Equations to modell an electric vehicle:

Lead Acid Batteries

$$R = no. of\ cells \cdot \frac{0.022}{C_{10}} \Omega$$

C_{10} is the amphour capacity at the 10h rate.

Nickel-Based Batteries

$$R = no. of\ cells \cdot \frac{0.06}{C_3} \Omega$$

Battery Modelling:

Formula for the open-circuit voltage:

$$E = n \cdot [2.15 - DoD \cdot (2.15 - 2.00)]$$

Formula for the open-circuit voltage for nickel-based batteries:

$$E = n \cdot (-8.2816\ DoD^7 + 23.5749\ DoD^6 - 30\ DoD^5 + 23.7053\ DoD^4 - 12.5877\ DoD^3 + 4.1315\ DoD^2 - 0.8658\ DoD + 1.37)$$

n … number of cells in the battery
DoD … depth of discharge of a battery, 0 = fully charged, 1.0 = empty

Peukert capacity:

$$C_p = I^k T$$
$$T = \frac{C_p}{I^k}$$

I … constant current I amps
T … this will last T hours
k … Peukert coefficient (1.2 for lead acid battery)

Loss of charge:

$$Loss\ of\ charge = \delta t \cdot I^k$$

t … time in seconds

$$CR_{n+1} = CR_n + \frac{\delta t \cdot I^k}{3600}\ Ah$$

Charge Supplied:

$$CS_{n+1} = CS_n + \frac{\delta t \cdot I}{3600} Ah$$

Current Charge of Battery:

$$CS_{n+1} = CS_n - \frac{\delta t \cdot I}{3600} Ah$$

Depth of Discharge:

$$DoD_n = \frac{CR_n}{C_p}$$

Equation to find current I from a battery when it is operating at a power P watts if P is positiv:

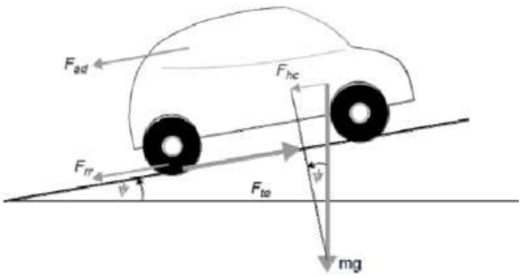
$$P = V\ x\ I$$

$$P = V \cdot I = (E - IR) \cdot I = EI - RI^2$$

$$I = \frac{E - \sqrt{E^2 - 4RP}}{2R}$$

Equation to find current I from a battery when it is operating at a power P watts if P is negative:

$$I = \frac{-E + \sqrt{E^2 + 4RP}}{2R}$$



Rolling Resistance Force:

$$F_{rr} = \mu_{rr} mg$$

Aerodynamic Drag:

$$F_{ad} = \frac{1}{2}\rho A C_d v^2$$

Hill Climbing Force:

$$F_{hc} = m\, g \sin\psi$$

Acceleration Force:

$$F_{la} = m\ a \ldots linear\ Acceleration$$

$$F_{wa} = I\frac{G^2}{\eta_g r^2}\ a \ldots\ rotational\ acceleration$$

Total Tractive Effort:

$$F_{te} = F_{rr} + F_{ad} + F_{hc} + F_{la} + F_{wa}$$

Energy required each second:

$$P_{te} = F_{te} \cdot v$$

Motor efficiency:

$$\eta_m = \frac{T\,\omega}{T\,\omega + k_c\,T^2 + k_i\omega + k_\omega\omega^3 + C}$$
$$k_c\,T^2 \ldots Copper\ losses$$
$$k_i\omega \ldots\ iron\ losses$$
$$k_\omega\omega^3 \ldots windage\ power$$
$$\omega \ldots angular\ velocity$$

Power of motor or Traction power:

$$P_{mot\_in} = \frac{P_{mot\_out}}{\eta_m} \qquad P_{mot_{out}} = \frac{P_{te}}{\eta_g}$$
$$\eta_g \ldots efficiency\ of\ the\ gear\ system\ (constant)$$

Power of motor or Traction power when motor is used to slow the vehicle (= P is negative):

