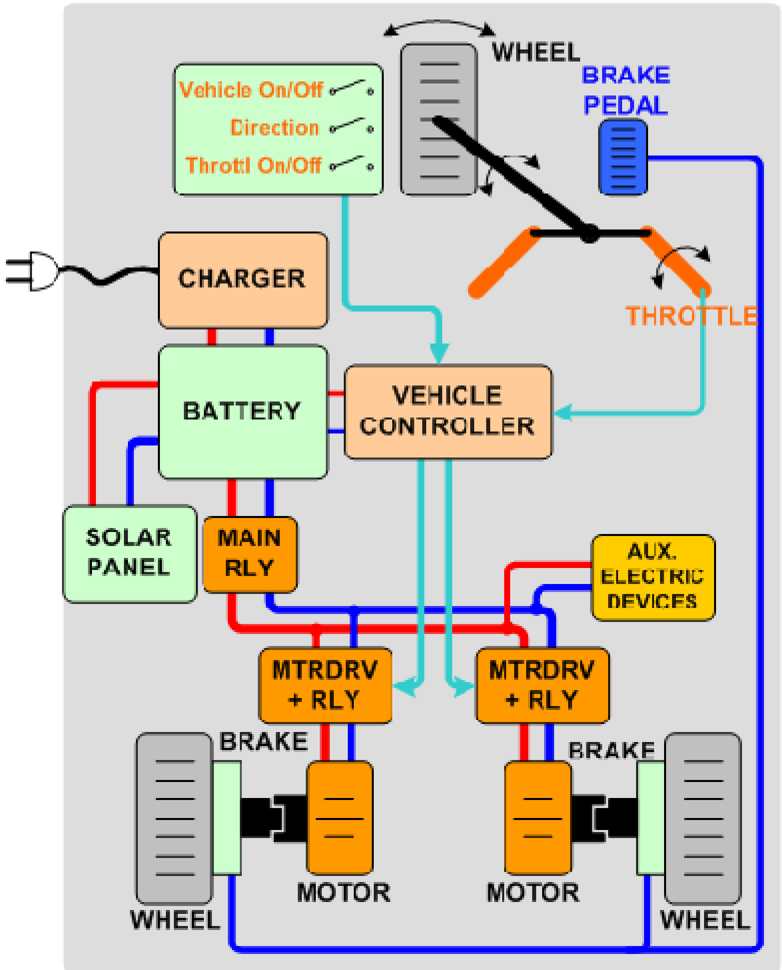
1.Title – MATLAB model of an electric rickshaw.

2.Objective –

- To design MATLAB model of an electric rickshaw and Perform simulation.
- To find energy consumption of three different standard driving cycle and find temperature rise of motor at given condition.
- Analyse the plots and make statements.

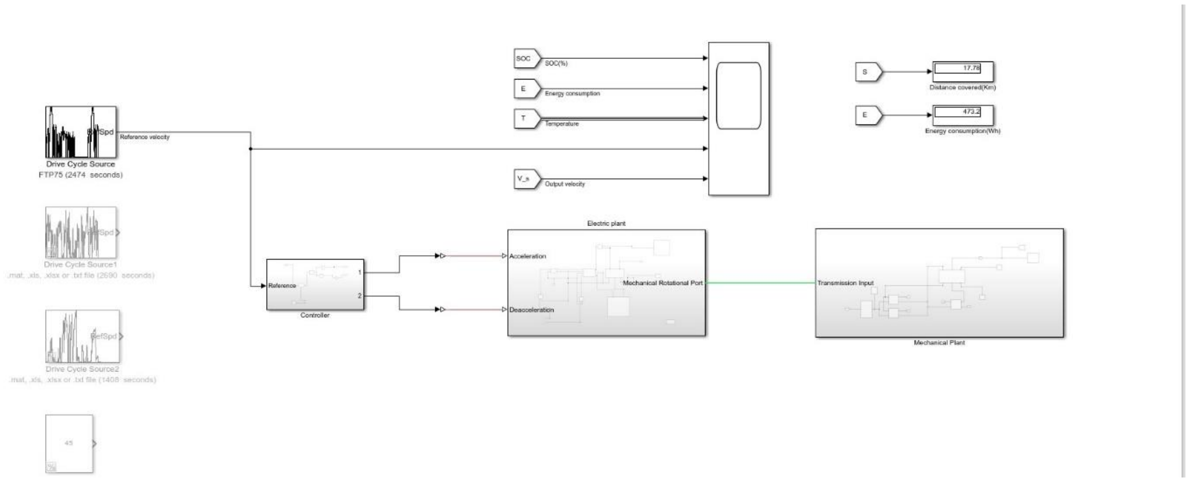
3. Introduction –

E-Rickshaw is a three wheeled, small vehicle operated by battery. E-rickshaws have emerged in the public sector in India owing to comfortable and economic mode of transport they provide to commuters. These vehicles generally propelled with brushless DC motor with lead-acid batteries. Generally, DC motor produces around 1KW power to propel and e-rickshaw can achieve 25Km/h-45Km/h maximum speed. E-rickshaws are environment friendly and have potential to reduce carbon foot-print due to passenger transport activities. Main components of E-rickshaw are – motor, inverter controller and auxiliaries.

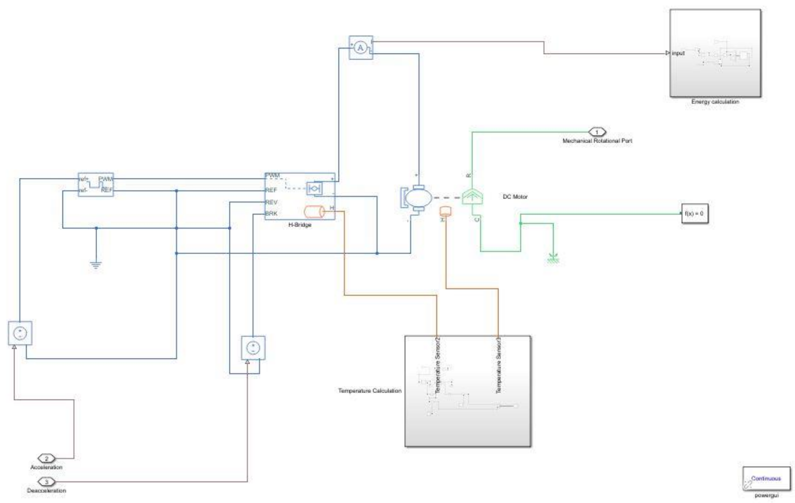


4. Description –

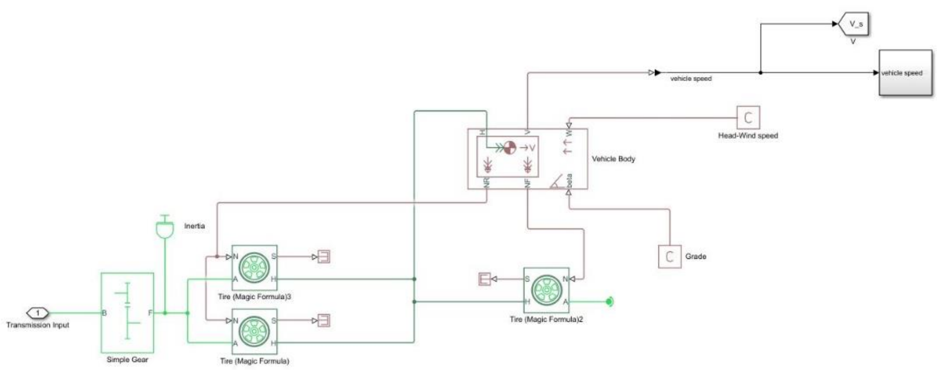
Modelling is a procedure to represent something, mostly using a computer software. Modelling saves plenty of time and cost to conduct experiment on real world system. In this project we are going to model e-rickshaw using Simulink and will perform simulation to find energy consumption and temperature rise for different driving cycle.



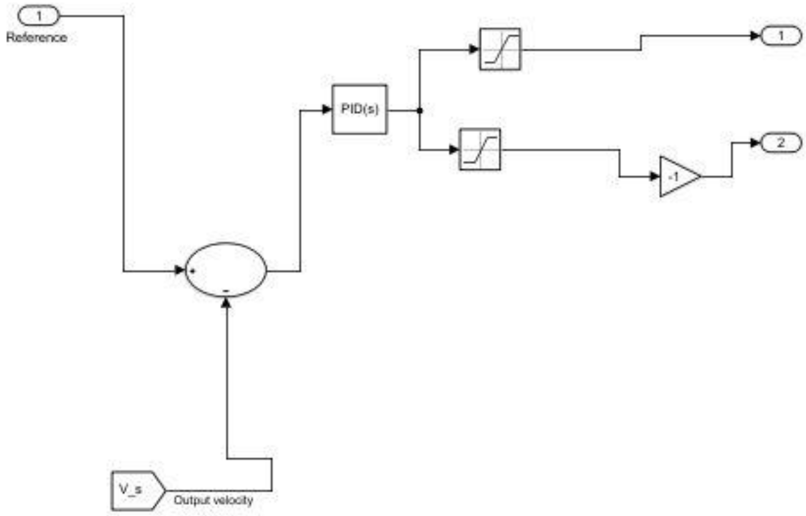
Electric plant -



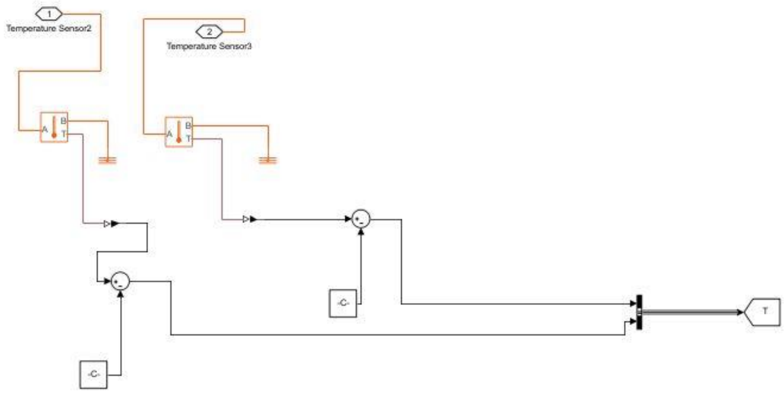
Mechanical plant -



Controller -

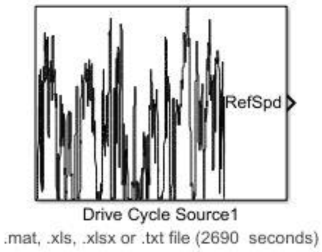


Temperature Measurement -

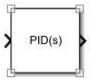


Blocks used –

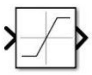
Drive cycle source – it generates standard or specified longitudinal drive cycle. .xls and .txt files can be imported directly. In this project we are going to use three standard drive cycle – FTP75, Indian urban drive cycle and west Virginia drive cycle and a constant velocity source to provide reference velocity.



PID controller – this block implements PID controller. It can be selected for continuous or discrete system. In this project we are going to give different PI values and set output velocity near to reference velocity.

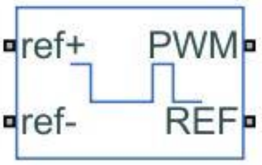


Saturation – the saturation block produces bounded values which is specified with upper and lower limit in block itself. Saturation will be fed with the signal which is directly coming from PID block. We are going to use two saturation block, one will produce acceleration signal and other will be gained with -1 value to produce deacceleration signal.

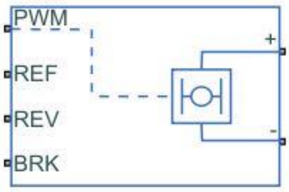


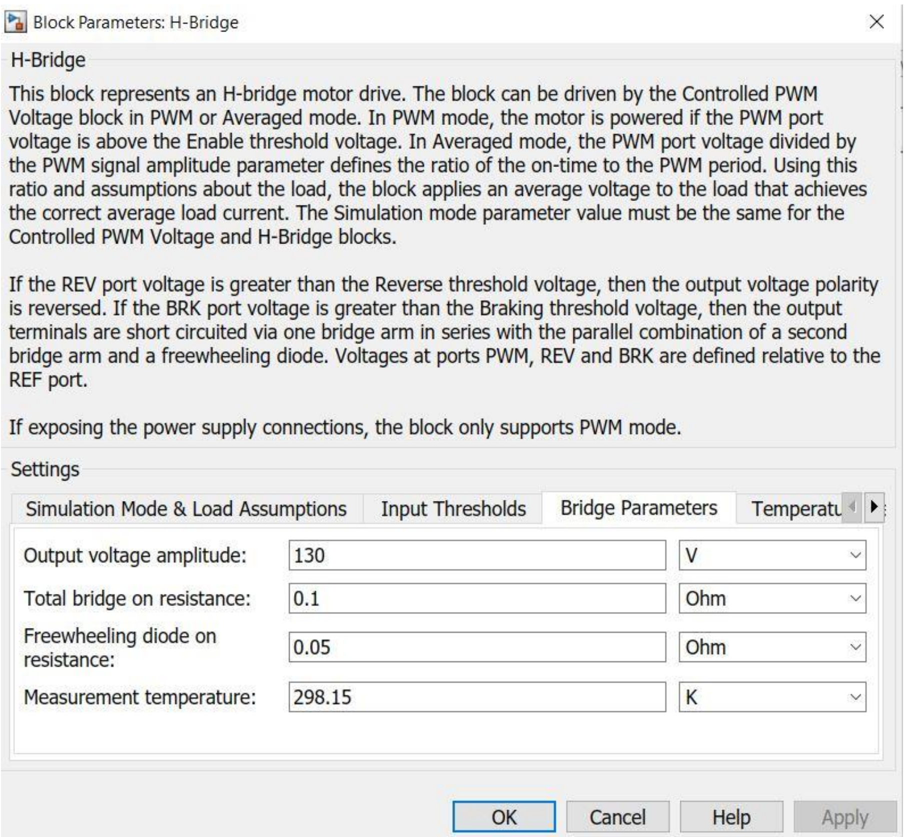
Controlled voltage source – this block converts signal to an equivalent voltage source, which is directly taken by controlled PWM source. There will be three control voltage sources two will be used for acceleration command and deacceleration command and third will be used to feed battery.

