Equations to model an electric vehicle:

DEFINITIONS:

Environment:

$\psi = 0°$

$\rho = 1.225 \frac{kg}{m^3}$

$C_d = 0.5$

$\mu_{rr} = 0.02$

$\delta t = 1s$

Car / Motor (100kW, high speed induction motor):

$m = 1360kg$

$\eta_g = 0.9$

$k_c = 0.3$

$k_\omega = 5.0 \cdot 10^{-6}$

$k_i = 0.01$

$C = 600$

$r = 323mm$

$a = 2.68 \frac{m}{s^2}$

$\mathrm{v} = 30 \frac{\mathrm{m}}{\mathrm{s}}$

$A = 2\, m^2$

Battery (LiMn2O4):

$no\ of\ cells = 300$

$type\ of\ battery = Lead\ Acid\ battery$

$C = 50Ah$

$k = 1.2$

$DoD = 0.7$

$P_{ac} = 12W$

CALCULATIONS:

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

$$F_{rr} = \mu_{rr} mg = 0.02 \cdot 1360kg \cdot 9.8\frac{m}{s^2} = 266.56\ N$$

$$F_{ad} = \frac{1}{2}\rho A C_d v^2 = 0.5 \cdot 1.225\frac{kg}{m^3} \cdot 2m^2 \cdot 0.5 \cdot \left(30\frac{m}{s}\right)^2 = 551.25\ N$$

$$F_{hc} = m\ g \sin\psi = 1360kg \cdot 9.8\frac{m}{s^2} \cdot \sin(0) = 0\ N$$

$$F_{la} = m\ a = 1360kg \cdot 2.68\frac{m}{s^2} = 3644.8\ N$$

$$F_{te} = 266.56N + 551.25N + 0N + 3644.8N = 4462.61N$$

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

$$P_{te} = 4462.61N \cdot 30\frac{m}{s} \approx 0.134 \cdot 10^6\ W$$

$$P_{motout} = P_{te} \cdot \eta_g$$

$$P_{motout} = 0.134 \cdot 10^6\ W \cdot 0.9 \approx 0.1205 \cdot 10^6\ W$$

$$\omega = \frac{v}{r} = \frac{30\frac{m}{s}}{0.323\ m} \approx 92.88\frac{rad}{s}$$

$$T = \frac{P}{\omega} = \frac{0.1205 \cdot 10^6\ W}{92.88\frac{rad}{s}} = 1297.373\ Nm$$

$$\eta_m = \frac{T\ \omega}{T\ \omega + k_c T^2 + k_i \omega + k_\omega \omega^3 + C}$$

$$\eta_m = \frac{1297.373\ Nm \cdot 92.88\frac{rad}{s}}{1297.373\ Nm \cdot 92.88\frac{rad}{s} + 0.3 \cdot (1297.373\ Nm)^2 + 0.01 \cdot 92.88\frac{rad}{s} + 5.0 \cdot 10^{-6} \cdot (92.88\frac{rad}{s})^3 + 600}$$

$$\eta_m = \frac{0.120500 \cdot 10^6}{0.626062 \cdot 10^6} \approx 0.1925$$

$$P_{motin} = \frac{P_{motout}}{\eta_m} = \frac{0.1205 \cdot 10^6\ W}{0.1925} \approx 0.625974 \cdot 10^6\ W$$

$$P_{bat} = P_{mot_{in}} + P_{ac}$$

$$P_{bat} = 0.625974 \cdot 10^6\ W + 12W = 0.625986 \cdot 10^6\ W$$

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

$$E = 300 \cdot [2.15 - 0.7 \cdot (2.15 - 2.00)]$$

$$E \approx 613.5\ V$$

$$C_{10} = \left(\frac{C}{10}\right)^{k} \cdot 10$$

$$C_{10} = \left(\frac{50}{10}\right)^{1.2} \cdot 10$$

$$C_{10} \approx 68.986\ Ah$$

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

$$\mathrm{R} = 300 \cdot \frac{0.022}{68.986}\Omega$$

$$\mathrm{R} \approx 95.67\ \mathrm{m}\Omega$$

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

$$I = \frac{613.5\ V - \sqrt{(613.5\ V)^2 - 4 \cdot 95.67 m\Omega \cdot 0.625986\ \cdot 10^6\ W}}{2 \cdot 19.13\ \mathrm{m}\Omega}$$

$$I = \frac{613.5V - \ 369.905V}{201.143 m\Omega} = \ 1211.054A$$

$$Loss\ of\ charge = \frac{\delta t\ \cdot\ I^k}{3600}\ Ah$$

$$Loss\ of\ charge = \frac{1s\ \cdot (1211.054)^{1.2}}{3600}\ Ah \approx 1.392 Ah$$