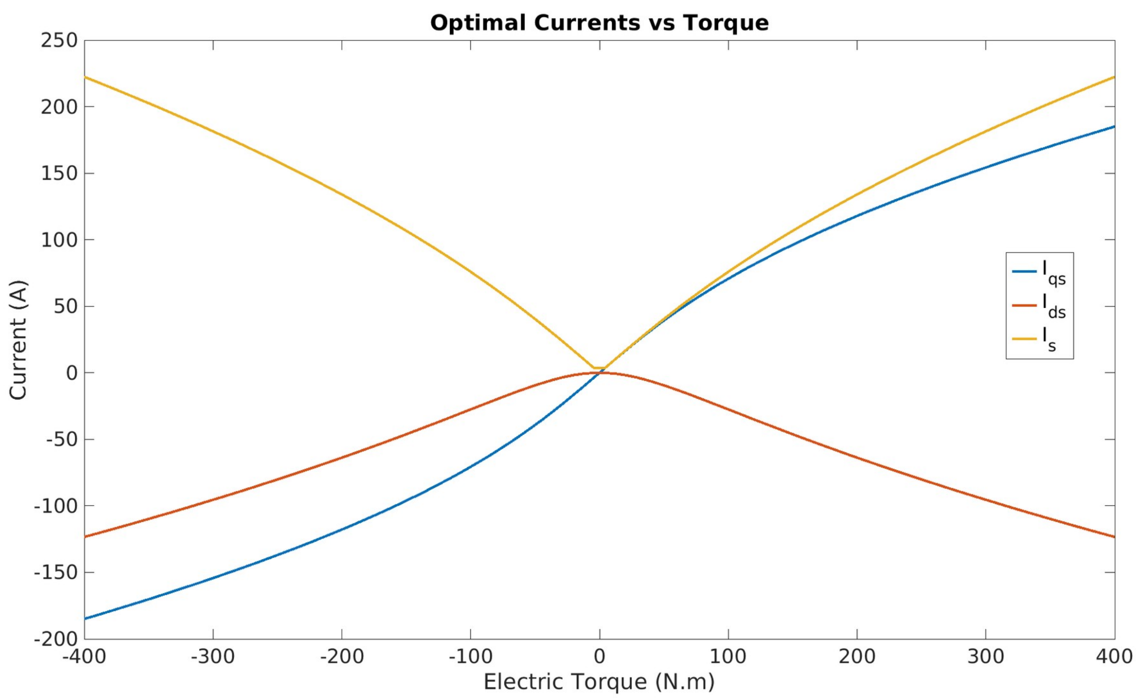
1. Write a Matlab script to determine and plot optimal $I_{qs}^r$ and $I_{ds}^r$ as a function of desired torque. In this case, the objective is to minimize the peak stator current $I_s = \sqrt{(I_{qs}^r)^2 + (I_{ds}^r)^2}$ subject to the constraint $T_e = \frac{P}{2}\frac{3}{2}\left[\lambda_m I_{qs}^r + (L_d - L_q)\, I_{qs}^r I_{ds}^r\right]$. Consider the following Matlab code snippets to do this. The vectors `I_qs`, `I_ds`, and `T_e` established in this step will be used to implement a table lookup in the Simulink model.

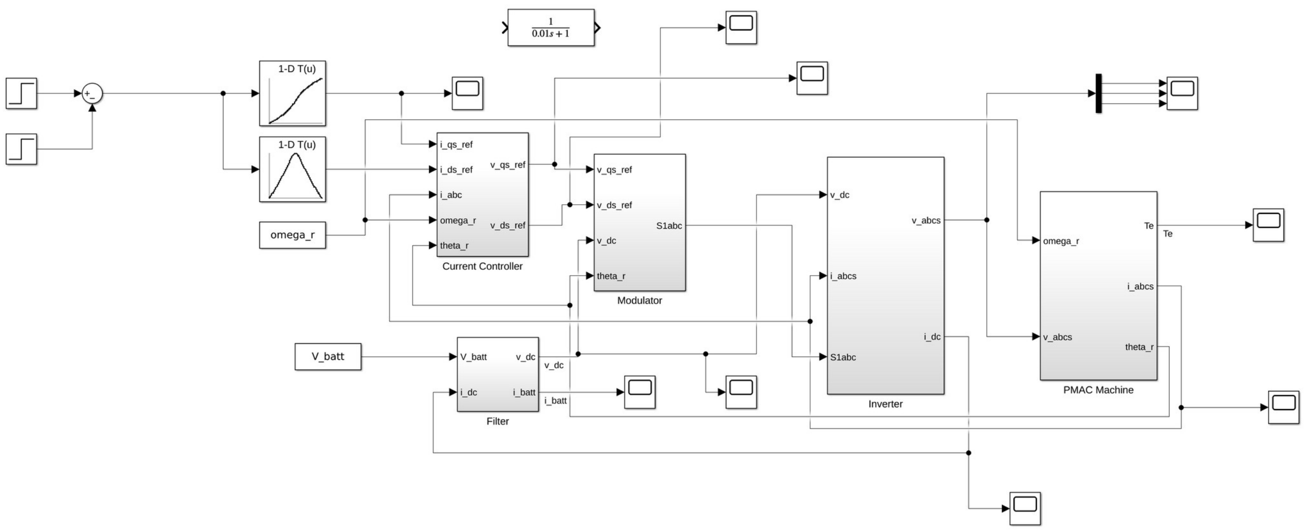


2. Assume the *mechanical* rotor speed is 500 rpm and the desired torque is 400 N · m. Given the values of $I_{qs}^r$ and $I_{ds}^r$ established in (1), calculate (using Park's equations) the steady-state values of $V_{qs}^r$ and $V_{ds}^r$. Calculate the power supplied to the motor. If the inverter is composed of ideal switches and dc filter losses are small, the power supplied to the motor in the steady state will be close to the average power supplied by the battery. Knowing the battery voltage, estimate the average steady-state battery current. Repeat these calculations assuming the desired torque is $-400$ N · m.

Using these equations + the currents that you calculated in your Part 1 program

$$\left.\begin{array}{ll}
V_{qs}^r = r_s I_{qs}^r + \omega_r L_d I_{ds}^r + \omega_r \lambda_m' & (SS-1) \\
V_{ds}^r = r_s I_{ds}^r - \omega_r L_q I_{qs}^r & (SS-2) \\
T_e = \frac{3}{2}\frac{P}{2}\left[\lambda_m' I_{qs}^r + (L_d - L_q) I_{qs}^r I_{ds}^r\right] & (SS-3) \\
P_e = \frac{3}{2}(V_{qs}^r I_{qs}^r + V_{ds}^r I_{ds}^r) & (SS-4)
\end{array}\right\} \text{All variables constant in steady state}$$

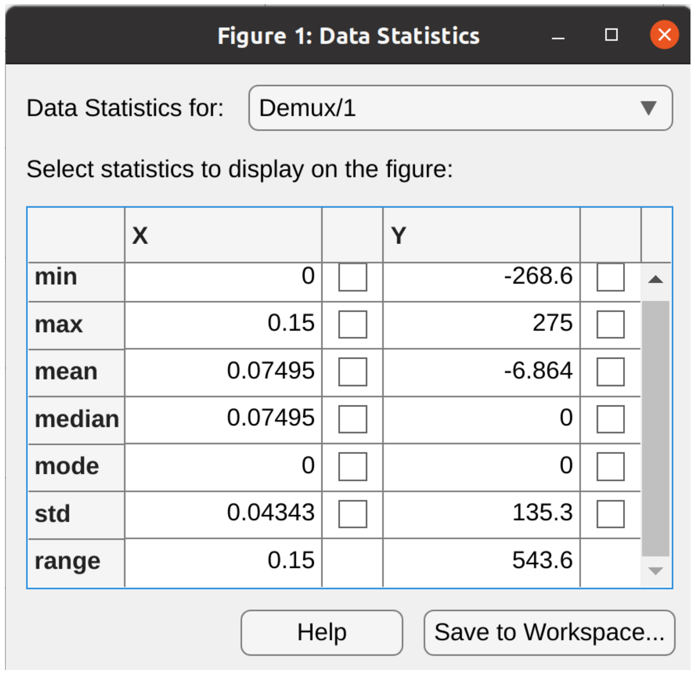
| Variable | Where it came from | | |
|---|---|---|---|
| Torque (N.m) | Commanded | 400 | -400 |
| Iqs (A) | Available in the code | 184.97 | -184.97 |
| Ids (A) | Available in the code | -123.4 | 123.4 |
| Vqs (V) | Calculated using (SS-1) | -6.1 | -13.5 |
| Vds (V) | Calculated using (SS-2) | -130.31 | 125.37 |
| Electric Power (kW) | Calculated using (SS-4) | 22.43 | -19.46 |
| Ibatt | Calculated using Ibatt = Pe/Vbatt | 56.06 | -48.65 |
| idc | = ibatt | 56.06 | -48.65 |




| Plot | vs |
|---|---|
| vas(t) | Time |
| ias(t) | Time |
| Vdc(t) | Time |
| idc(t) | Time |
| ibatt(t) | Time |
| Te(t) | Time |

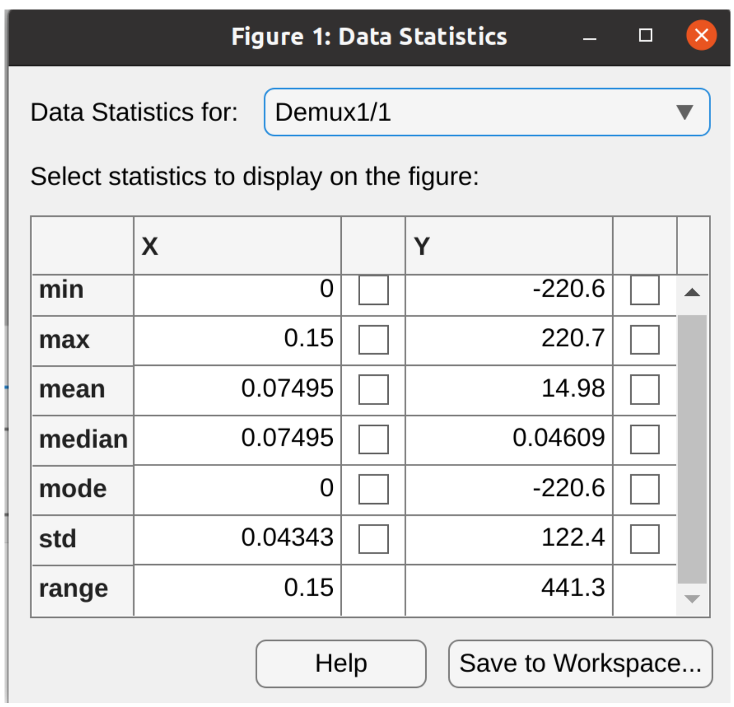
| Variable | Calculated | Simulated | Calculated | Simulated |
|---|---|---|---|---|
| Torque (N.m) | 400 | | -400 | |
| Ias (A) sqrt(Iq^2 + Id^2) | 222.35 | 220.7 | 222.35 | 220.7 |
| | | | | |
| Vqs (V) | -6.1 | | -13.5 | |
| Vds (V) | -130.31 | | 125.37 | |
| Electric Power (kW) | 22.43 | | -19.46 | |
| Ibatt | 56.06 | | -48.65 | |
| Ias peak | | | | |
| Idc | 56.06 | 55.95 | -48.65 | -47.1 |

I got this when I did print to figure, then found an option of data statistics




| | X | Y |
|---|---|---|
| min | 0 | -268.6 |
| max | 0.15 | 275 |
| mean | 0.07495 | -6.864 |
| median | 0.07495 | 0 |
| mode | 0 | 0 |
| std | 0.04343 | 135.3 |
| range | 0.15 | 543.6 |

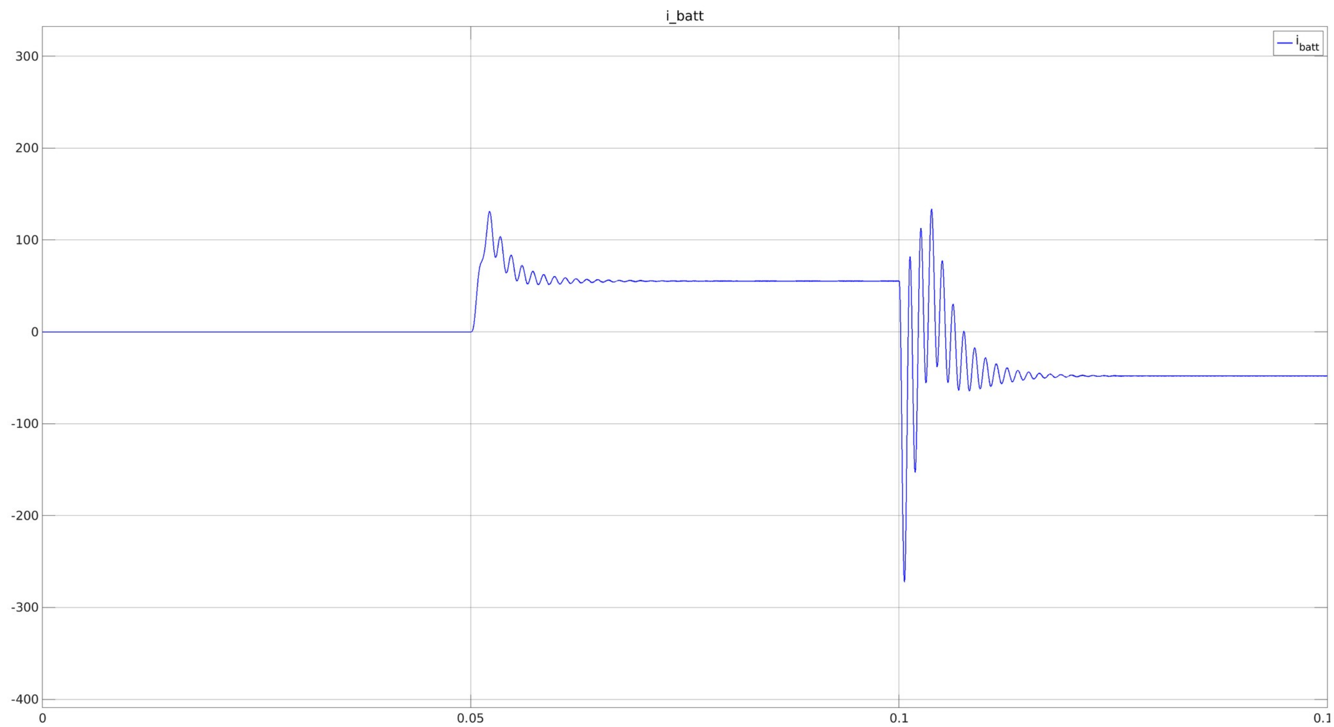
This is the data stats for vas(t)




| | X | Y |
|---|---|---|
| min | 0 | -220.6 |
| max | 0.15 | 220.7 |
| mean | 0.07495 | 14.98 |
| median | 0.07495 | 0.04609 |
| mode | 0 | -220.6 |
| std | 0.04343 | 122.4 |
| range | 0.15 | 441.3 |

this is ias stats

Ibatt:



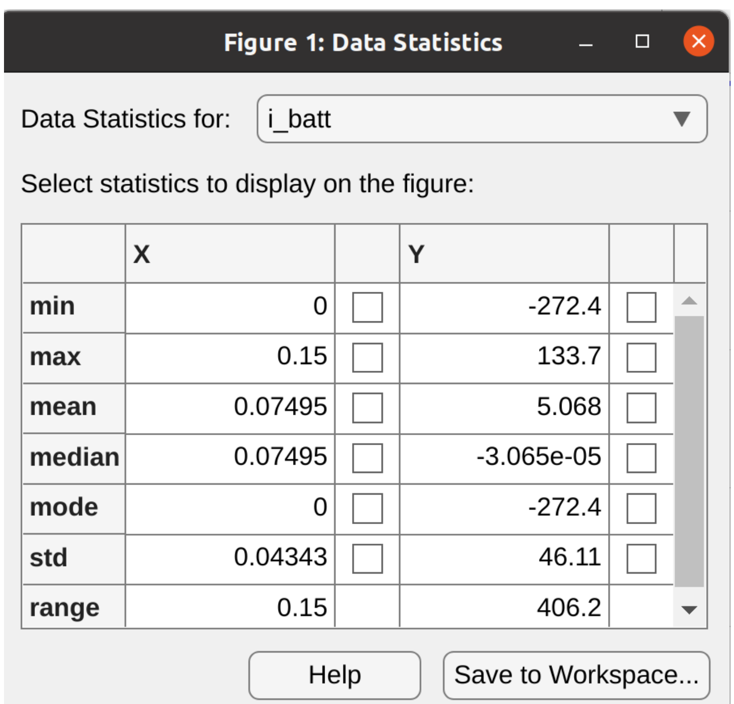



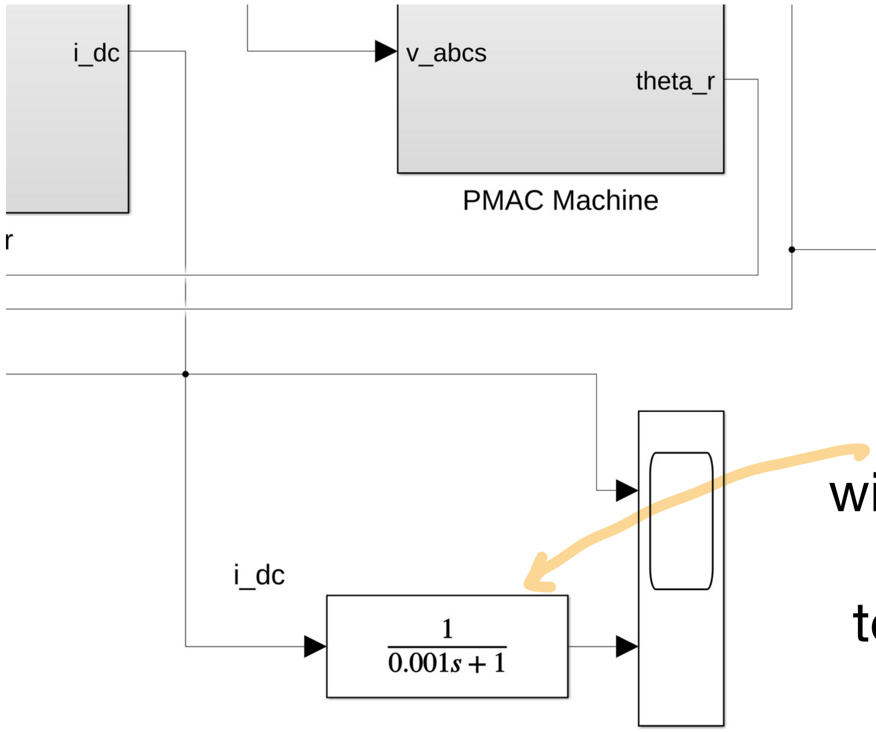
Figure 1: Data Statistics

Data Statistics for: i_batt

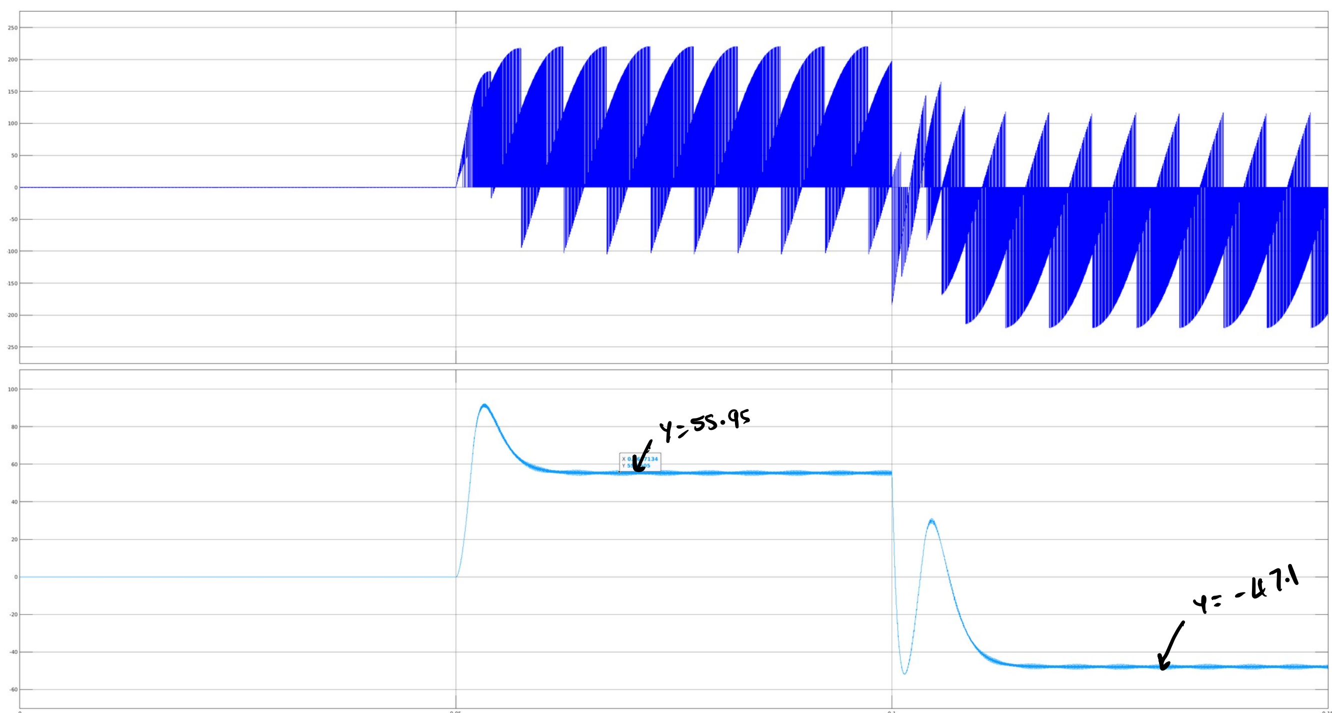
Select statistics to display on the figure:

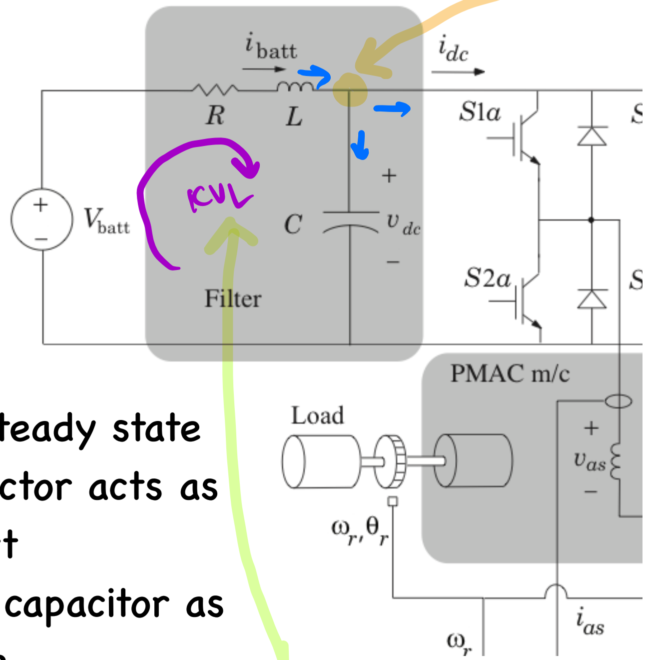
| | X | | Y | |
|---|---|---|---|---|
| **min** | 0 | ☐ | -272.4 | ☐ |
| **max** | 0.15 | ☐ | 133.7 | ☐ |
| **mean** | 0.07495 | ☐ | 5.068 | ☐ |
| **median** | 0.07495 | ☐ | -3.065e-05 | ☐ |
| **mode** | 0 | ☐ | -272.4 | ☐ |
| **std** | 0.04343 | ☐ | 46.11 | ☐ |
| **range** | 0.15 | | 406.2 | |

Help | Save to Workspace...




apply a filter
with time constant
0. 001
to smooth idc to
be
able to find the
average easily.






KCL $i_{batt} = i_c + i_{dc}$

$i_c = C \dfrac{dV_{dc}}{dt}$ plug

$$i_{batt} = C \frac{dV_{dc}}{dt} + i_{dc}$$

$$\frac{dV_{dc}}{dt} = \frac{1}{C}\left(i_{batt} - i_{dc}\right)$$

@ steady state

$$\frac{dV_{dc}}{dt} = 0$$

plug

$$0 = \frac{1}{C}\left(i_{batt} - i_{dc}\right)$$

$$\Rightarrow \underline{i_{batt} = i_{dc}}$$

In steady state
inductor acts as
short
and capacitor as
open.

KVL

$$-V_{batt} + R\, i_{batt} + L \frac{di_{batt}}{dt} + V_{dc} = 0$$

$$L \frac{di_{batt}}{dt} = V_{batt} - R\, i_{batt} - V_{dc}$$

in steady state $\dfrac{di_{batt}}{dt} = 0$

$$\underline{V_{dc} = V_{batt} - R\, i_{batt}}$$

for analysis vs simulation.

why do we use the filter?

All harmonics due to switching in idc would cause losses and heat in the battery.

The filter's job is to smooth the battery current. The capacitor acts as stabilizer to the six-pack's input voltage (vdc)