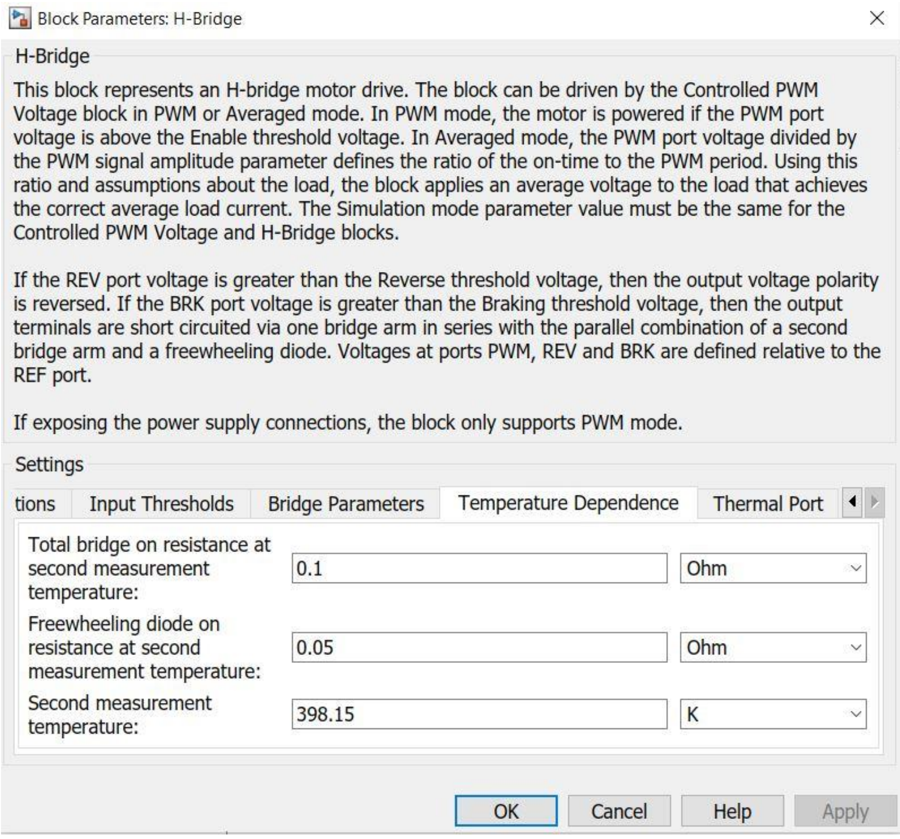
Controlled PWM voltage – it represents a PWM voltage source which produce signal equal to output voltage when pulse is high, otherwise it will be zero. We will get PWM signal and reference signal, which will be taken by H-bridge.



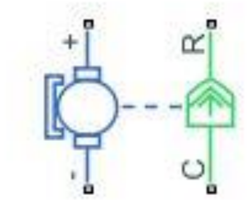
H-bridge – it represents an H-bridge motor driver block. Which takes reference signal, reverse signal and braking signal, which will be used to operate motor. Thermal can be used measure temperature rise of H-bridge.

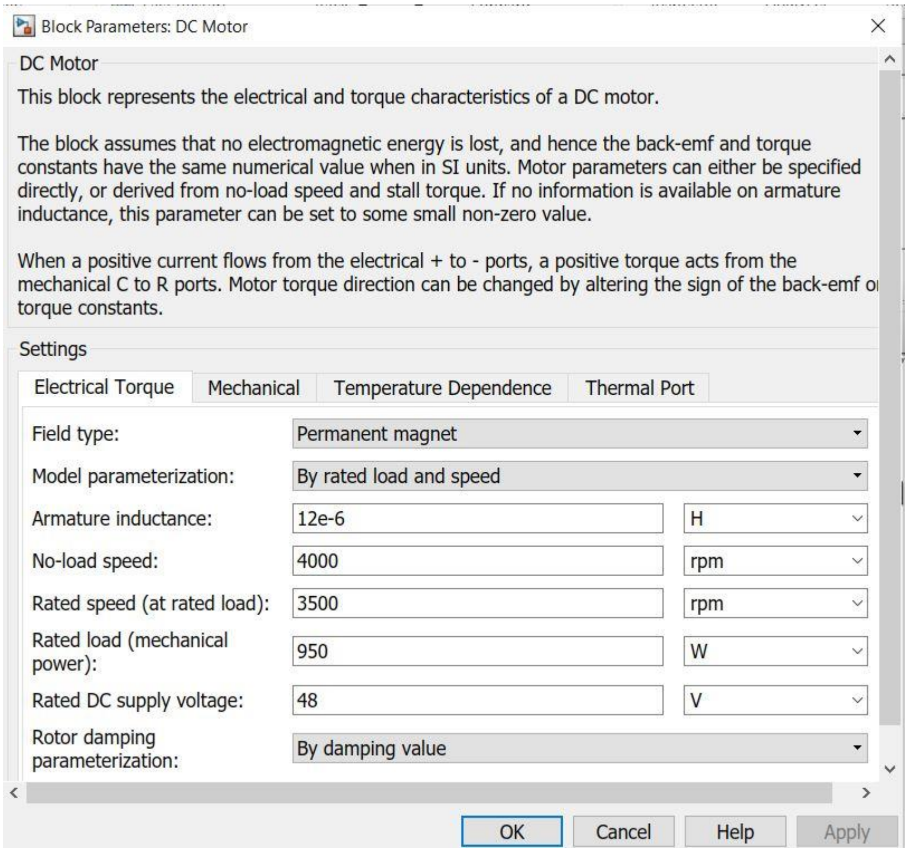

PWM
REF
REV
BRK
+
-

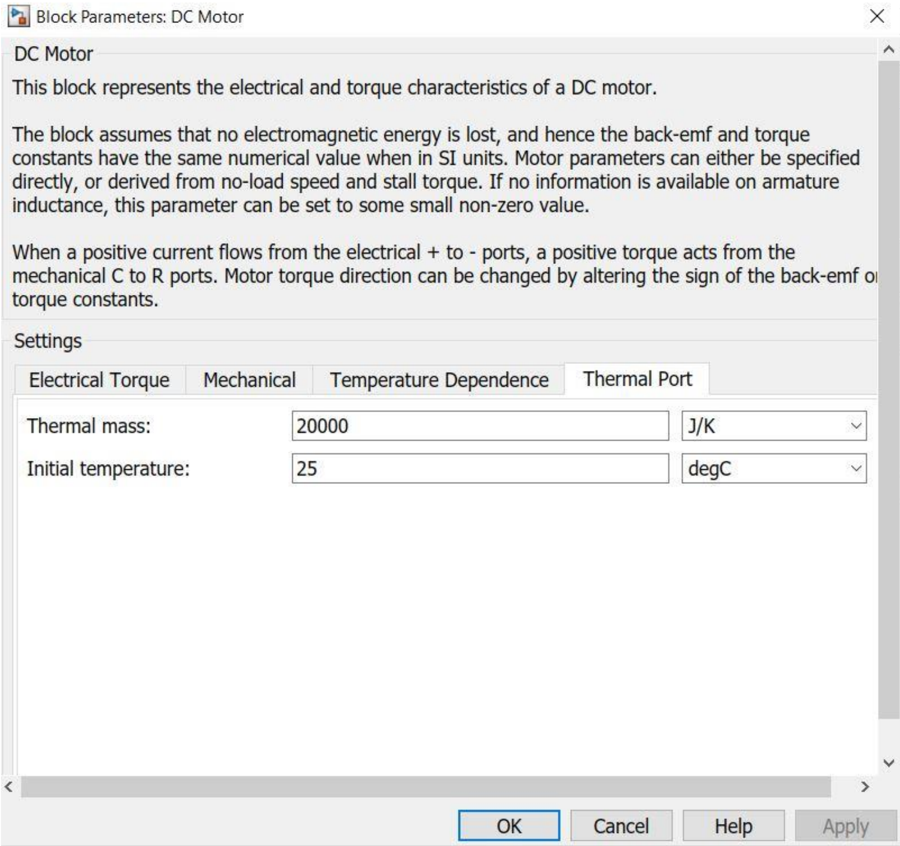

Block Parameters: H-Bridge
H-Bridge
This block represents an H-bridge motor drive. The block can be driven by the Controlled PWM Voltage block in PWM or Averaged mode. In PWM mode, the motor is powered if the PWM port voltage is above the Enable threshold voltage. In Averaged mode, the PWM port voltage 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.
If the REV port voltage is greater than the Reverse threshold voltage, then the output voltage polarity is reversed. If the BRK port voltage is greater than the Braking threshold voltage, then the output terminals are short circuited via one bridge arm in series with the parallel combination of a second bridge arm and a freewheeling diode. Voltages at ports PWM, REV and BRK are defined relative to the REF port.
If exposing the power supply connections, the block only supports PWM mode.
Settings
Simulation Mode & Load Assumptions
Input Thresholds
Bridge Parameters
Temperatu
Output voltage amplitude:
130
V
Total bridge on resistance:
0.1
Ohm
Freewheeling diode on resistance:
0.05
Ohm
Measurement temperature:
298.15
K
OK
Cancel
Help
Apply



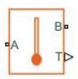
DC-motor – it represents electric and torque characteristic of a DC motor, which follows a specific circuit. DC-motor will be regulated by H-bridge and it has a mechanical rotational port represented by letter R and C represent motor case, which will be connected to mechanical reference. Thermal port of the motor will be used to sense temperature. Motor parameters will be changed for different drive cycles.


+
R
C

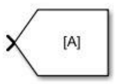

Block Parameters: DC Motor
DC Motor
This block represents the electrical and torque characteristics of a DC motor.
The block assumes that no electromagnetic energy is lost, and hence the back-emf and torque constants have the same numerical value when in SI units. Motor parameters can either be specified 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 flows 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.
Settings
Electrical Torque
Mechanical
Temperature Dependence
Thermal Port
Field type:
Permanent magnet
Model parameterization:
By rated load and speed
Armature inductance:
12e-6
H
No-load speed:
4000
rpm
Rated speed (at rated load):
3500
rpm
Rated load (mechanical power):
950
W
Rated DC supply voltage:
48
V
Rotor damping parameterization:
By damping value
OK
Cancel
Help
Apply



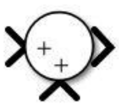
Temperature sensor – it represents an ideal temperature sensor which sense temperature without drawing heat. There will be two temperature sensors in our project, one will be for motor other one is for controller.



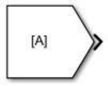
Go-to – this block sends signal to from block with same name tag.



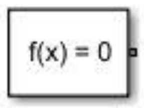
Sum – this block produces signal from input which are added or subtracted.



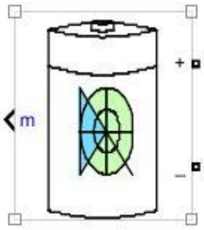
From – this block provides signal which was produced by Go-to block, but we need to give same name tag to from block as Go-to block has.

