**Top Force and Speed Method**

**Parameters:**

step (seconds): Time step between iterations

total\_time (seconds): Used for creating long enough arrays

wheel\_radius (meters): Radius of wheel of bike

gearing (ratio): Gear ratio from motor to wheel

rider\_mass(kg): Mass of rider

bike\_mass(kg): Mass of bike

gravity(m/s^2): Acceleration of Gravity

air\_resistance or drag coefficient(dimensionless): Resistance of air considering shape of bike

air\_density(kg/m^2): Density of air

frontal\_area(m^2): Frontal cross sectional area of the bike, the area of the bike the air will hit

rolling\_resistance(dimensionless): Coefficient of friction given to material of tire and ground

top\_torque(Nm): Top amount of force the motor can output.

top\_rpm(rpm): Top rpm of motor

chain\_efficiency: Power efficiency of the chain

battery\_efficiency: Power efficiency of the batteries

motor\_torque\_constant(Nm/amps rms): Ratio to convert amperes to motor torque of motor

motor\_rpm\_constant(rpm/voltage): Ratio to convert voltage to rpm

series\_cells: Number of cells in series in the bike.

max\_amphour(amphour): Max amphours in the bike. Capacity

batt\_max\_current: max Current out of the batteries (used for power limiting)

motor\_thermal\_conductivity(W/m\*C): Motor thermal conductivity

motor\_heat\_capacity (J/C): Motor heat capacity

coolant\_temp ( C ) : Temperature of the coolant, assumed to be constant.

max\_motor\_temp ( C) : Max Temperature of Motor. When Temperature limiting happens

**Output Arrays:**

time (seconds): Cumulative time at each time step

distance(meters): Cumulative distance at each time step

speed(m/s): Speed after all comparisons, official speed for time step

force(newton): Force after all comparisons, official force for time step

power(watts): Power at each time step not including inefficiency

energy(watt/hour): Cumulative energy at each time step

acceleration(newton): Force associated to acceleration at each time step

drag(newton): Force associated to drag at each time step

slope(ratio): Slope of the rode at each time stop

incline(newton): Force associated to the inclination of the road at each time step

rolling(newton): Force associated to rolling resistance at each time stop.

motor\_torque(Nm): Motor torque used for efficiency

motor\_rpm(rpm): Rpm of the motor used for efficiency

motor\_loss(watts): Power loss due to motor inefficiency

motor\_controller\_loss(watts): Power loss due to motor controller inefficiency

chain\_loss(watts): Power loss due to the chain inefficiency

battery\_loss(watts): Power loss due to battery inefficiency

total\_power(watts): Power to overcome including inefficiency

arms(amps rms): Amps rms out of motor controller used for efficiency

vrms(volts rms): Voltage rms out of the motor controller used for efficiency

motor\_efficiency(%): Motor efficiency

motor\_controller\_efficiency(%): Motor controller efficiency

chain\_power(watts): Power required at chain, after chain losses

motor\_power(watts): Power required at motor, after motor and chain losses

motor\_controller\_power(watts): Power required at motor controller after motor, chain, and controller losses

battery\_power(watts): Power required at batteries given all losses

voltage(volts): Traction pack voltage

top\_force(newton): Top allowable force at that time (given motor)

top\_speed(m/s): Top allowable speed at that time (given motor)

top\_power(watts): Top allowable power at that time (given motor and battery pack)

amphour

motor\_energy\_in (J): Amount of energy going into heating the motor

motor\_energy\_out (J): Amount of the energy taking out of the motor by cooling

motor\_energy (J): Change in motor energy

motor\_temp (C ): Motor temperature at that point in time

mt\_speed (m/s): Speed before motor thermal limiting

mt\_force (newton): Force before motor thermal limiting

mt\_power (Watt): Power before motor thermal limiting

mt\_total\_power (Watt): Power with efficiency losses before motor thermal limiting

l\_speed(m/s): Look up speed at each time step

t\_speed(m/s): Speed after limited by top speed

c\_force(newton): Force after limited by top force

**Logic Flow:**

1) Time:

Step time by time step

2) Distance:

Determine current distance given time step and previous speed

If over max distance end simulation

3) Look Up Speed:

Look up speed using a distance to speed look up table

For IOM use distance to speed table of a faster bike

4)Top Speed Check:

Check if look up speed is higher than top speed of simulated bike.

If higher than stop speed make speed equal to top speed

5) Force:

Calculate force necessary for bike to apply to ground to overcome forces (drag, rolling resistance, inclination, acceleration)

6)Top Force Check:

Check if force is higher than top force of simulated bike

If higher find speed that gives top force and set force equal to top force

7) Power:

Calculate power from force, speed, and efficiency

8) Power Check:

Check power given motor and battery limits

9) Motor Temperature:

Calculate Temperature of the motor

10) Motor Temperature Check:

Check Temperature and limit speed to top temperature

11) Energy

Calculate Energy (KW/hour) and Amphours used from power and time step

**Equations:**

subscript (n) is current time step

subscript (n+1) is next time step

1) Time:

2) Distance:

5)Force: