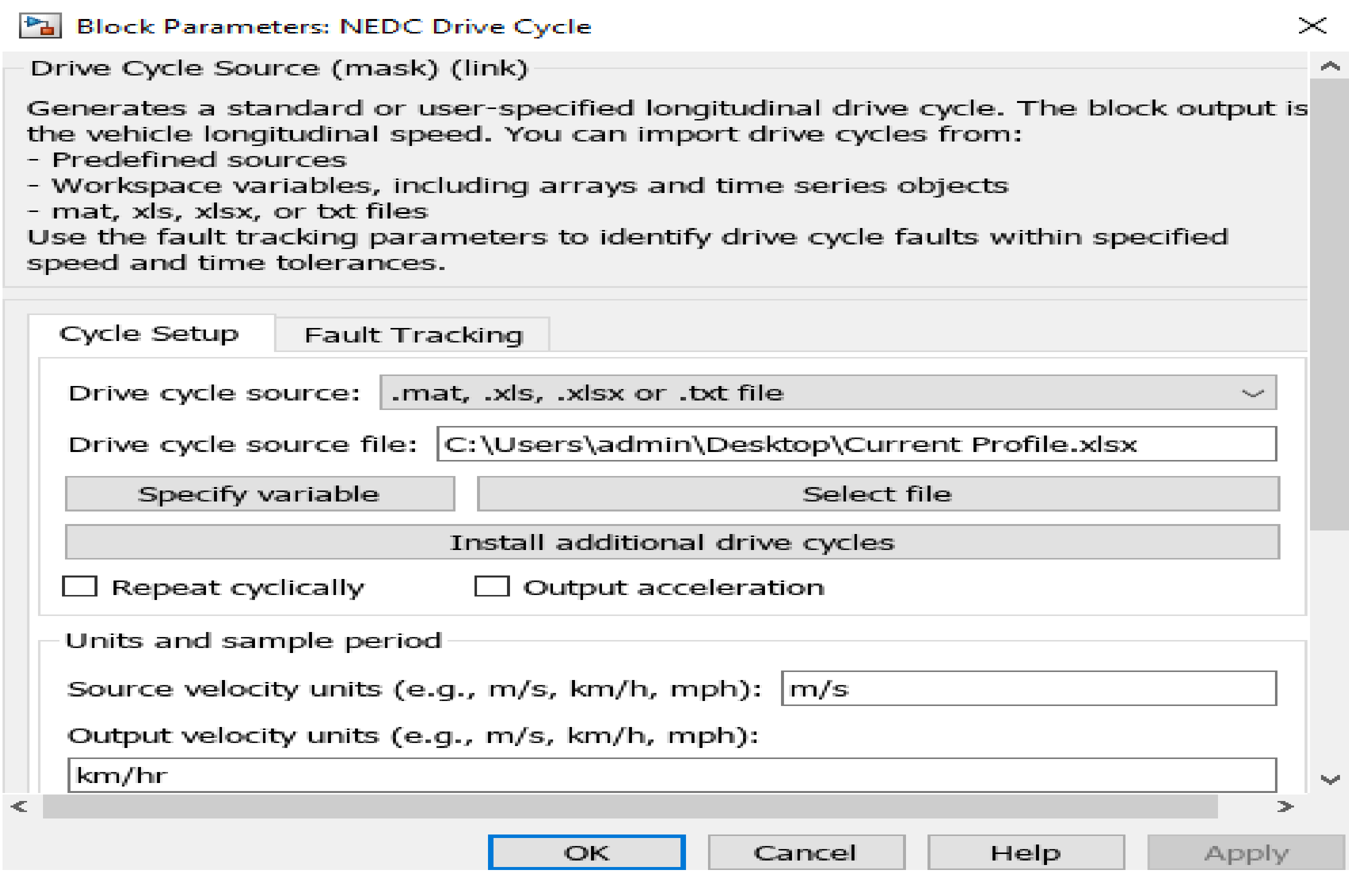
Connections + and - are conserving electrical ports through which the sensor is inserted into the circuit. Connection I is a physical signal port that outputs current value.



<u>Reference Velocity (NEDC Drive Cycle):</u>

The Drive Cycle Source block is used to provide the reference speed for the simulation. It generates a standard or user-specified longitudinal drive cycle.


Custom Data Set
File Edit View Insert Tools Desktop Window Help
Custom Data Set
Velocity [km/hr]
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200
Time [s]
Activate Windows
Go to Settings to activate Windows.

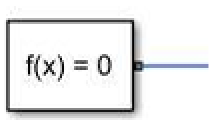

Block Parameters: NEDC Drive Cycle
Drive Cycle Source (mask) (link)
Generates a standard or user-specified longitudinal drive cycle. The block output is the vehicle longitudinal speed. You can import drive cycles from:
- Predefined sources
- Workspace variables, including arrays and time series objects
- mat, xls, xlsx, or txt files
Use the fault tracking parameters to identify drive cycle faults within specified speed and time tolerances.
Cycle Setup
Fault Tracking
Drive cycle source:
.mat, .xls, .xlsx or .txt file
Drive cycle source file:
C:\Users\admin\Desktop\Current Profile.xlsx
Specify variable
Select file
Install additional drive cycles
Repeat cyclically
Output acceleration
Units and sample period
Source velocity units (e.g., m/s, km/h, mph):
m/s
Output velocity units (e.g., m/s, km/h, mph):
km/hr
OK
Cancel
Help
Apply

Power GUI block:

The block should be named 'powergui' and should be located at the highest level of your diagram where Sims cape Electrical Specialized Power Systems blocks are found.

Simulation:

The system is running for simulation for **1180 s** which is the total time for which the input drive cycle is defined.



A **Solver Configuration** is added to ensure proper solving of the mathematical equations by the model.

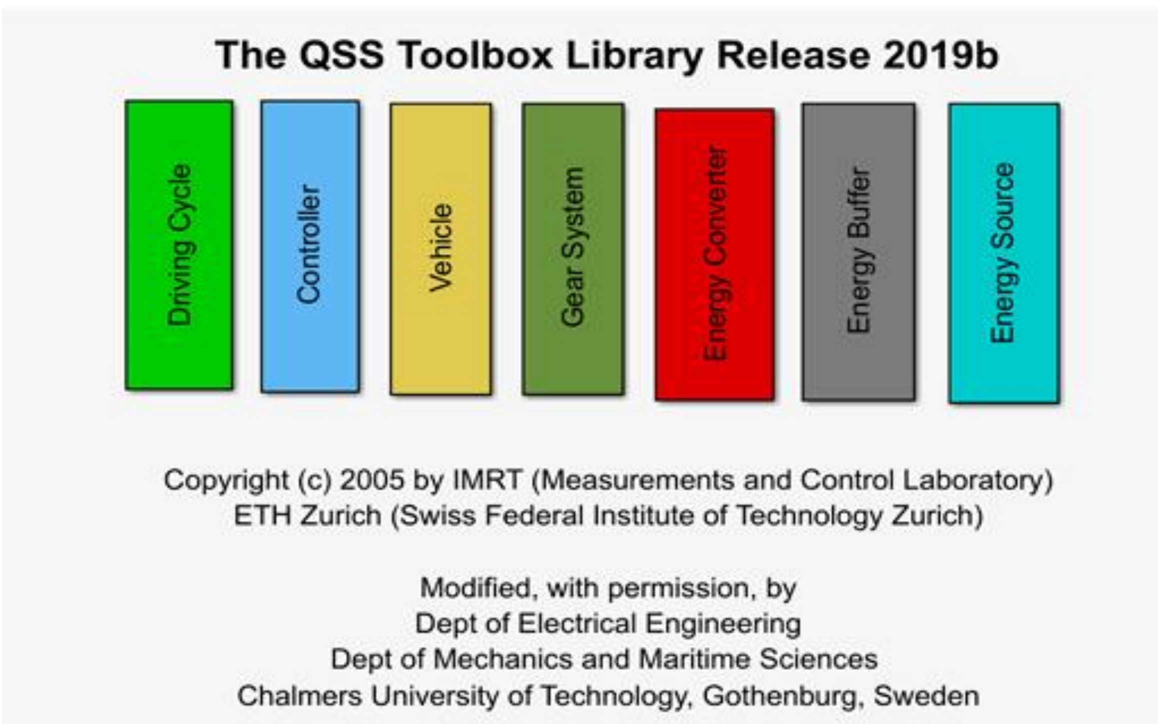
Scopes are connected to analyze different outputs such as the SOC of the battery, the reference velocity & the actual velocity of the vehicle and the distance covered by the vehicle during the total run.

The 2 velocities are first converted from **m/s to kmph** values. For this, simple Gain blocks are used. The distance is calculated by simply time-integration of the vehicle velocity.

EV Modeling Using QSS TOOLBOX

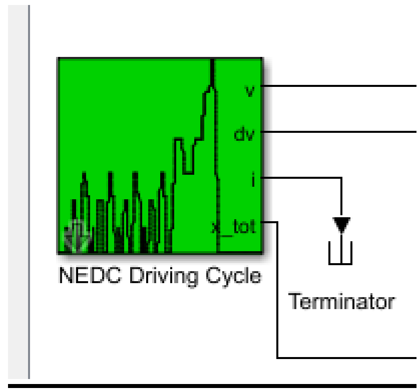
The QSS Toolbox (Quantized State Systems Toolbox) in MATLAB is a tool for simulating systems in a smarter, event-driven way. Instead of continuously calculating every little change, it only updates when something significant happens, like a key state crossing a set threshold. This makes it perfect for electric vehicles (EVs), where you often deal with sudden changes—like switching between regenerative braking and acceleration or managing quick shifts in power.

