Series Brush DC Motor Modeling

UNIVERSITY OF ILLINOIS AT CHICAGO

ECE 458: Electromechanical Energy Conversion - Fall 2024

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1 Introduction

This report will demonstrate the process of modeling a Brush DC Motor 14207S007-SP. And replicating the plots provided in the datasheets for its speed, current, power, and the efficiency all vs torque. All model and the plots units will be converted to SI units.

1.1 Units Conversions

Though not all units need conversion some did; like oz-in to Nm, RPM to rad/s, Regarding the Motor Torque Constant (K_t) and the Motor Voltage Constant (K_e) should be "identical" they are rather close 0.0706155 and 0.0705693 respectively, rounding them would have made them the same but was chosen not to, seeing as they should be close enough to not cause substantial change in the data.

$$1Nm = 141.612\,Ounce - force\,inch \quad 1rad/s = 9.54929\,RPM$$

Table 1: Table of the values in SI units used in the modeling for the simulation

units	**SI**	**units**	**SI**
Supply Voltage (V)	24 V	**Peak Current A**	41 A
Inductance (mH)	0.87 mH	**Terminal Resistance(Ω)**	0.59 Ω
Motor Torque Constant(oz-in/A)	0.0706155 (Nm/A)	**Motor Voltage Constant (V/krpm)**	0.0705693 (V/rad/s)
viscous damping factor(oz-in/krpm)	5.40917723 e6 Nm/rad/s	**Output speed @ cont. torque(RPM)**	294.2625 (rad/s)
Continuous Ouput Torque(oz-in)	0.353078 Nm	**no load ouput speed (RPM)**	330.914 (rad/s)
cont. ouput powewr W	200 W	**rotor inertia(oz-in-s2)**	4.7312 e-5 Nm-s2
Peak ouptput Torque (oz-in)	2.82462 Nm		

$$\text{viscous damping factor: } 0.25\,(oz\,in/krpm) \rightarrow \frac{1Nm}{141.612oz\,in}\frac{30s}{\pi} \tag{1}$$

$$= \frac{1}{1.8487090662} * 1000 = 5.40917723e6Nm/rad/s \tag{2}$$

$$\text{rotor inertia: } 0.0067oz\,in\,s^2\frac{1}{141.612} = 4.731237 \times 10^{-5}Nms^2 \tag{3}$$

$$\text{motor torque const. } 10oz\,in/A\frac{1Nm}{141.612oz\,in} = 0.0706155Nm/A \tag{4}$$

$$\text{motor voltage const. } 7.39V/krpm\frac{30s}{\pi}\frac{1}{1000} = 0.0705693V/rad/s \tag{5}$$

$$\text{peak output torque: } 400oz\,in = \frac{1Nm}{141.612oz\,in} = 2.82462Nm \tag{6}$$

$$\text{no load output speed: } 3160rpm = \frac{\pi}{30s} = 330.914rad/s \tag{7}$$

$$\text{output speed at cont. torque load : } 2810rpm = \frac{\pi}{30s} = 294.2625rad/s \tag{8}$$

$$\text{cont. ouput torque: } 50os\,in\frac{1Nm}{141.612oz\,in} = 0.3530878Nm \tag{9}$$

2 Motor Modeling

The modeling of the motor have been split in 3 parts. The first part is the electrical model of the motor, the second part is the Mechanical model side of the motor; while the third part is the simulation waveform part this is discussed more in the Simulation section.