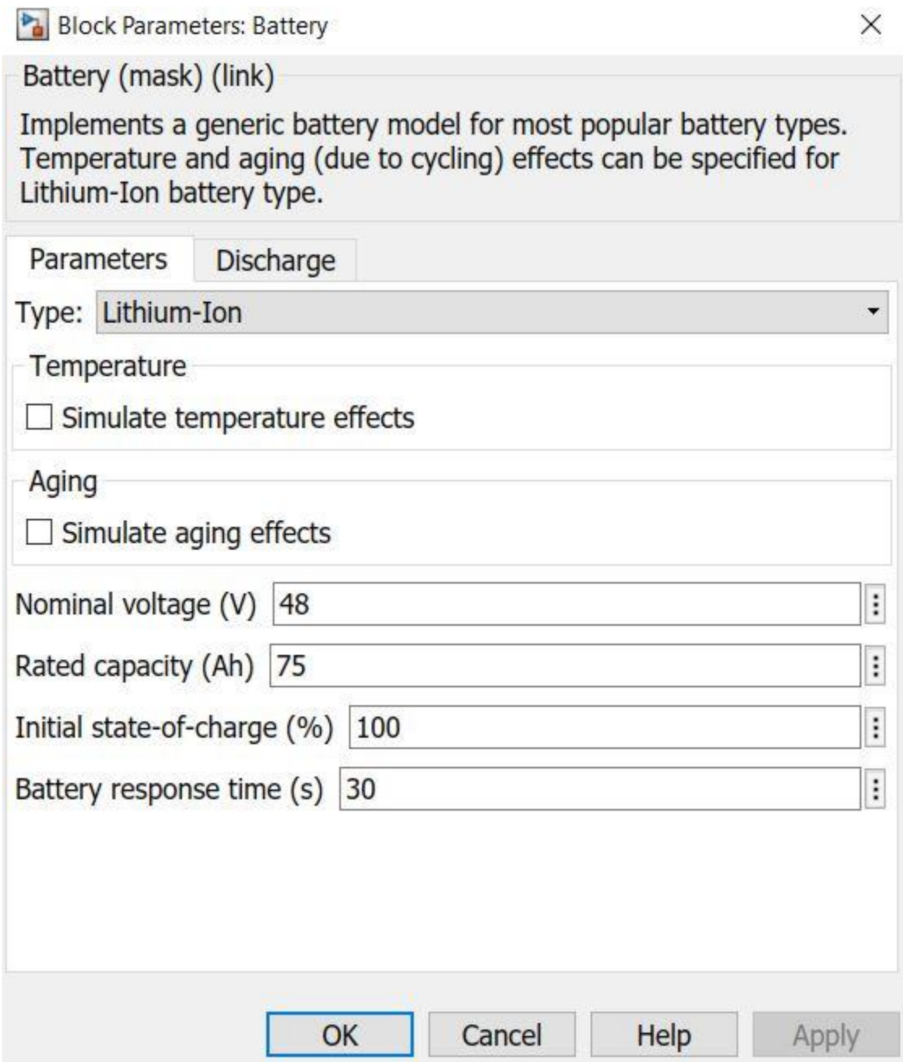


Solver Configuration – this block provides some of the specific parameters which models needs before simulation. Each model must be connected to one solver configuration block.

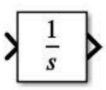


Battery – it represents a battery model with various types like lithium-ion, lead-acid, Ni-Cd etc. Positive and negative ports are conserving port and port represented by m provides multiple information signal, which can be separated by Bus. In this battery is used to find state of charge.

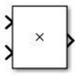




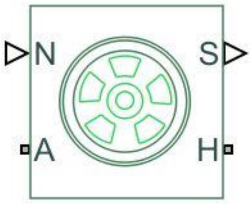
Integrator – this block produces signal by integrating input signal with respect to time.

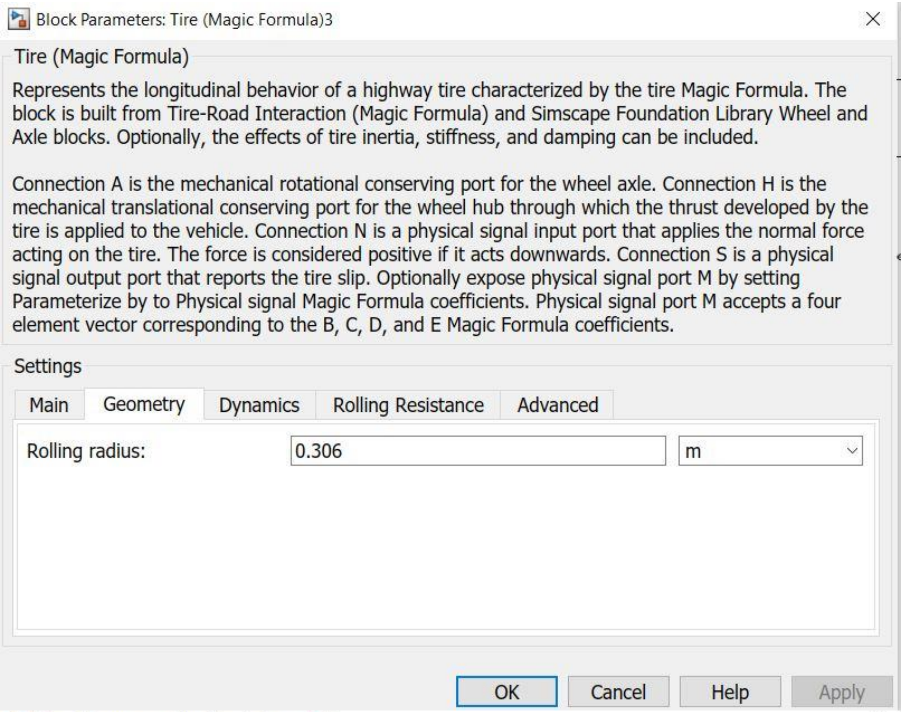


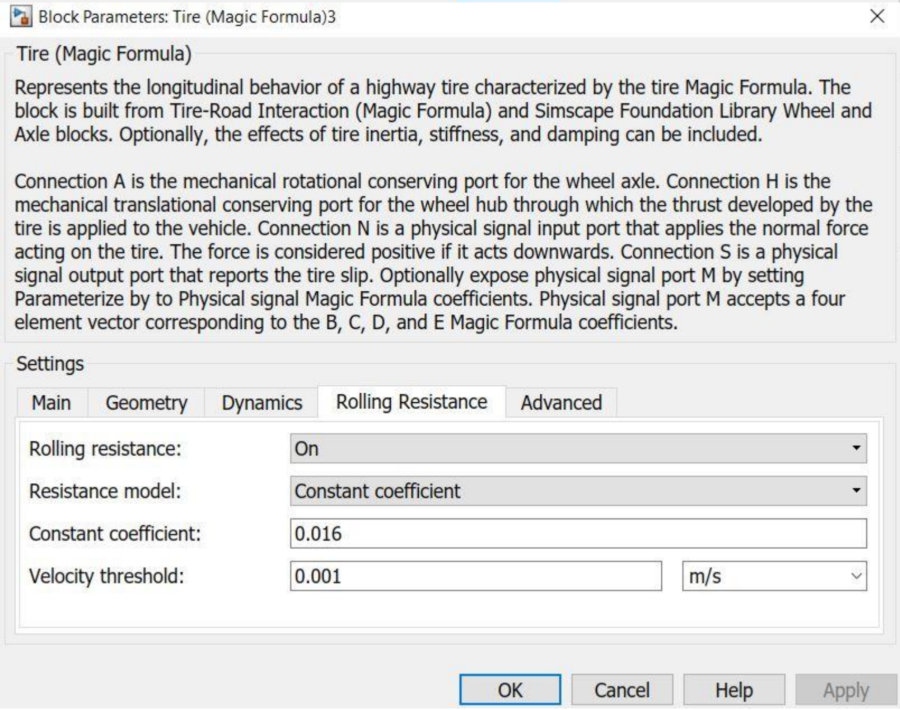
Product – it produces output by multiplying wo input signals.



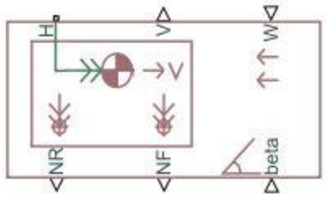
Tire – this block represents a tire, whose behaviour defined by magic formula, which an equation fitted by four coefficients. It has four ports N represents normal force, S takes slip value, H will be connected with hub or vehicle body and A port will be used to connect tire to axle. tire has parameterized by peak longitudinal and corresponding slip.

