Full Throttle Drivetrain Voltage Drop Model

Everything is in SI units

User-defined constants

Motor specs

Vspec	voltage at which the following motor parameters are specified
Tspec	stall torque
Ispec	stall current
Wspec	free speed
n	number of motors

Electrical

Vbat	battery open-circuit volts fully charged
Rcom	battery internal resistance (fully charged) plus resistance of main breaker and all wires and connectors from battery to Power Distribution Board
Rone	resistance of all wires and connectors from PDB to *one* motor, including 40A breaker

Mechanical

G	gear ratio from motor to wheel
r	wheel radius

Derived Constants

Kt	motor torque constant (Tspec/Ispec)

Variables

V	vehicle speed
Wm	motor speed corresponding to vehicle speed
Im	motor current
Tm	motor torque
Vm	voltage at motor
Tstall	stall torque at Vm
Wfree	motor free speed at Vm

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Kt: Tspec/Ispec;
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$$\frac{Tspec}{Ispec}$$

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Im: Tm/Kt;
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$$\frac{Ispec * Tm}{Tspec}$$

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Vm: Vbat-n*Im*Rcom-Im*Rone;
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$$Vbat - \frac{Ispec * Rone * Tm}{Tspec} - \frac{Ispec * n * Rcom * Tm}{Tspec}$$

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Tstall: (Vm/Vspec)*Tspec;
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$$\frac{Tspec * \left(Vbat - \frac{Ispec * Rone * Tm}{Tspec} - \frac{Ispec * n * Rcom * Tm}{Tspec} \right)}{Vspec}$$

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Wfree: (Vm/Vspec)*Wspec;
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$$\frac{\left(Vbat - \frac{Ispec * Rone * Tm}{Tspec} - \frac{Ispec * n * Rcom * Tm}{Tspec} \right) * Wspec}{Vspec}$$

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q1: Tm = Tstall*(1-Wm/Wfree);
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$$Tm = \frac{Tspec * \left(Vbat - \frac{Ispec * Rone * Tm}{Tspec} - \frac{Ispec * n * Rcom * Tm}{Tspec} \right) * \left(1 - \frac{Vspec * Wm}{\left(Vbat - \frac{Ispec * Rone * Tm}{Tspec} - \frac{Ispec * n * Rcom * Tm}{Tspec} \right) * Wspec} \right)}{Vspec}$$

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_Tm: expand(solve(q1,Tm)[1]);
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$$Tm = \frac{Tspec * Vbat * Wspec}{Vspec * Wspec + Ispec * Rone * Wspec + Ispec * n * Rcom * Wspec} - \frac{Tspec * Vspec * Wm}{Vspec * Wspec + Ispec * Rone * Wspec + Ispec * n * Rcom * Wspec}$$

Notes for equations on previous page

Kt: Derived constant Kt is computed (once) from motor specs Tspec and Ispec

Im: Current through a motor is equal to the motor torque divided by the motor torque constant

Vm: The actual voltage at the motor is equal to the battery open-circuit voltage minus the voltage drops in the circuit due to current

Tstall: The motor stall torque for the actual voltage at the motor

Wfree: The motor free speed for the actual voltage at the motor

q1: An equation is formed relating the motor torque and the motor speed. This gives the motor torque versus speed curve for the actual voltage at the motor

_Tm: The implicit equation "q1" is solved explicitly for motor torque Tm. This equation allows Tm to easily be calculated, given motor speed Wm. The equation is linear with an offset and slope, given by Tm = Toffset - Tslope*Wm, where the offset and slope are fixed by the user-specified values and are calculated once:

Toffset: (Tspec*Vbat*Wspec)/(Vspec*Wspec+Ispec*Rone*Wspec+Ispec*n*Rcom*Wspec);

Tslope: (Tspec*Vspec)/(Vspec*Wspec+Ispec*Rone*Wspec+Ispec*n*Rcom*Wspec);

C code

In the C code, there is an accel(V) function which computes the vehicle acceleration given its speed V. The vehicle speed V is directly related to the motor speed Wm through the wheels and the transmission, assuming no wheel slip. This motor speed Wm is then used in the formula Tm=Toffset-Tslope*Wm derived above to obtain the motor torque. By using this formula for motor torque, the voltage drops due to current are automatically included in the calculation. Tm is then used to calculate the torque at the wheels, and the motive force exerted by the wheels on the carpet. Slip logic is used at this point to test if the wheel coefficient is capable of sustaining that force. The motive force is then used to determine vehicle acceleration, and this is numerically integrated to obtain the vehicle speed at the next point in time.