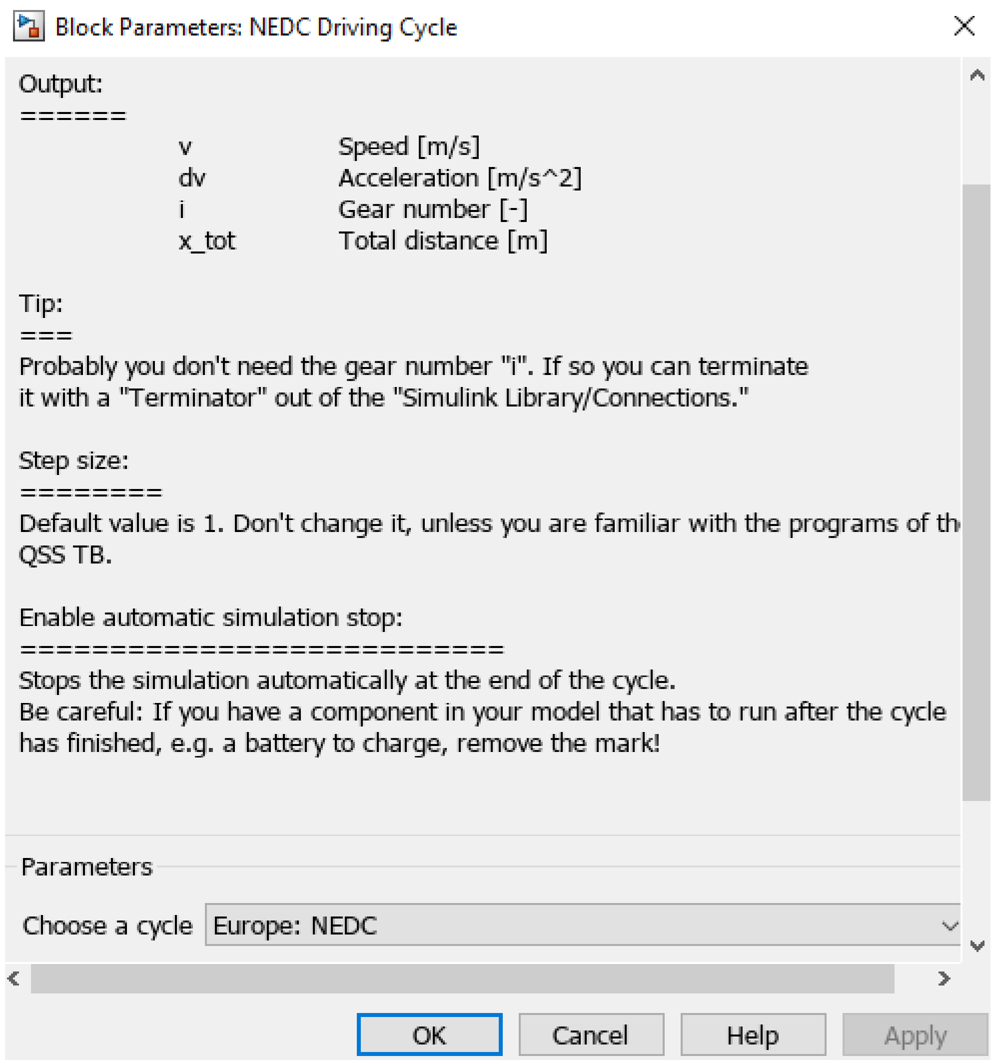
By focusing on important events, the QSS Toolbox keeps simulations efficient, saving time and resources, while still accurately capturing critical behaviors. It's a great fit for dynamic systems where precision matters but you don't want the heavy computational load of traditional methods.



Drive Cycle Block:

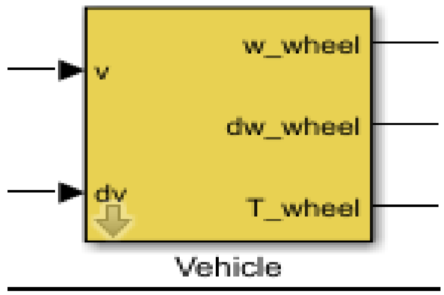
Here is insertion of drive cycle and specified it as NEDC driving cycle.

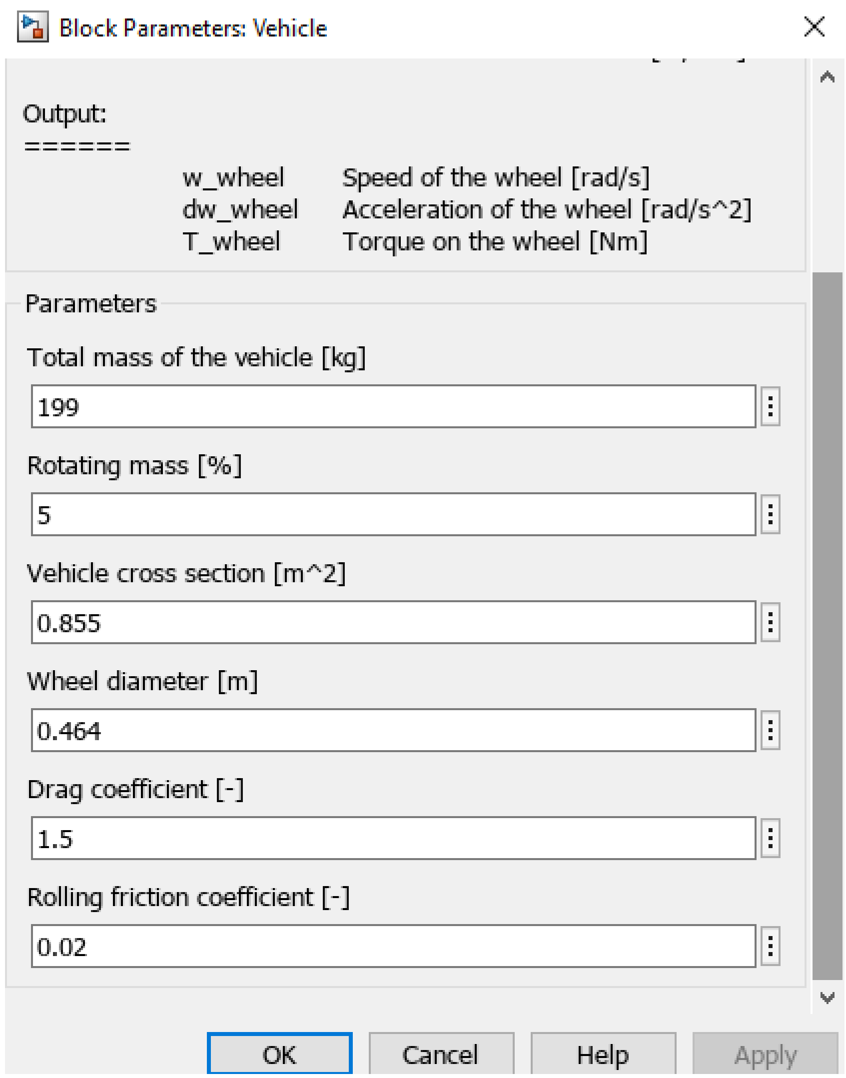




Vehicle Block:

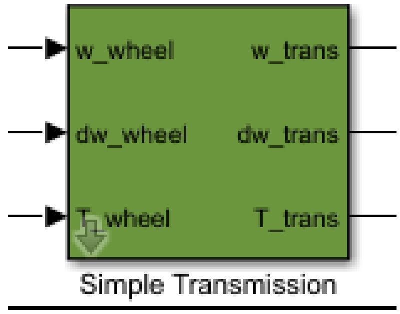
Here is insertion of Vehicle Block and specified it as per mentioned table.

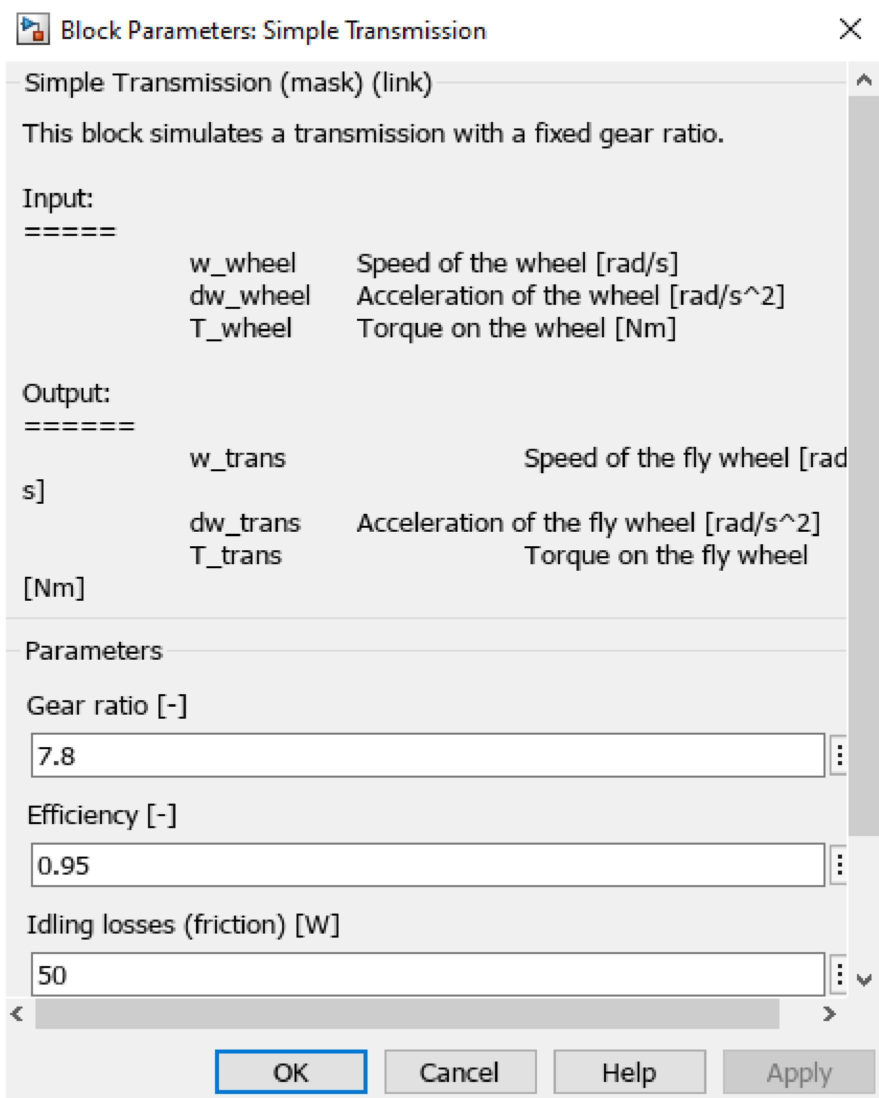




Simple Transmission Block:

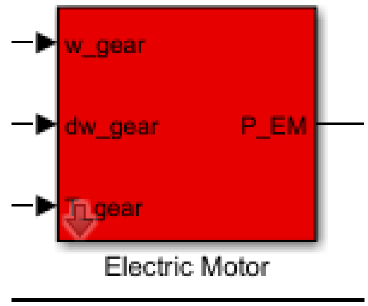
Here is insertion of Simple Transmission Block and specified it as per mentioned table.

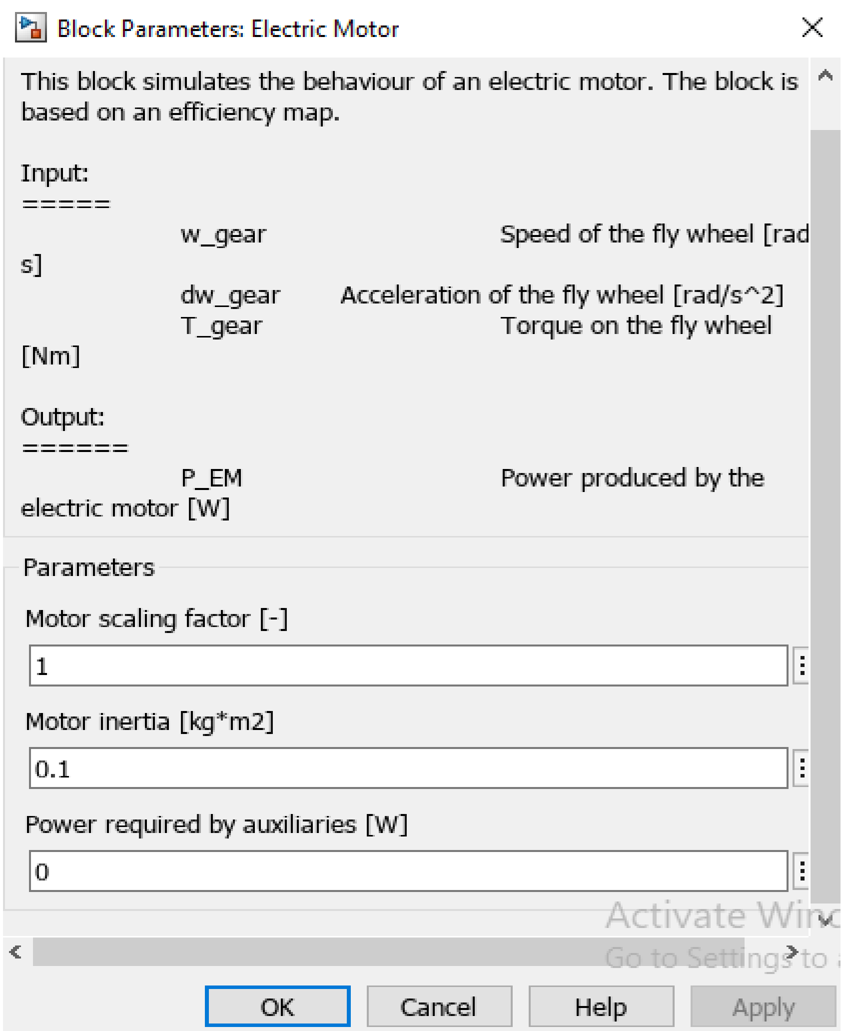




Electric Motor Block:

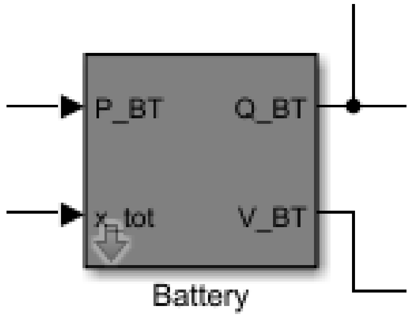
Here is insertion of Electric Motor Block and specified it as per mentioned table.

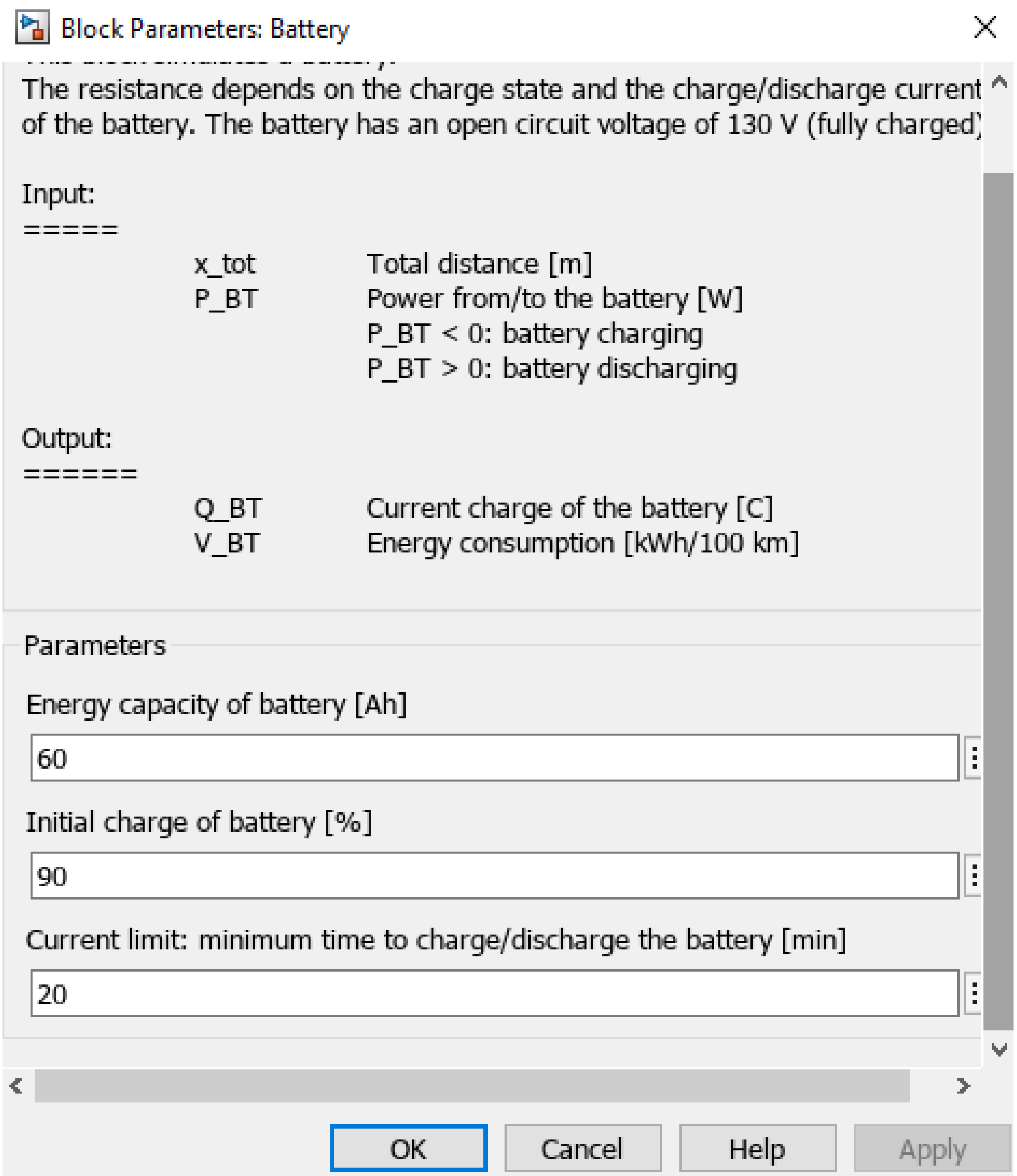




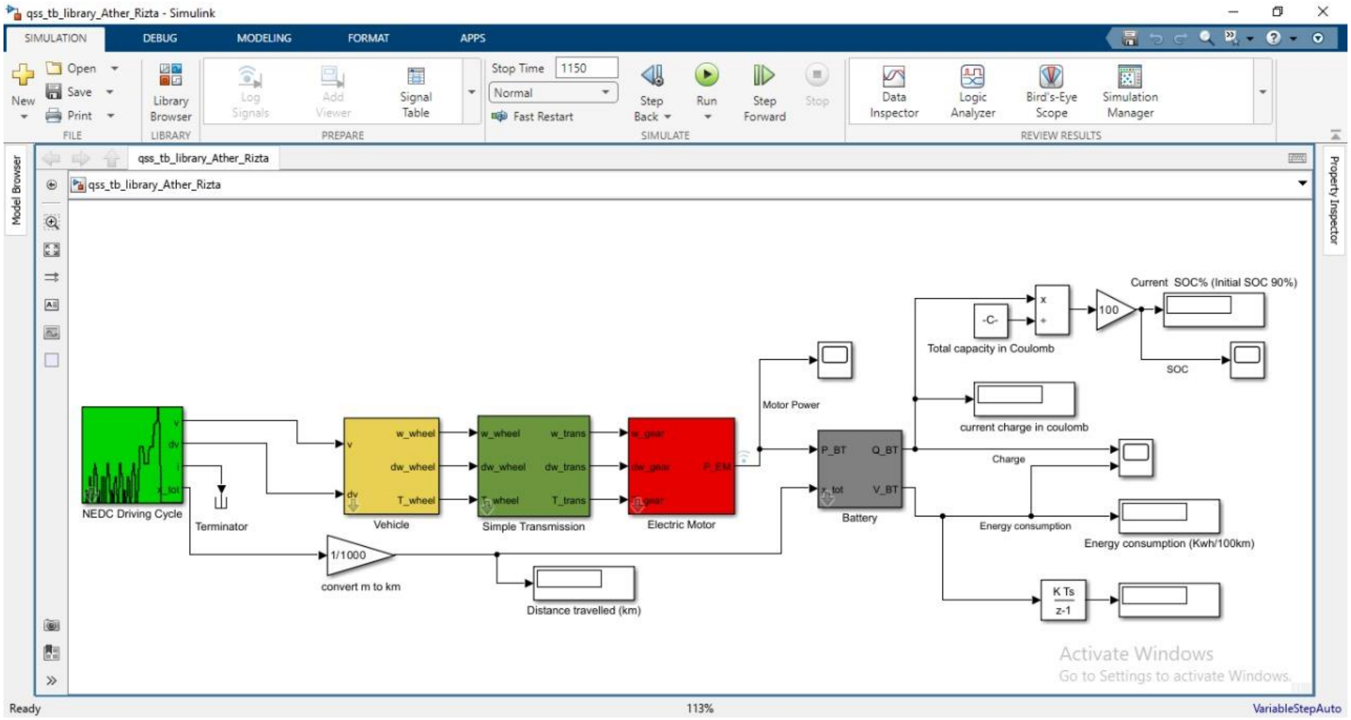
Battery Block:

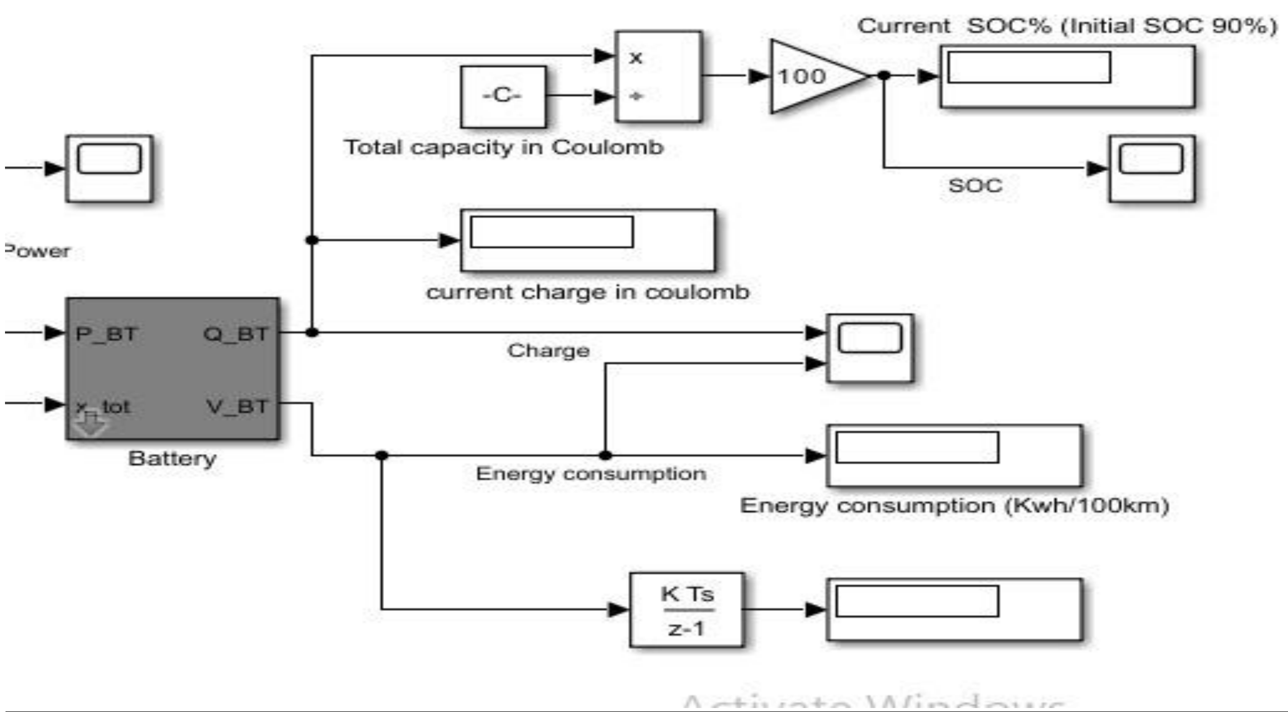
Here is insertion of Battery Block and specified it as per mentioned table.





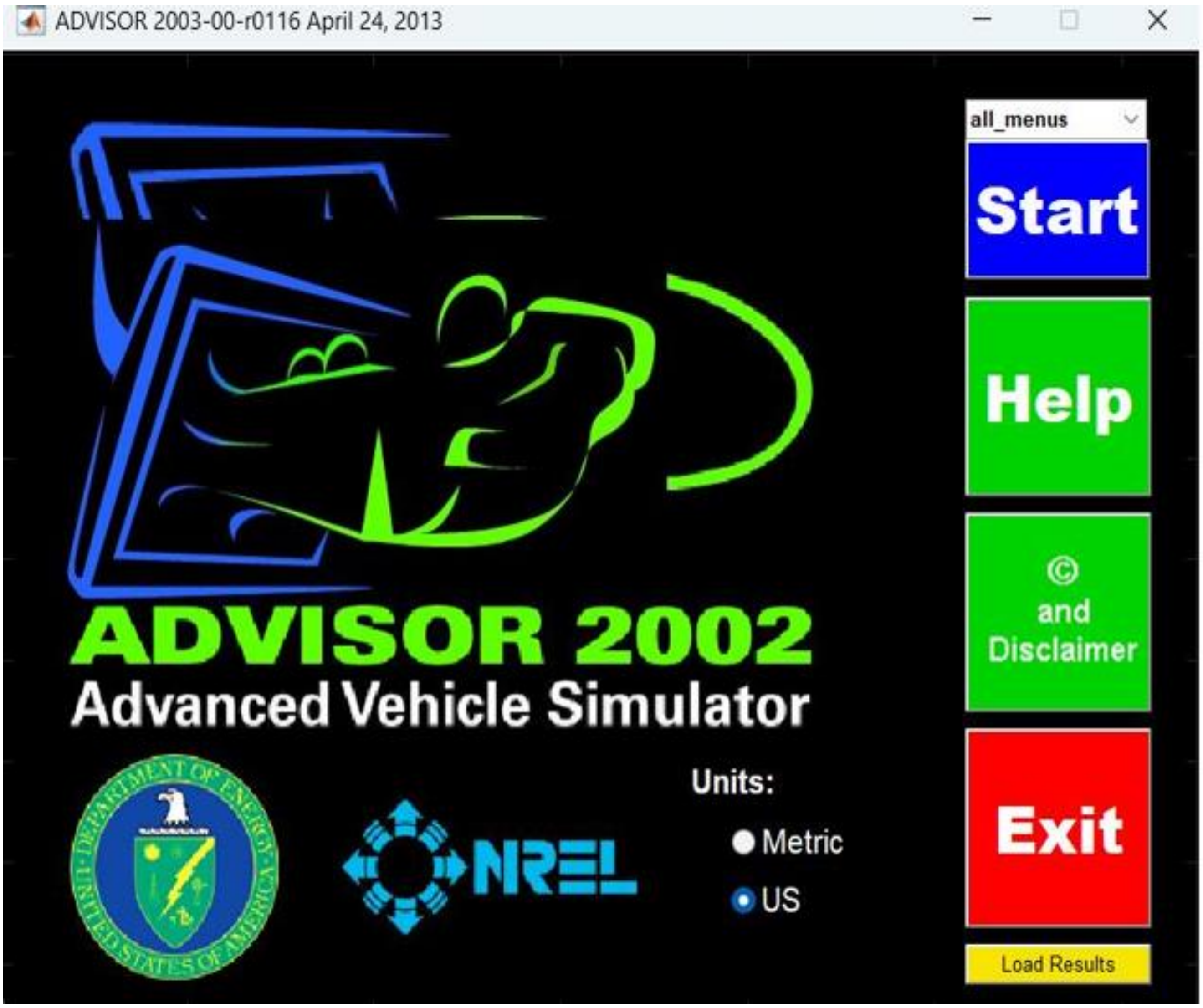
EV MODELING IN MATLAB USING QSS TOOLBOX:



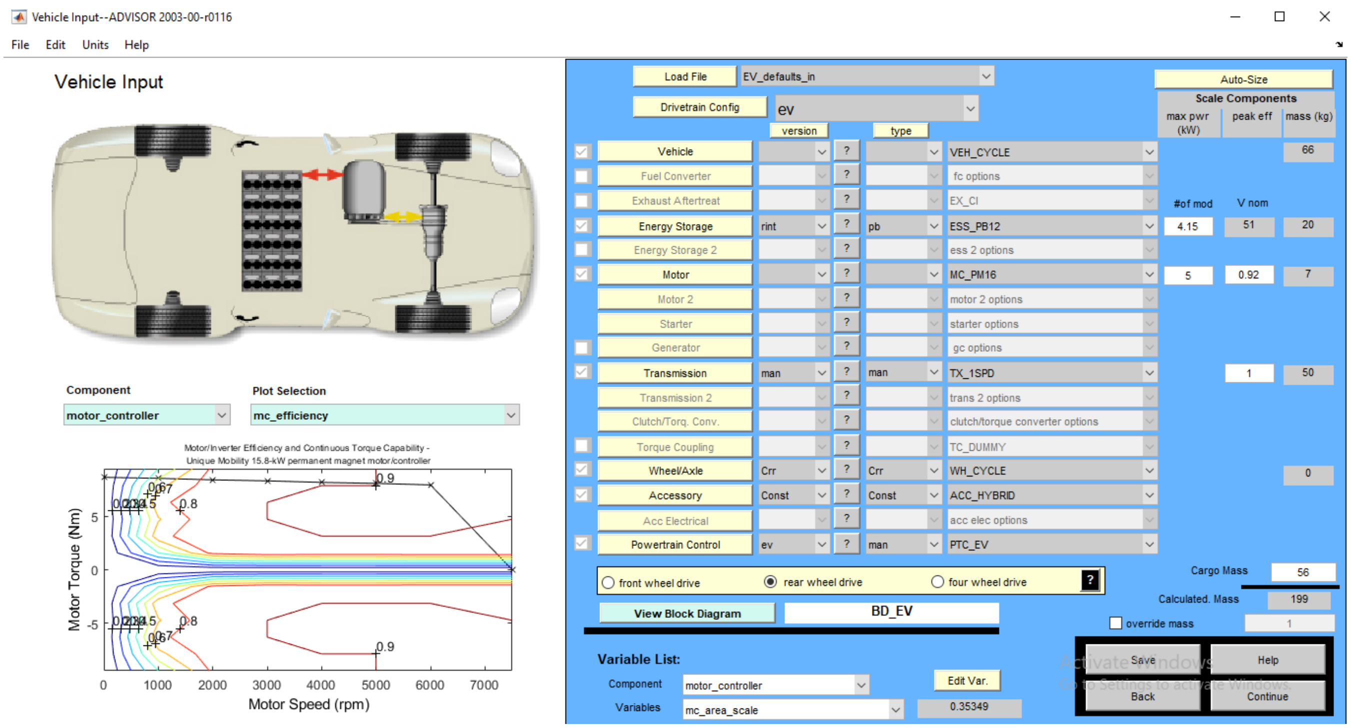


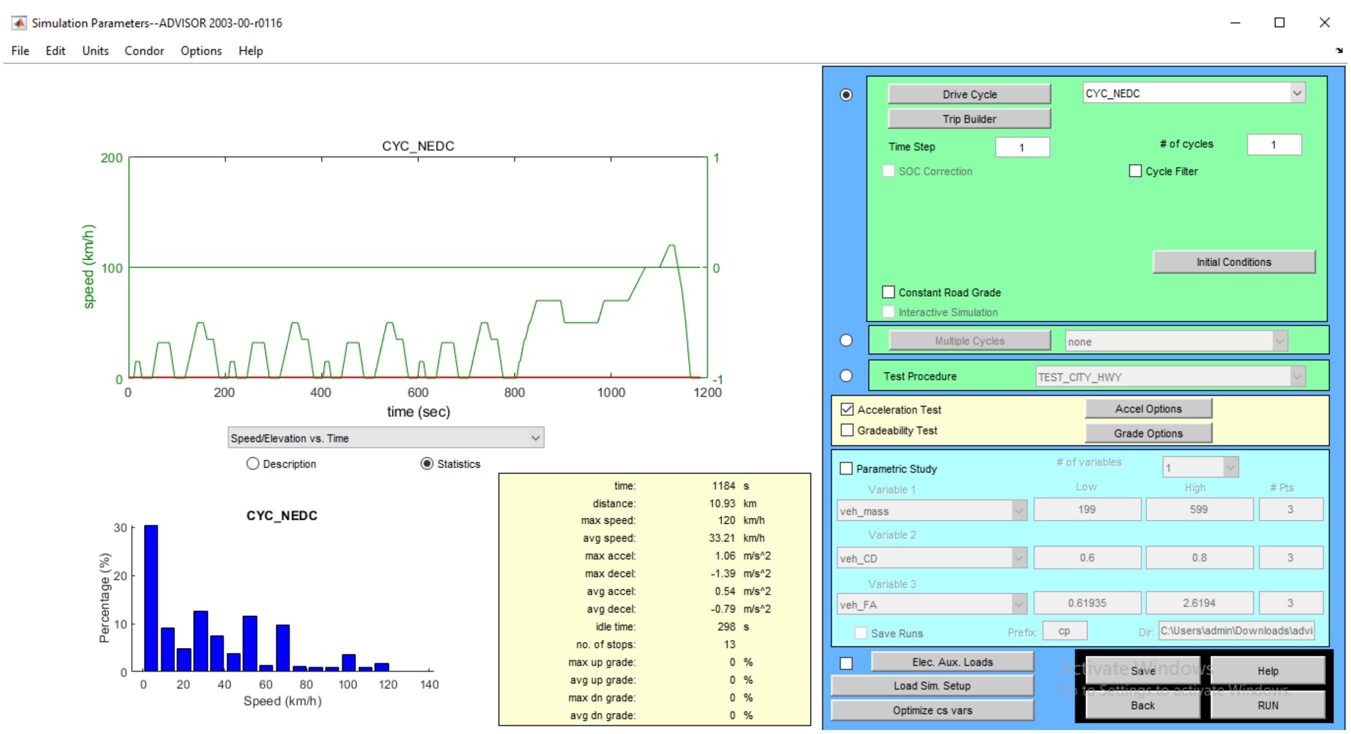
EV Modeling Using ADVISOR TOOLBOX

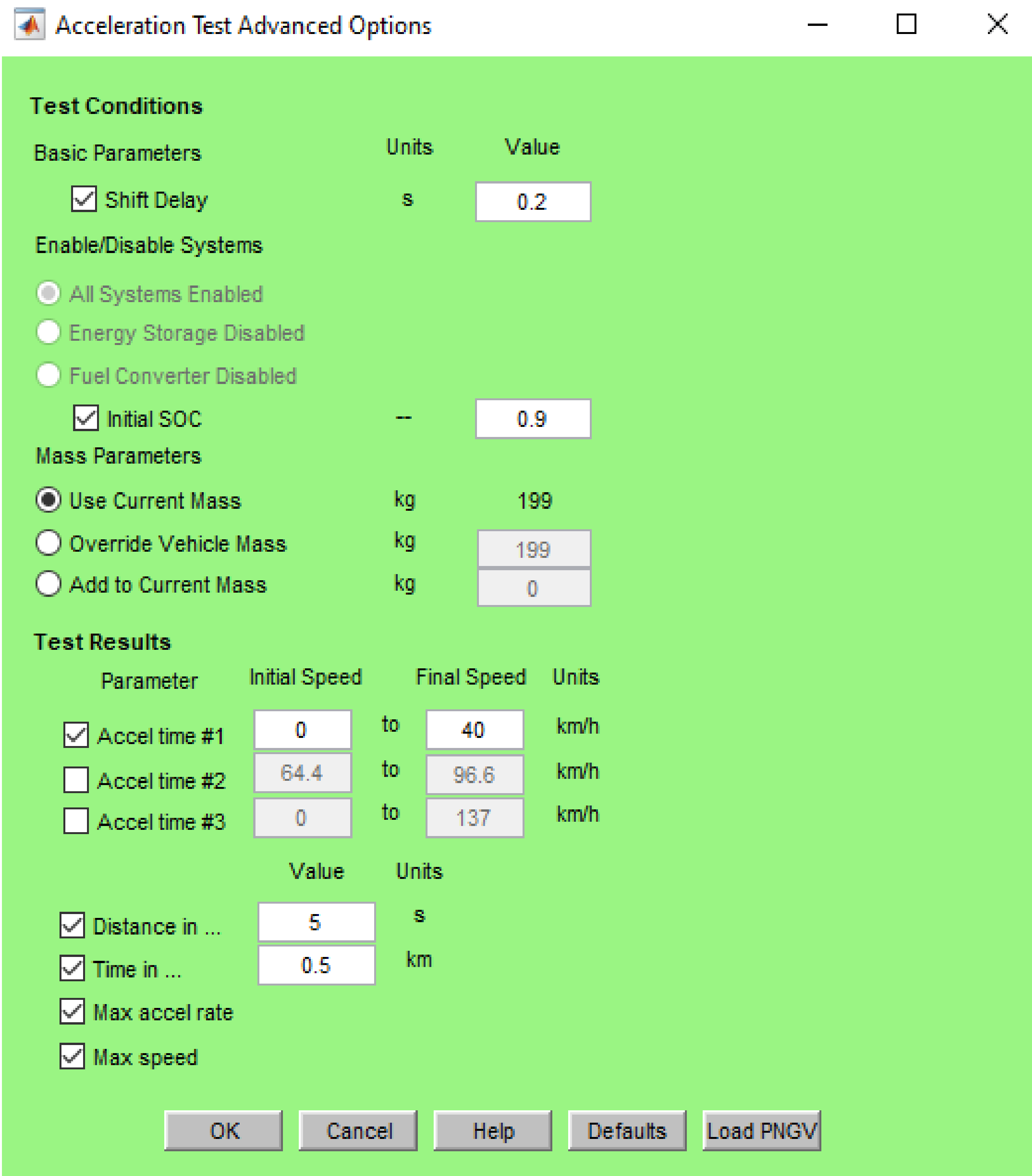
The ADVISOR (Advanced Vehicle Simulator) Toolbox is a tool built for MATLAB and Simulink that helps engineers quickly design and analyze different types of vehicles, such as electric cars, hybrids, and traditional gas-powered vehicles. It comes with ready-made templates and components, so users don't have to create models from the ground up. This makes it easier to test and improve vehicle performance efficiently.



Only the vehicle's dimensional and mechanical performance parametric values and drive cycle of NEDC are given as an input, rest all the electrical parameters are kept constant.


Vehicle Input--ADVISOR 2003-00-r0116
File Edit Units Help
Vehicle Input
Component
motor_controller
Plot Selection
mc_efficiency
Motor/Inverter Efficiency and Continuous Torque Capability - Unique Mobility 15.8-kW permanent magnet motor/controller
Motor Torque (Nm)
Motor Speed (rpm)
Load File
EV_defaults_in
Drivetrain Config
ev
version
type
Auto-Size
Scale Components
max pwr (kW)
peak eff
mass (kg)
Vehicle
VEH_CYCLE
Fuel Converter
fc options
Exhaust Aftertreat
EX_CI
Energy Storage
rint
pb
ESS_PB12
Energy Storage 2
ess 2 options
Motor
MC_PM16
Motor 2
motor 2 options
Starter
starter options
Generator
gc options
Transmission
man
TX_1SPD
Transmission 2
trans 2 options
Clutch/Torq. Conv.
clutch/torque converter options
Torque Coupling
TC_DUMMY
Wheel/Axle
Crr
WH_CYCLE
Accessory
Const
ACC_HYBRID
Acc Electrical
acc elec options
Powertrain Control
ev
PTC_EV
#of mod
V nom
front wheel drive
rear wheel drive
four wheel drive
View Block Diagram
BD_EV
Cargo Mass
56
Calculated. Mass
199
override mass
Variable List:
Component
motor_controller
Edit Var.
Variables
mc_area_scale
0.35349
Save
Help
Back
Continue

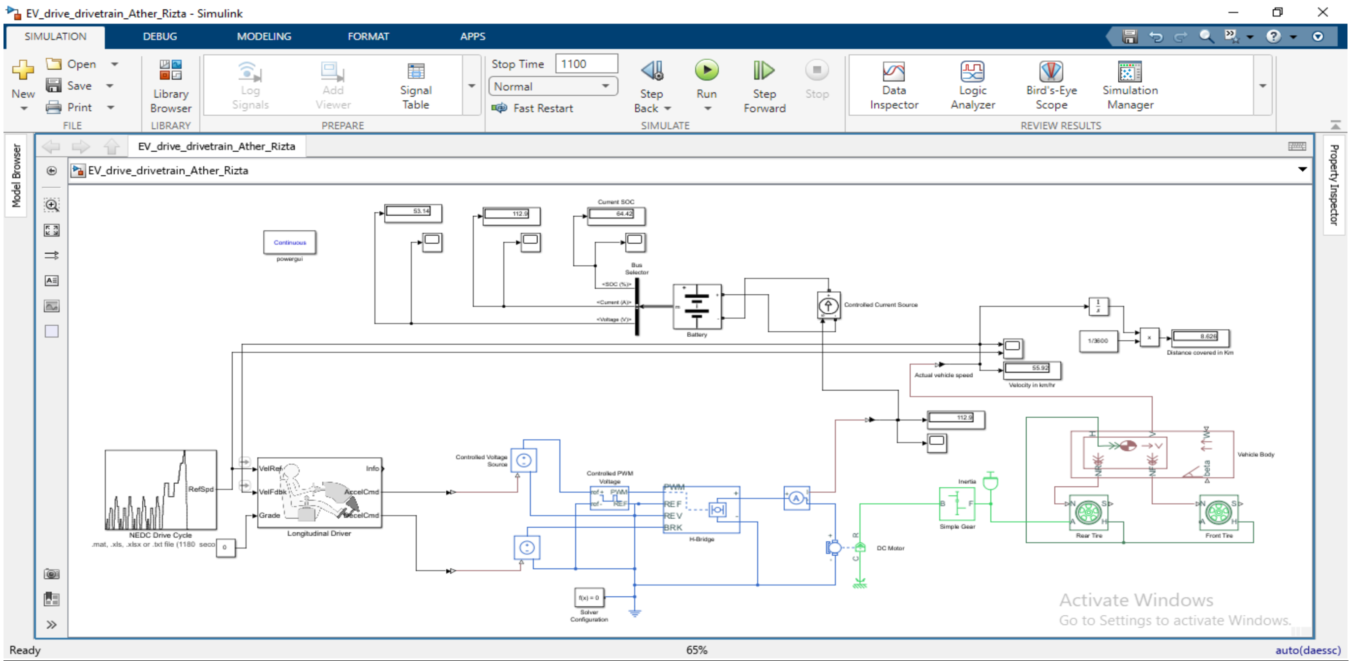

Simulation Parameters--ADVISOR 2003-00-r0116
File Edit Units Condor Options Help
CYC_NEDC
speed (km/h)
time (sec)
Speed/Elevation vs. Time
Description
Statistics
CYC_NEDC
Percentage (%)
Speed (km/h)
time: 1184 s
distance: 10.93 km
max speed: 120 km/h
avg speed: 33.21 km/h
max accel: 1.06 m/s^2
max decel: -1.39 m/s^2
avg accel: 0.54 m/s^2
avg decel: -0.79 m/s^2
idle time: 298 s
no. of stops: 13
max up grade: 0 %
avg up grade: 0 %
max dn grade: 0 %
avg dn grade: 0 %
Drive Cycle
CYC_NEDC
Trip Builder
Time Step
# of cycles
SOC Correction
Cycle Filter
Initial Conditions
Constant Road Grade
Interactive Simulation
Multiple Cycles
none
Test Procedure
TEST_CITY_HWY
Acceleration Test
Accel Options
Gradeability Test
Grade Options
Parametric Study
# of variables
Variable 1
Low
High
Pts
veh_mass
199
599
Variable 2
veh_CD
0.6
0.8
Variable 3
veh_FA
0.61935
2.6194
Save Runs
Prefix
cp
Dir
Elec. Aux. Loads
Load Sim. Setup
Optimize cs vars
Save
Help
Back
RUN

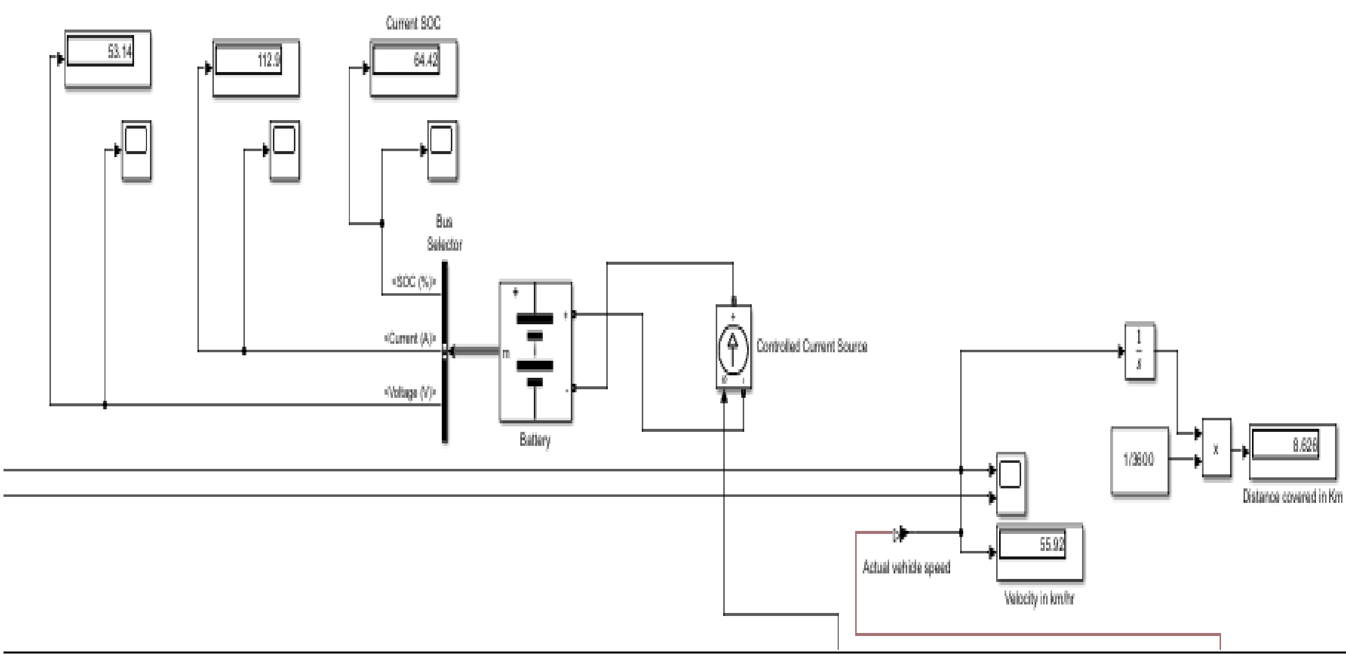

Acceleration Test Advanced Options
Test Conditions
Basic Parameters
Units
Value
Shift Delay
s
0.2
Enable/Disable Systems
All Systems Enabled
Energy Storage Disabled
Fuel Converter Disabled
Initial SOC
--
0.9
Mass Parameters
Use Current Mass
kg
199
Override Vehicle Mass
kg
199
Add to Current Mass
kg
0
Test Results
Parameter
Initial Speed
Final Speed
Units
Accel time #1
0
to
40
km/h
Accel time #2
64.4
to
96.6
km/h
Accel time #3
0
to
137
km/h
Value
Units
Distance in ...
5
s
Time in ...
0.5
km
Max accel rate
Max speed
OK
Cancel
Help
Defaults
Load PNGV

CHAPTER 3

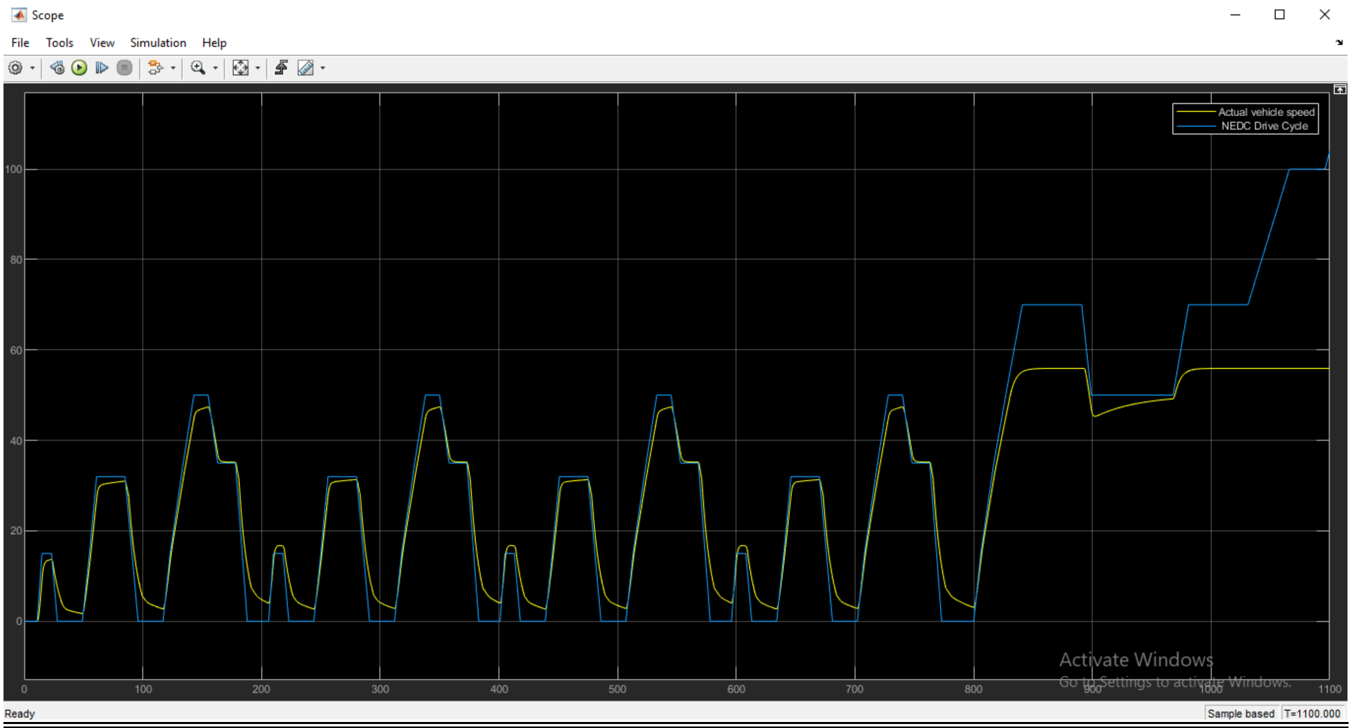
OUTPUT PARAMETERS

SIMULINK MODEL:



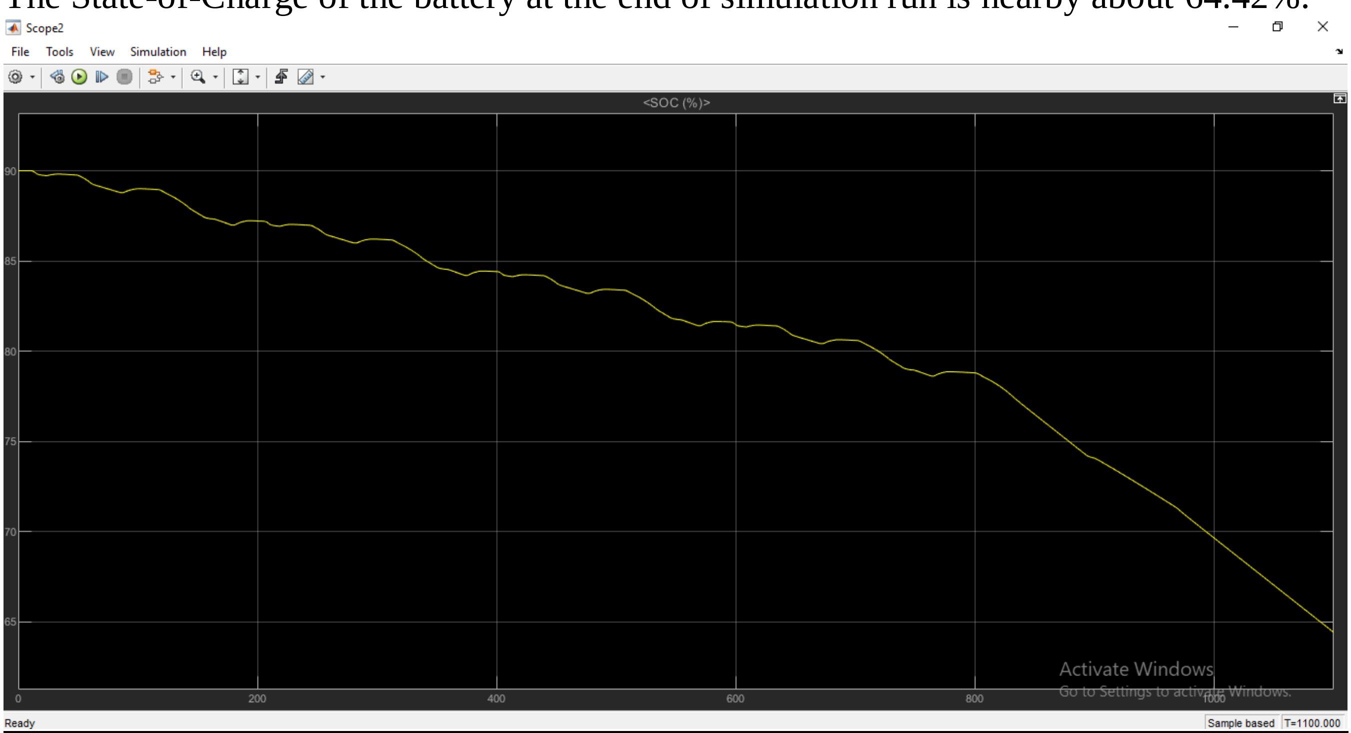


Reference Speed VS Vehicle Speed

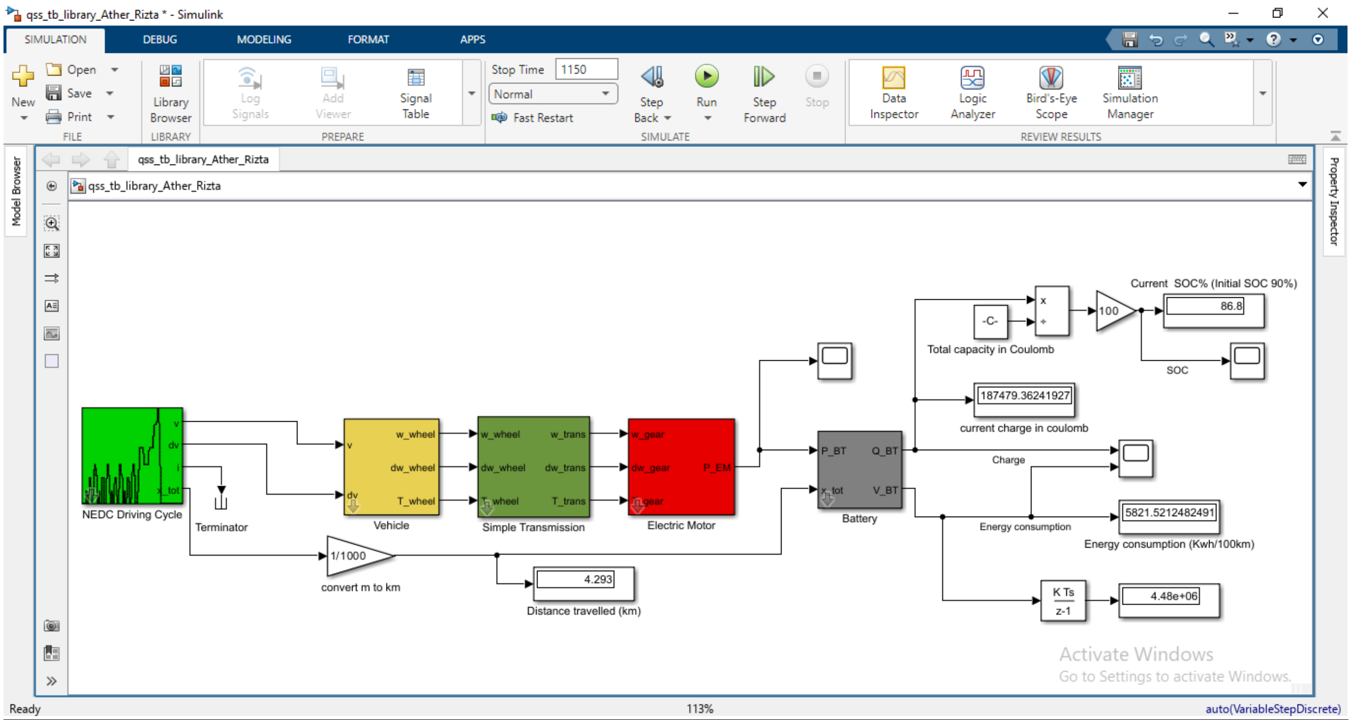


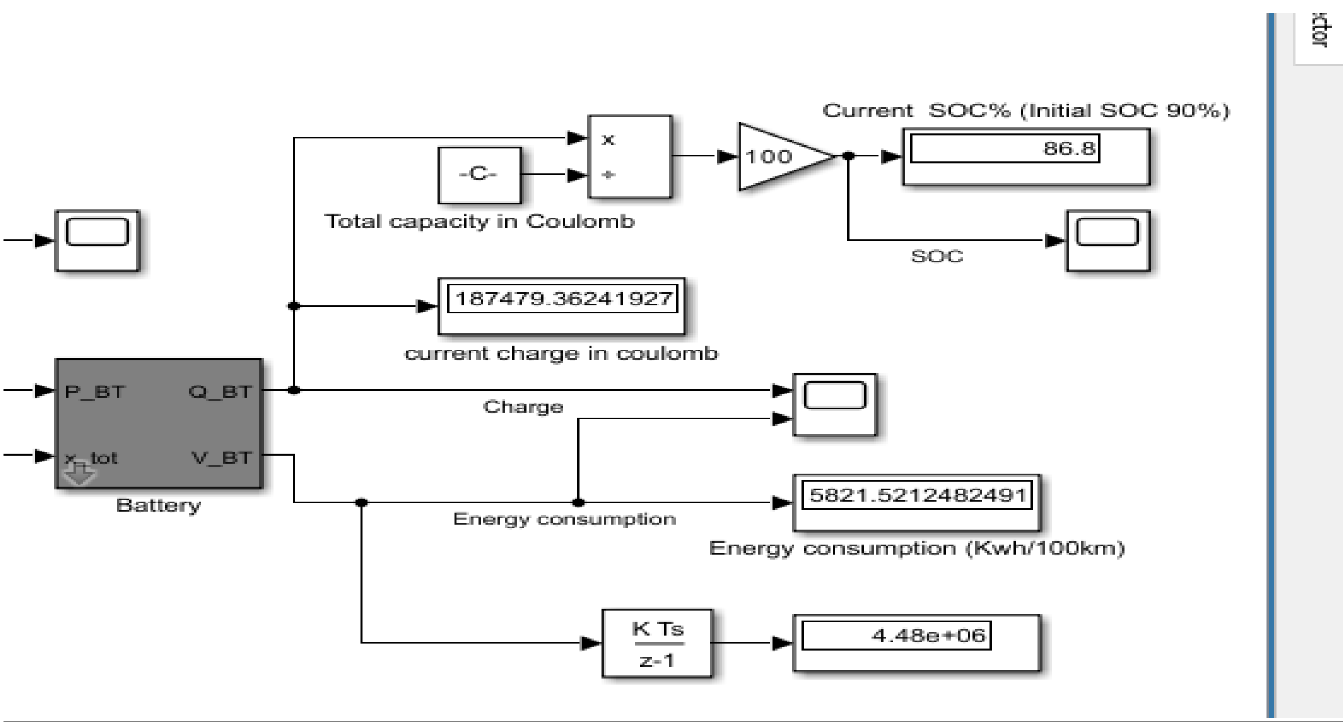
Battery State of Charge (SOC)

The State-of-Charge of the battery at the end of simulation run is nearby about 64.42%.