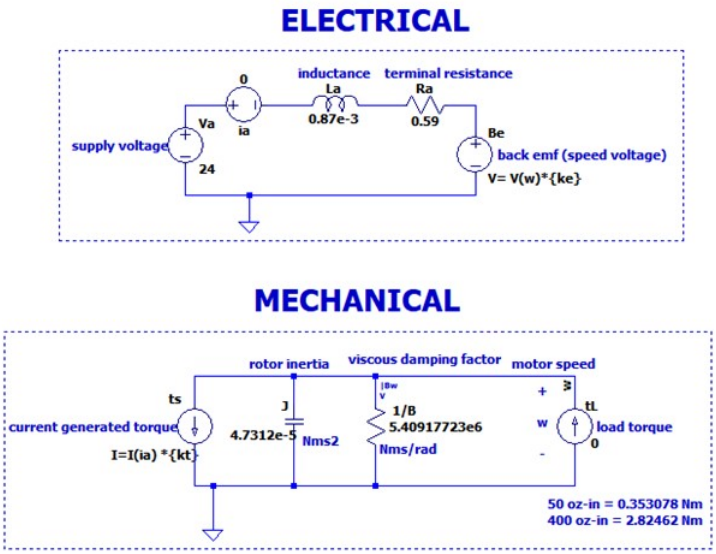


Figure 1: Electrical and Mechanical model

3 Simulation

The simulation was simplified which did not affect the overall plotting and data output. This can be seen in fig 2. The equation used for the plotting are shown bellow from eq. (10) to (13). The simulation units where adjusted accordingly as speed in volts, efficiency as unitless, power in watts, and current in ampeere. The units for speed are regarded for radian per second, and torque in A are corresponding for Nm.

$$Current \Rightarrow I(ia) \tag{10}$$

$$Power \Rightarrow V(w) * I(tL) \tag{11}$$

$$Speed \Rightarrow V(w) \tag{12}$$

$$Efficiency \Rightarrow \underbrace{V(w) * I(tL)}_{V(Power)} / (I(ia) * \underbrace{V(n001)}_{\text{supply voltage} 24V}) \tag{13}$$

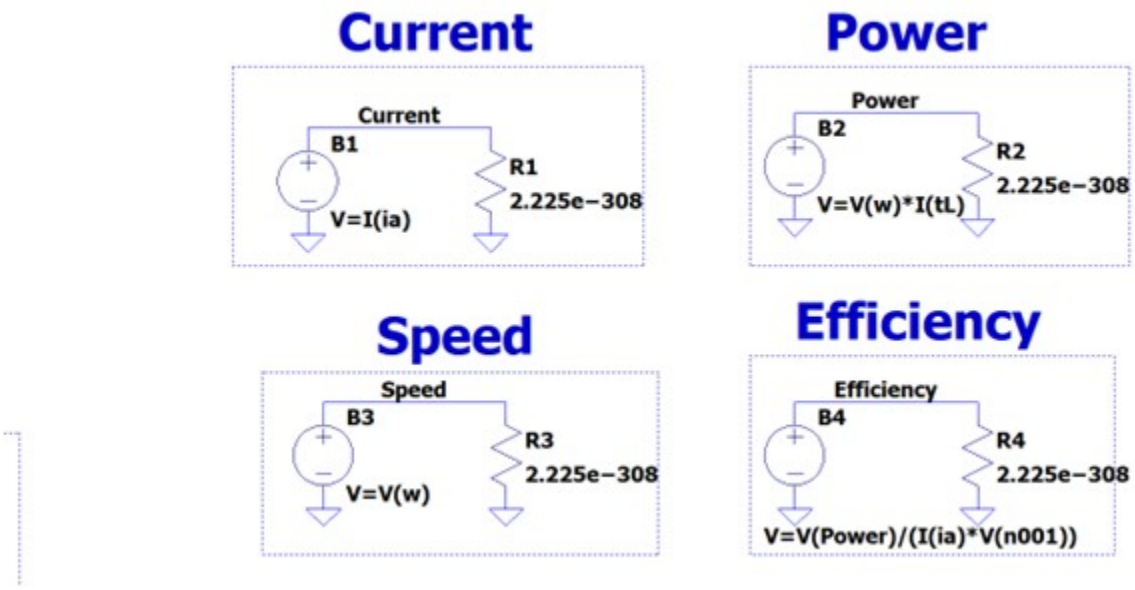
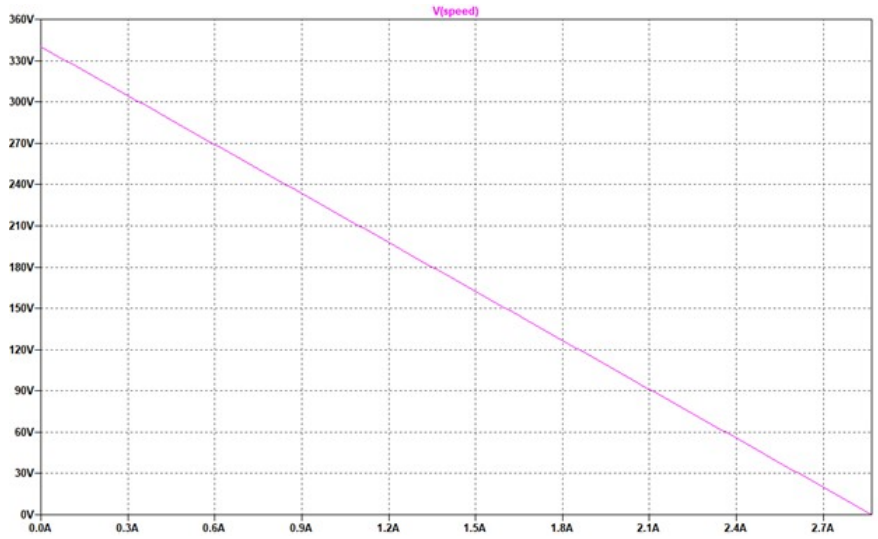
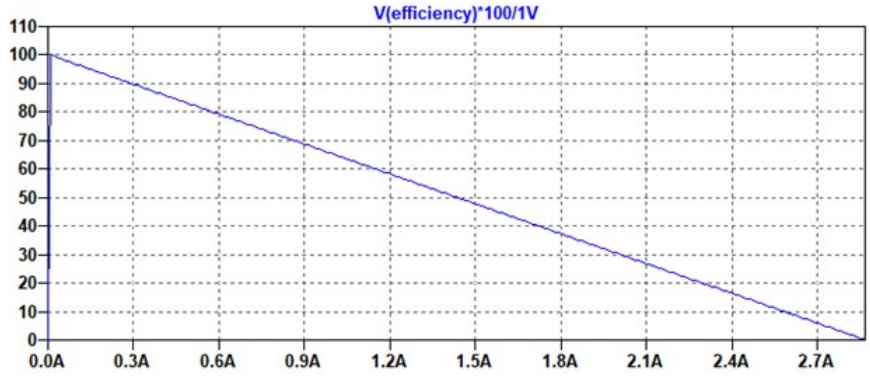


