Student	Last Name, First Name	Userid
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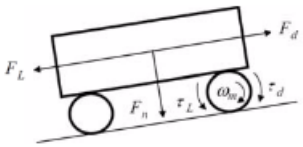
V_D = 400V

a) Operating Condition 1 (Uphill)



n_1=800rpm – Clockwise

T_L = 500 Nm

$$V_{ctrl} = V_{Peak,tri}\frac{V_{A1}}{V_D}$$

$$n_1 = \frac{V_{A1}}{K'\emptyset} - \frac{R_a}{K'K\emptyset^2}T_L$$

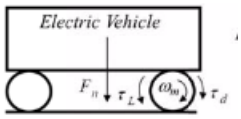
$$V_{A1} = \left[n_1 + \frac{R_a}{K'K\emptyset^2}T_L\right]K'\emptyset$$

$$V_{A1} = \left[800 + \frac{0.2}{4(0.42)}500\right]0.42$$

V_{A1}= 361V

$$V_{ctrl} = 5\frac{361}{400} = \mathbf{4.5125V}$$

b) Operating Condition 2 (Flat)



$n_2 = n_1$=800rpm

T_L= 0

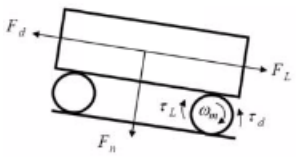
$$V_{ctrl} = V_{Peak,tri}\frac{V_{A2}}{V_D}$$

$$n_2 = \frac{V_{A2}}{K'\emptyset}$$

$V_{A2} = [n_2]K'\emptyset$ = 800(0.42) = 336V

$$V_{ctrl} = 5\frac{336}{400} = \mathbf{4.2V}$$

c) Operating Condition 3



$n_2 = n_1$=800rpm

T_L= -500 Nm

$$V_{ctrl} = V_{Peak,tri}\frac{V_{A3}}{V_D}$$

V_{A3}= $\left[n_1 + \frac{R_a}{K'K\emptyset^2}T_L\right]K'\emptyset$

V_{A3}= $\left[800 + \frac{0.2}{4(0.42)}(-500)\right]0.42$

V_{A3}= 311V

$$V_{ctrl} = 5\frac{311}{400} = \mathbf{3.8875}\boldsymbol{V}$$

d) Operating Condition 4 (hold on downhill)

The speed, n_4, is zero because of the vehicle stopping, but the load torque remains the same.

V_{A4}= $n_4K'\emptyset + \frac{R_a}{K'K\emptyset^2}$ = 0 + $\frac{0.2}{0.42*4}$(-500) = -24.99V

$$V_{ctrl} = V_{Peak,tri}\frac{V_{A4}}{V_D}$$

$$V_{ctrl} = 5\frac{(-24.99)}{400} = -\mathbf{0.3125}\boldsymbol{V}$$

e) Operating Condition 5

The speed, n_5 = -400, is negative because the vehicle is going in reverse, but the load torque remains the same.

V_{A5}= $n_5K'\emptyset + \frac{R_a}{K'K\emptyset^2}$ = -400(0.42) + $\frac{0.2}{0.42*4}$ (-500) = -192.99V

$$V_{ctrl} = V_{Peak,tri}\frac{V_{A4}}{V_D}$$

$$V_{ctrl} = 5\frac{(-192.99)}{400} = -\mathbf{2.412}\boldsymbol{V}$$

f) Operating Condition 6

The speed and load torque becomes zero when the vehicle stops.