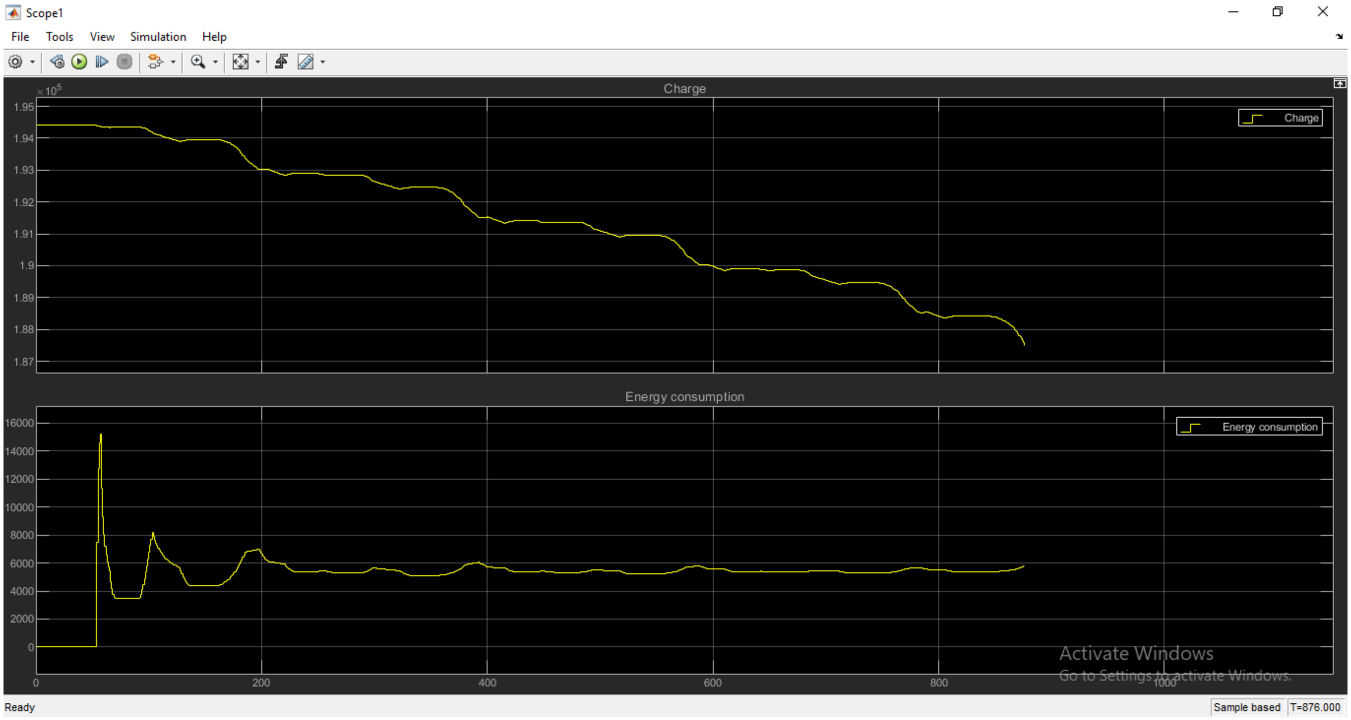


QSS TOOLBOX Model

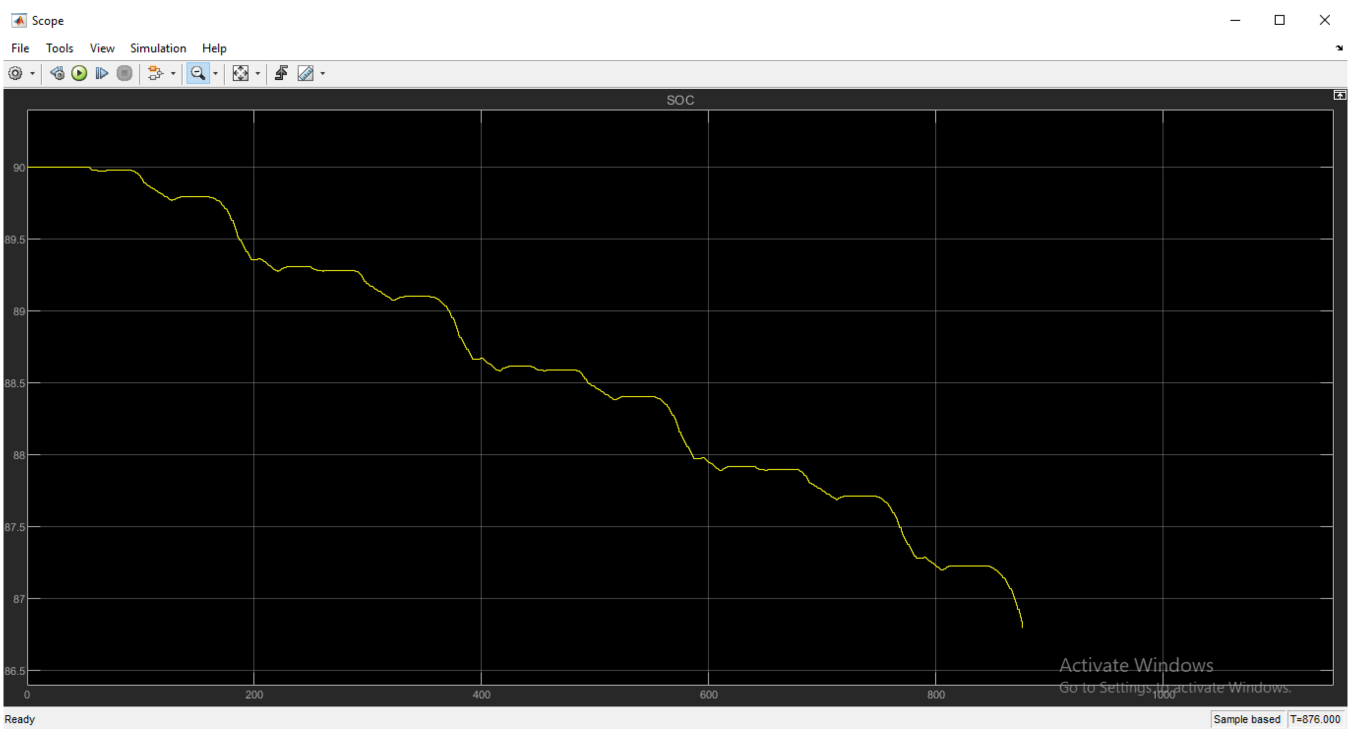




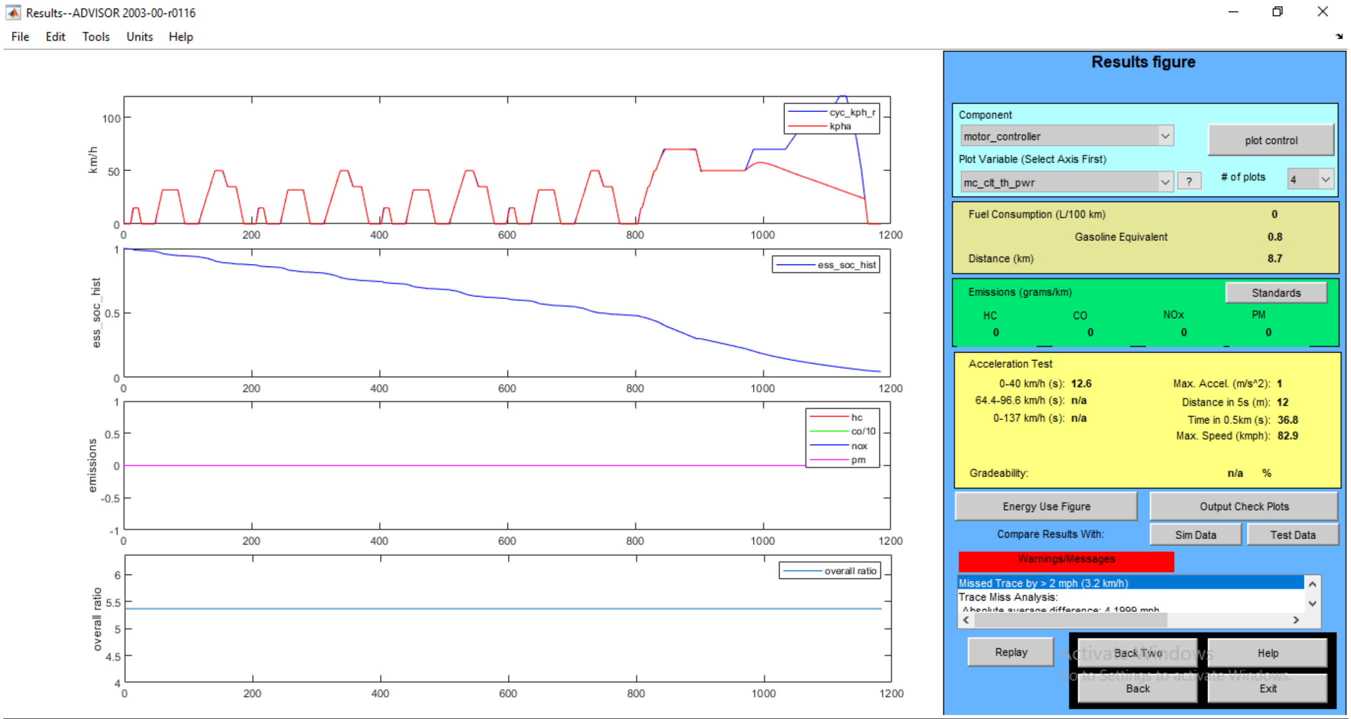
Current Charge & Energy Consumption

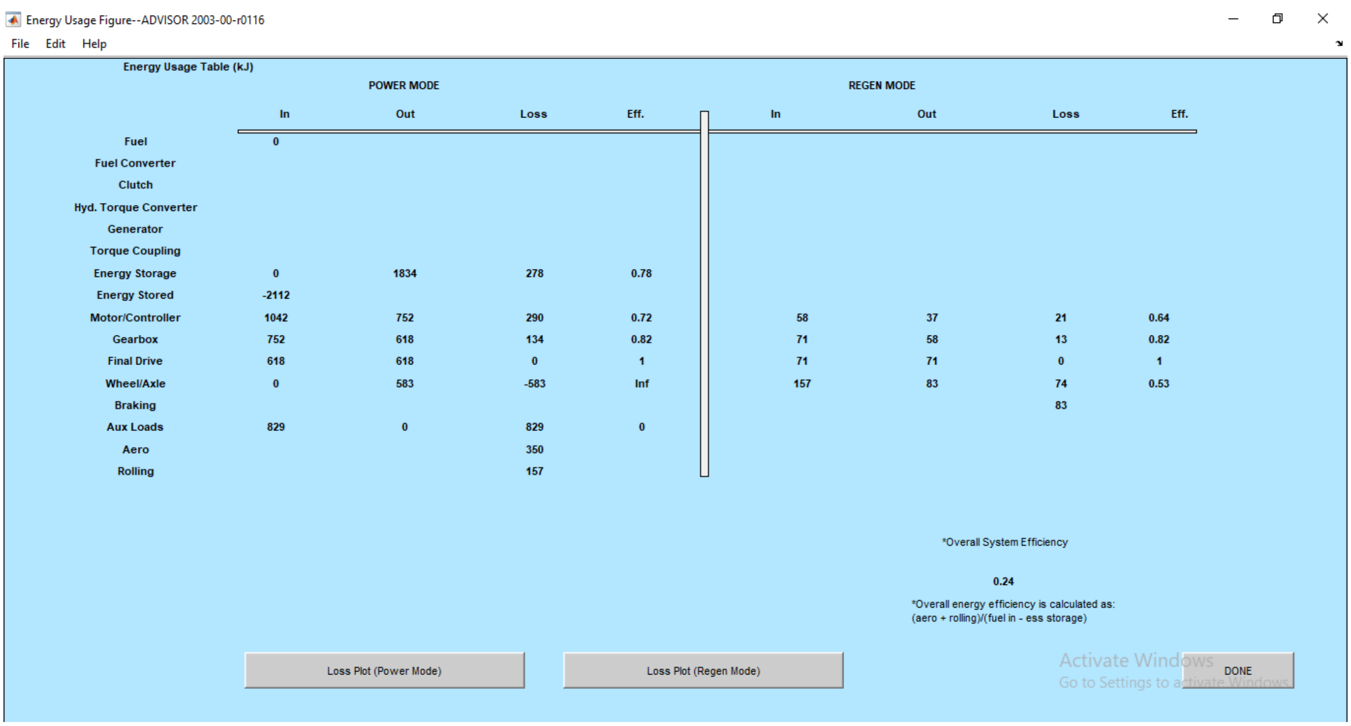


State of Charge



ADVISOR TOOLBOX





	POWER MODE In	POWER MODE Out	POWER MODE Loss	POWER MODE Eff.	REGEN MODE In	REGEN MODE Out	REGEN MODE Loss	REGEN MODE Eff.
Fuel	0							
Fuel Converter								
Clutch								
Hyd. Torque Converter								
Generator								
Torque Coupling								
Energy Storage	0	1834	278	0.78				
Energy Stored	-2112							
Motor/Controller	1042	752	290	0.72	58	37	21	0.64
Gearbox	752	618	134	0.82	71	58	13	0.82
Final Drive	618	618	0	1	71	71	0	1
Wheel/Axle	0	583	-583	Inf	157	83	74	0.53
Braking							83	
Aux Loads	829	0	829	0				
Aero			350					
Rolling			157					

*Overall System Efficiency

0.24

*Overall energy efficiency is calculated as:
(aero + rolling)/(fuel in - ess storage)

Loss Plot (Power Mode) | Loss Plot (Regen Mode) | DONE

CHAPTER 4

RESULTS AND CONCLUSIONS

	Simulink Model	QSS toolbox	ADVISOR toolbox
SOC%	64.42	86.8	~10
Distance (km)	8.626	4.293	8.7
Benefits	It provides an all-in-one graphical interface with a wide range of blocks and toolboxes, making it easy to create customized and complex models. It enables precise dynamic simulations, including advanced control strategies, detailed battery modelling, and thermal management systems. It works directly with MATLAB, so you can use MATLAB scripts, control algorithms, and data processing tools in your simulations. Useful for real time applications hardware-in-loop (HIL) testing and control system environment.	It focuses on steady-state modelling, which is simpler to set up and needs fewer parameters compared to full dynamic simulations. Since it only simulates steady state conditions, it uses less computing power, making simulations faster and ideal for early feasibility studies. It works well for estimating energy consumption and ranges using steady state driving cycles, without requiring complex dynamic models.	It offers a library of pre-built vehicle components and configurations, making it easier to set up simulations. It's user-friendly for powertrain analysis and fuel economy studies, needing minimal customization and specific knowledge. Contains pre-configured models for battery and motor simulations, making it efficient for analyzing the energy consumption and performance of electric vehicles.

Drawbacks	It requires a solid understanding of control systems, along with Simulink blocks and occasional MATLAB coding for complex models. High-fidelity models can be computationally intensive, potentially slowing down simulations, especially on less powerful computers. MATLAB Simulink and its toolboxes are proprietary and may be expensive, especially if multiple toolboxes are needed for specific functionality.	It has limited dynamic response, making it less suitable for time-based analysis, control strategy testing, or handling transient effects crucial for control system development. Since it relies on simpler standard models, there's reduced flexibility for custom component modelling or adding detailed subsystems like thermal management.	Being an older tool, may not have latest features for modern electric vehicles and lacks support for some newer technologies. It may be challenging to introduce custom models or detailed subsystem analysis beyond the existing template structure, reducing flexibility for noval applications. This toolbox is not optimized for real time or HIL applications, as it was primarily designed for powertrain analysis and feasibility studies.