Figure 2: Simplified model

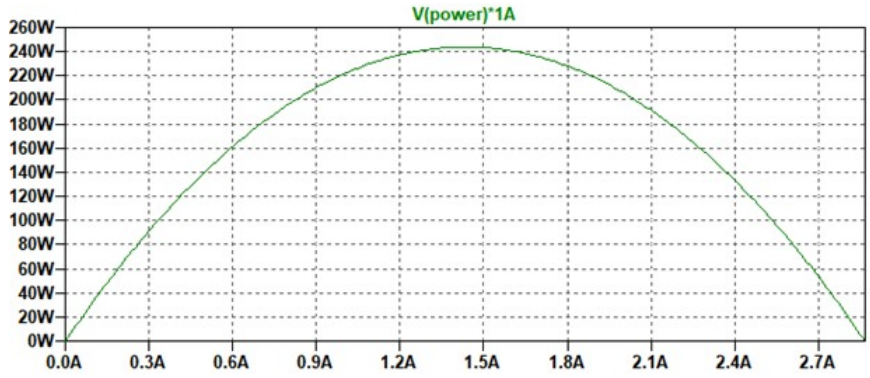
4 Final Plots



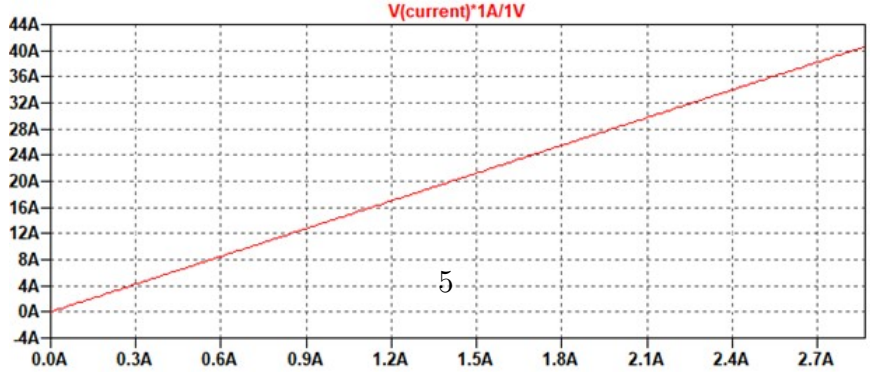
(a)



(b)