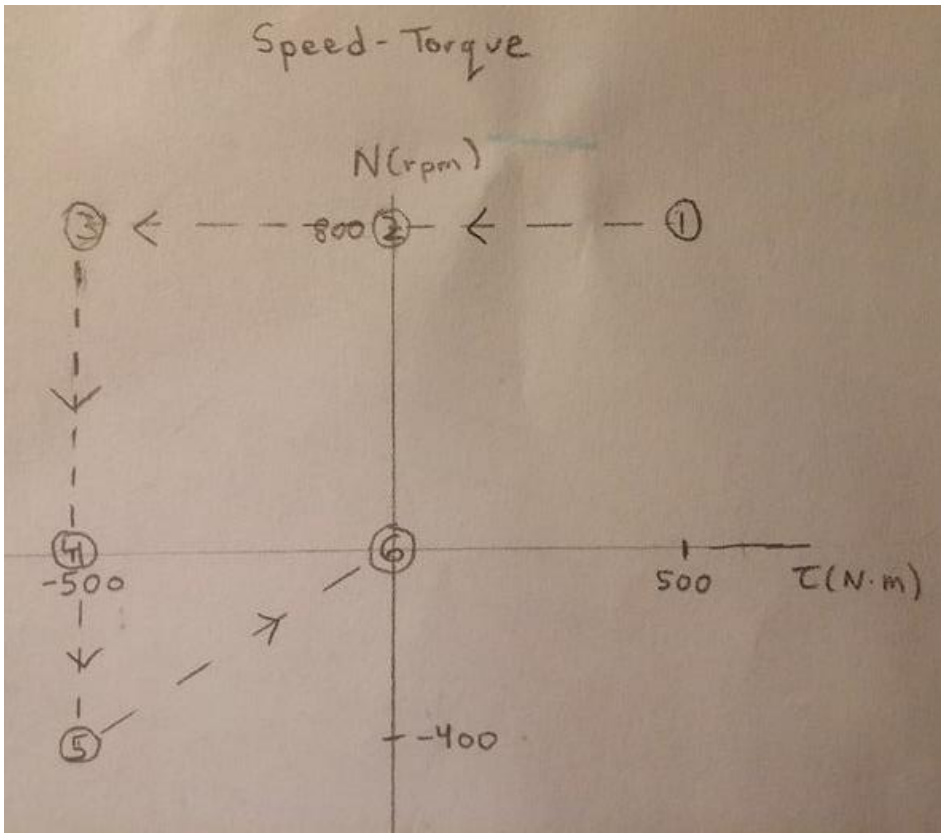
n_6=0 rpm

T_L= 0 Nm

V_{A6} = 0 V

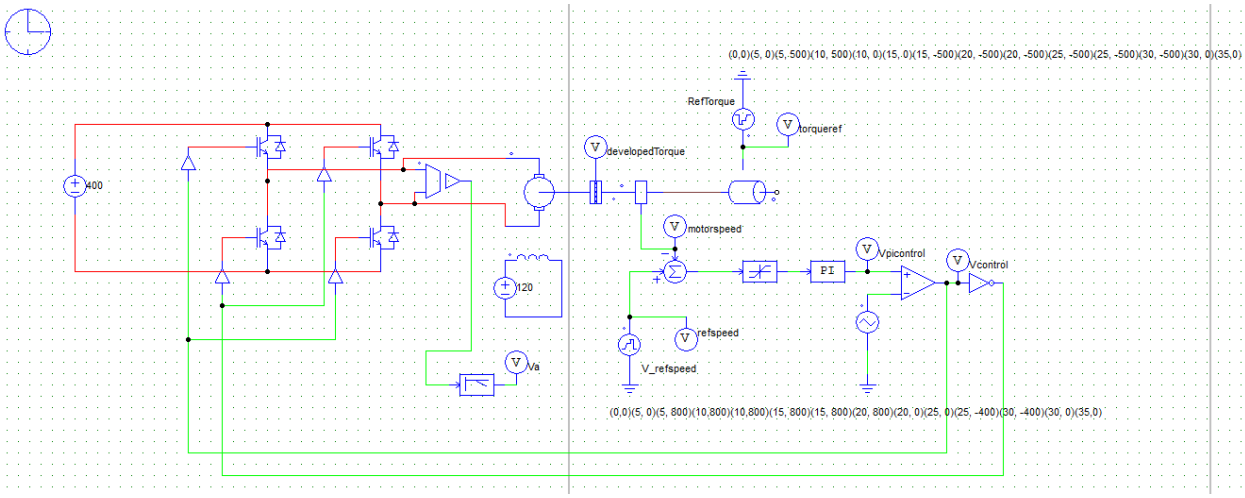
$$V_{ctrl} = V_{Peak,tri}\frac{V_{A6}}{V_D} = \mathbf{0}\boldsymbol{V}$$