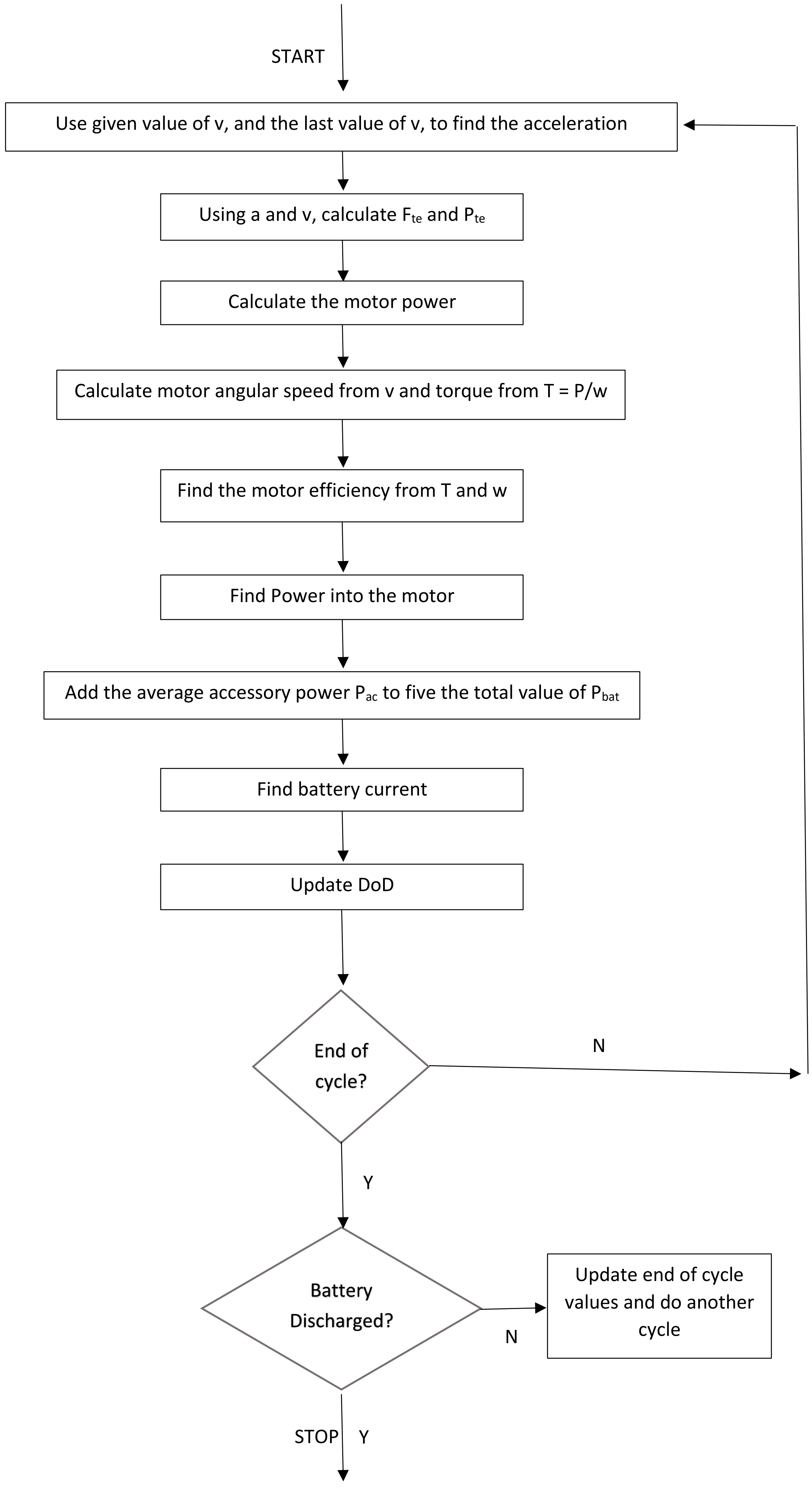
$$P_{mot\_in} = P_{mot\_out} \cdot \eta_m \qquad P_{mot\_out} = P_{te} \cdot \eta_g$$

Motor angular speed:

$$T = \frac{P}{\omega}$$

Power required from the battery:

$$P_{bat} = P_{mot\_in} + P_{ac}$$


START
Use given value of v, and the last value of v, to find the acceleration
Using a and v, calculate F_{te} and P_{te}
Calculate the motor power
Calculate motor angular speed from v and torque from T = P/w
Find the motor efficiency from T and w
Find Power into the motor
Add the average accessory power P_{ac} to five the total value of P_{bat}
Find battery current
Update DoD
End of cycle?
N
Y
Battery Discharged?
N
Update end of cycle values and do another cycle
STOP
Y