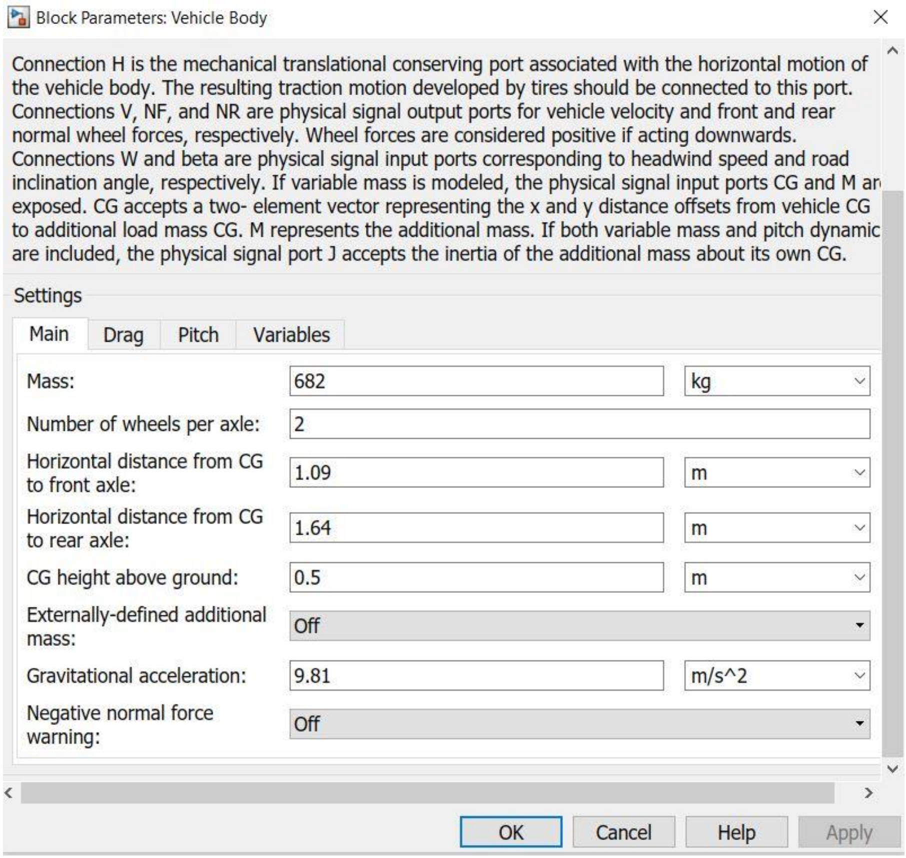

N
S
A
H

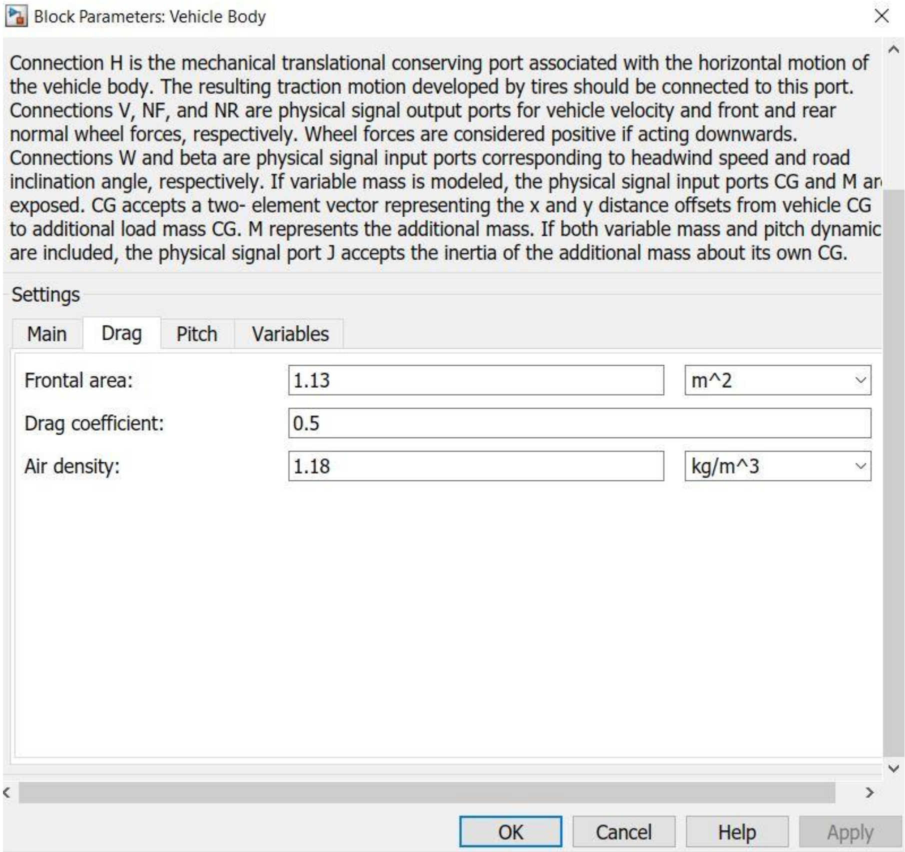

Block Parameters: Tire (Magic Formula)3
Tire (Magic Formula)
Represents the longitudinal behavior of a highway tire characterized by the tire Magic Formula. The block is built from Tire-Road Interaction (Magic Formula) and Simscape Foundation Library Wheel and Axle blocks. Optionally, the effects of tire inertia, stiffness, and damping can be included.
Connection A is the mechanical rotational conserving port for the wheel axle. Connection H is the mechanical translational conserving port for the wheel hub through which the thrust developed by the tire is applied to the vehicle. Connection N is a physical signal input port that applies the normal force acting on the tire. The force is considered positive if it acts downwards. Connection S is a physical signal output port that reports the tire slip. Optionally expose physical signal port M by setting Parameterize by to Physical signal Magic Formula coefficients. Physical signal port M accepts a four element vector corresponding to the B, C, D, and E Magic Formula coefficients.
Settings
Main
Geometry
Dynamics
Rolling Resistance
Advanced
Rolling radius:
0.306
m
OK
Cancel
Help
Apply


Block Parameters: Tire (Magic Formula)3
Tire (Magic Formula)
Represents the longitudinal behavior of a highway tire characterized by the tire Magic Formula. The block is built from Tire-Road Interaction (Magic Formula) and Simscape Foundation Library Wheel and Axle blocks. Optionally, the effects of tire inertia, stiffness, and damping can be included.
Connection A is the mechanical rotational conserving port for the wheel axle. Connection H is the mechanical translational conserving port for the wheel hub through which the thrust developed by the tire is applied to the vehicle. Connection N is a physical signal input port that applies the normal force acting on the tire. The force is considered positive if it acts downwards. Connection S is a physical signal output port that reports the tire slip. Optionally expose physical signal port M by setting Parameterize by to Physical signal Magic Formula coefficients. Physical signal port M accepts a four element vector corresponding to the B, C, D, and E Magic Formula coefficients.
Settings
Main
Geometry
Dynamics
Rolling Resistance
Advanced
Rolling resistance:
On
Resistance model:
Constant coefficient
Constant coefficient:
0.016
Velocity threshold:
0.001
m/s
OK
Cancel
Help
Apply

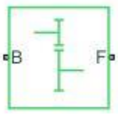
Vehicle body – this block represents vehicle body with two-axle in longitudinal motion. Three tire of rickshaw will be connected to its H port and we can give wind speed and grade angle using w and beta port. NR and NF give normal force to tires.


H
V
W
V
NR
NF
beta


Block Parameters: Vehicle Body
Connection H is the mechanical translational conserving port associated with the horizontal motion of the vehicle body. The resulting traction motion developed by tires should be connected to this port. Connections V, NF, and NR are physical signal output ports for vehicle velocity and front and rear normal wheel forces, respectively. Wheel forces are considered positive if acting downwards. Connections W and beta are physical signal input ports corresponding to headwind speed and road inclination angle, respectively. If variable mass is modeled, the physical signal input ports CG and M ar exposed. CG accepts a two- element vector representing the x and y distance offsets from vehicle CG to additional load mass CG. M represents the additional mass. If both variable mass and pitch dynamic are included, the physical signal port J accepts the inertia of the additional mass about its own CG.
Settings
Main
Drag
Pitch
Variables
Mass:
682
kg
Number of wheels per axle:
2
Horizontal distance from CG to front axle:
1.09
m
Horizontal distance from CG to rear axle:
1.64
m
CG height above ground:
0.5
m
Externally-defined additional mass:
Off
Gravitational acceleration:
9.81
m/s^2
Negative normal force warning:
Off
OK
Cancel
Help
Apply



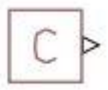
Simple gear – it has base and follower gear which be connected to driveline, to produce rotational velocity according to gear ratio. gear ratio value is 10 for this project.



Inertia – it represents an ideal inertia, which is considered as mass. It represents side shafts in vehicle.

Terminator – it terminates the signal.

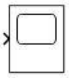
Constant – this block generates constant value.



Display – it displays value of signal.

Bus creator – it combines a set of input signal into a bus. We can get access to signal by specifying signal name.

Scope – it displays signal.



Result –

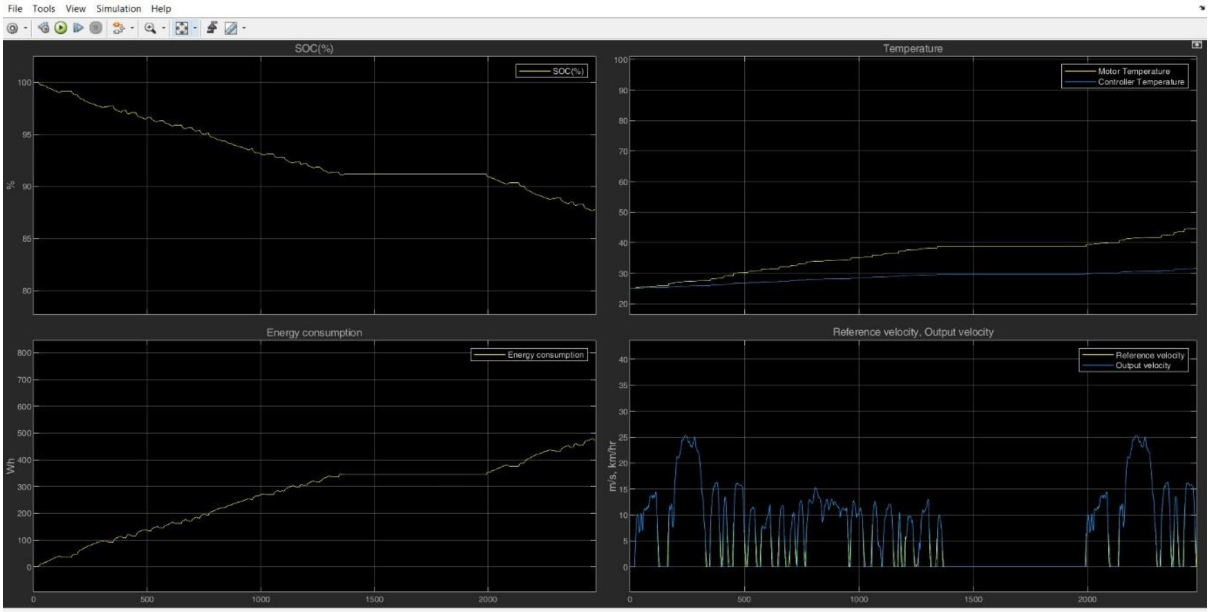
1. Drive cycle – FTP75 (2474s)

Energy consumed – 473.2Wh

Distance covered – 17.78KM

SoC(%) – 80.4%

Temperature – motor – 44.6C(Rise – 19.6C) , controller – 31.5C(Rise – 6.5C)



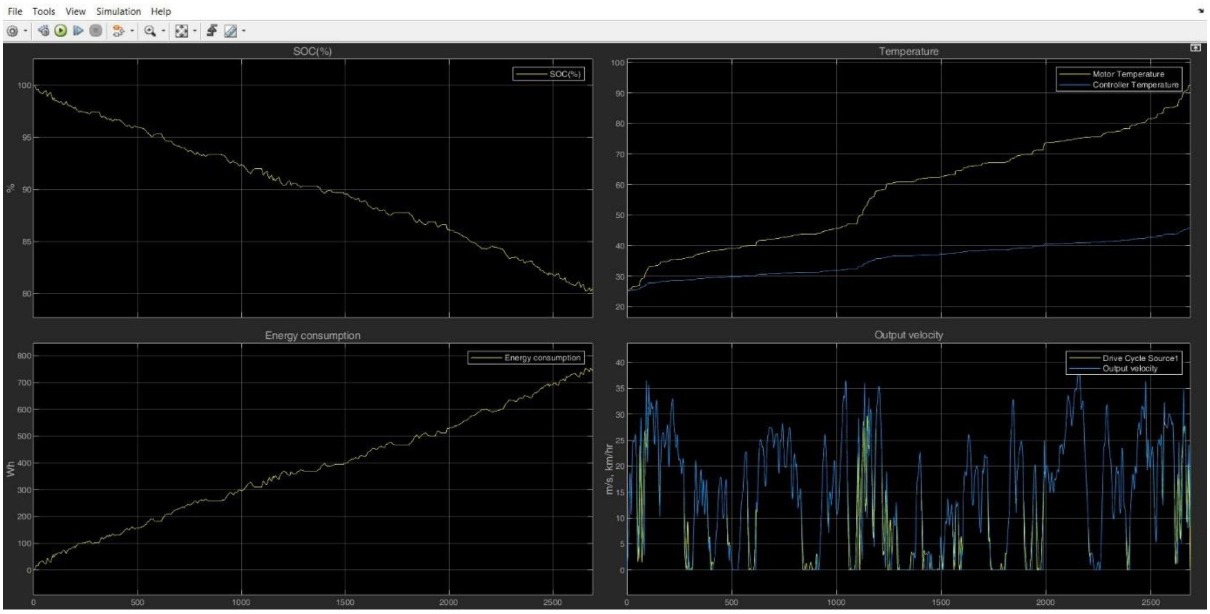
2. Drive cycle – Indian urban drive cycle(2690s)