g) Speed Torque Graph



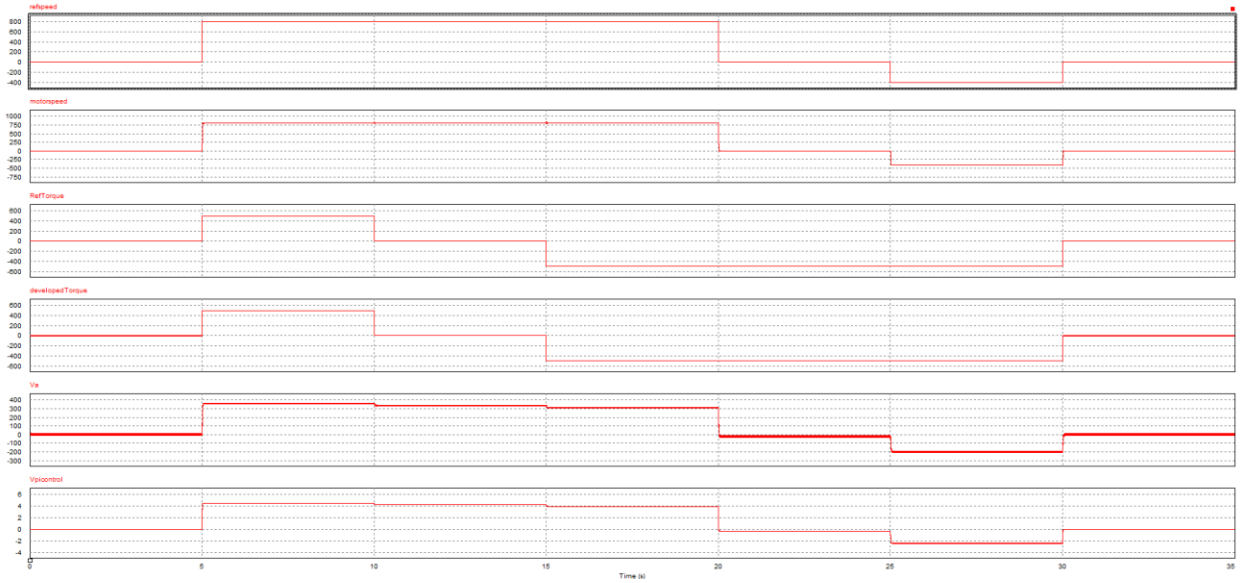
h) Simulation

The operating conditions for the vehicle were operated in PSIM using the circuit below.

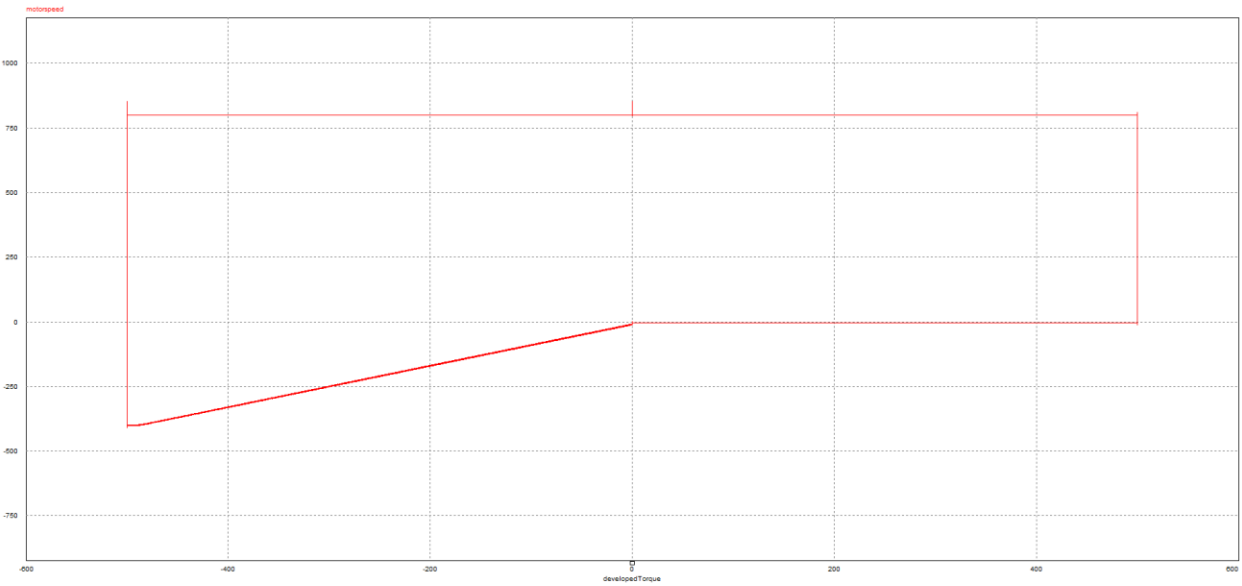


These are the results from the psim simulation that was ran for 35 seconds with the starting reference

speed and torque being 0 for 5 seconds before the operation speed and torque are provided.



This graph shows the speed torque. For the last two operating points, a gradual change was instead of a step change to ensure that the simualted trajectory matched the trajectory found in part g. Without this gradual change, the two operating points are connected by a step instead of a diagonal line.



The table below summarizes the results of calculations.

	Operation 1	Operation 2	Operation 3	Operation 4	Operation 5	Operation 6
Speed (RPM)	800	800	800	0	-400	0
Load Torque (Nm)	500	0	-500	-500	-500	0
Armature Voltage (V)	361	336	311	-24.99	-192.99	0

Control Voltage (V)	4.5125	4.2	3.8875	-0.3125	-2.412	0

This table below summarizes the results of the simulation.

	Operation 1	**Operation 2**	**Operation 3**	**Operation 4**	**Operation 5**	**Operation 6**
Speed (rpm)	800	800	800	1.68	-400	-0.84
Developed Torque (Nm)	500	0.002	-500	-500	-500	0
Armature Voltage (V)	360	336	312	-23	-200	-0.48
Control Voltage (V)	4.5	4.2	3.89	-0.307	-2.41	-0.0023

It can be seen that simulation and calculation results are similar to each other and have an error percentage less than 5%. The speed torque graphs also match up.