Energy consumed – 744.6Wh

Distance covered – 39.2KM

SoC(%) – 80.5%

Temperature – motor – 92.5C(Rise – 67.5C) , controller – 45.8C(Rise – 20.8C)



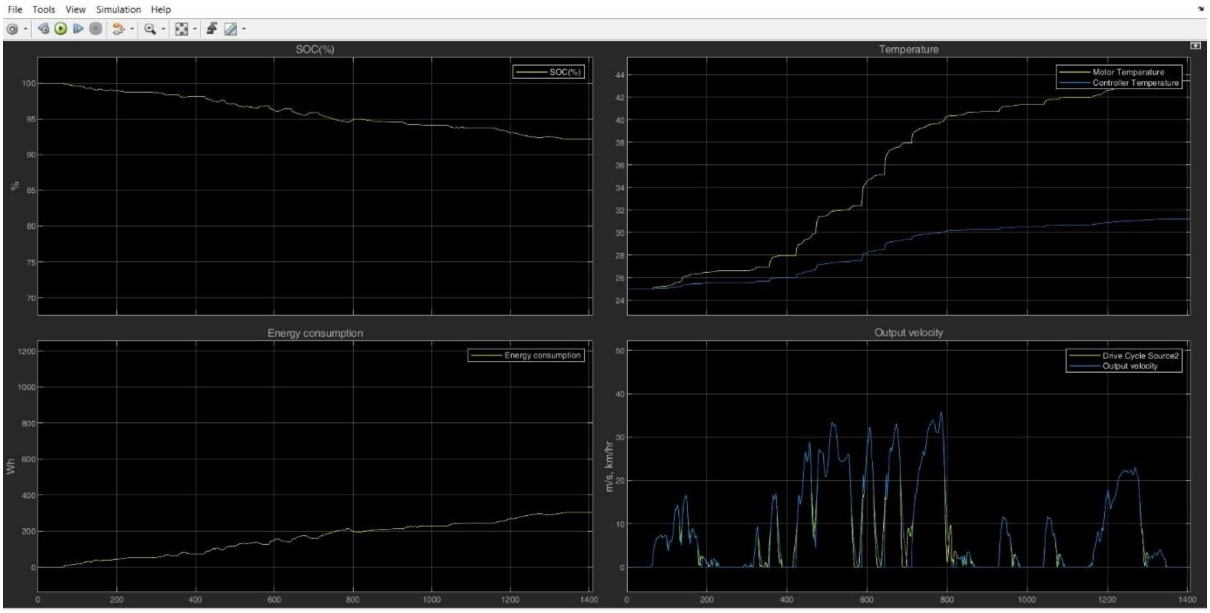
3. Drive cycle – West Virginia university drive cycle(1408s)

Energy consumed – 302.6Wh

Distance covered – 11.9KM

SoC(%) – 92.2%

Temperature – motor – 43.5C(Rise – 18.5C) , controller – 31.18C(Rise – 6.18C)



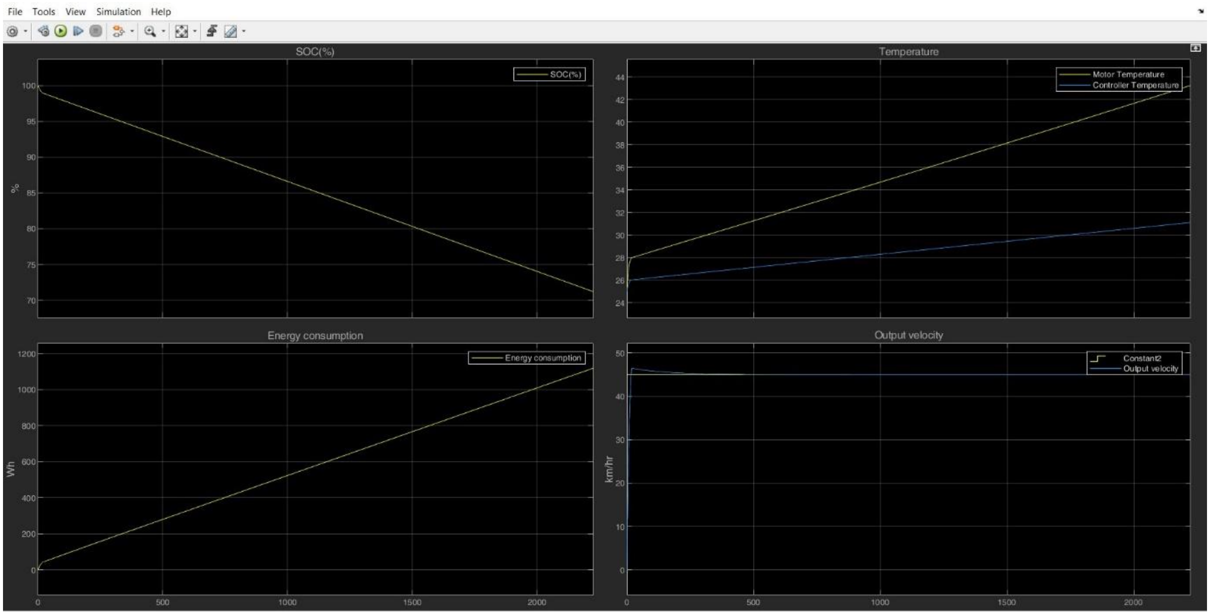
4. Drive cycle – Constant velocity 45KM/hr

Energy consumed – 1118Wh

Distance covered – 100KM

SoC(%) – 71.2%

Temperature – motor – 43.25C(Rise – 18.25C) , controller – 31.1C(Rise – 6.1C)



5. Conclusion – we successfully simulated to find energy consumption for different drive cycle. Output velocity imitates reference velocity, so we can our model is working well. Motor parameter and PI value was tweaked to match output velocity to reference. We plotted for energy consumption, soc, and temperature rise as well.