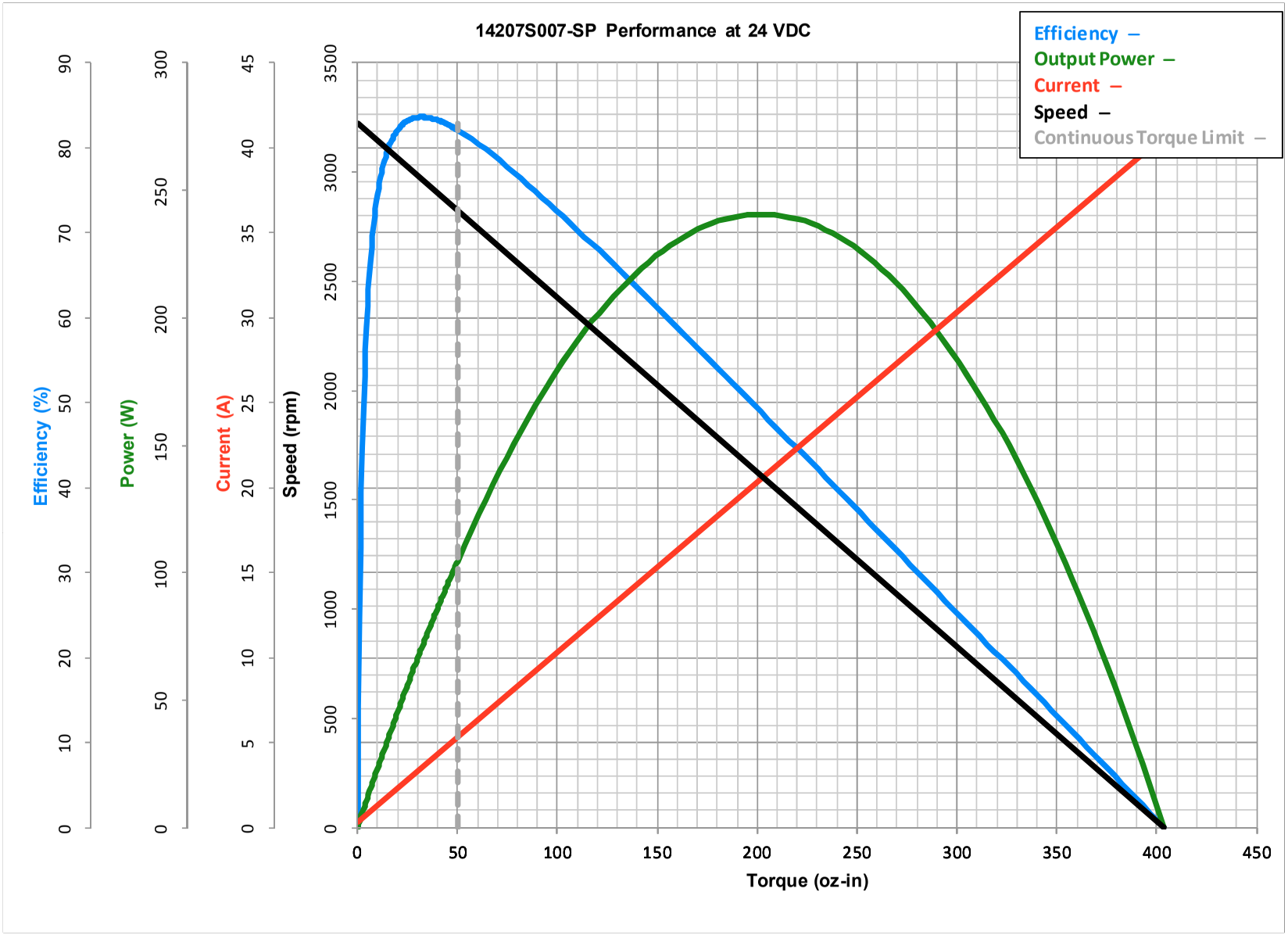
(c)



(d)

5 Conclusion

Overall the simulation was succesful in replicating the plots from the datasheets. Possible differences compared to desired plots, most likley from not including thermal variables or reactions from temperature and how resistance could react to outside sources. Also the difference in the efficiency can be due to thermal reistance, the thermal time constant, especially the electrical and mechanical time constant which where left out of the final simulation.



All values are nominal at 25°C. Peak torque and peak current are theoretical values. Curves are shown for reference only.
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Figure 4: Target plots

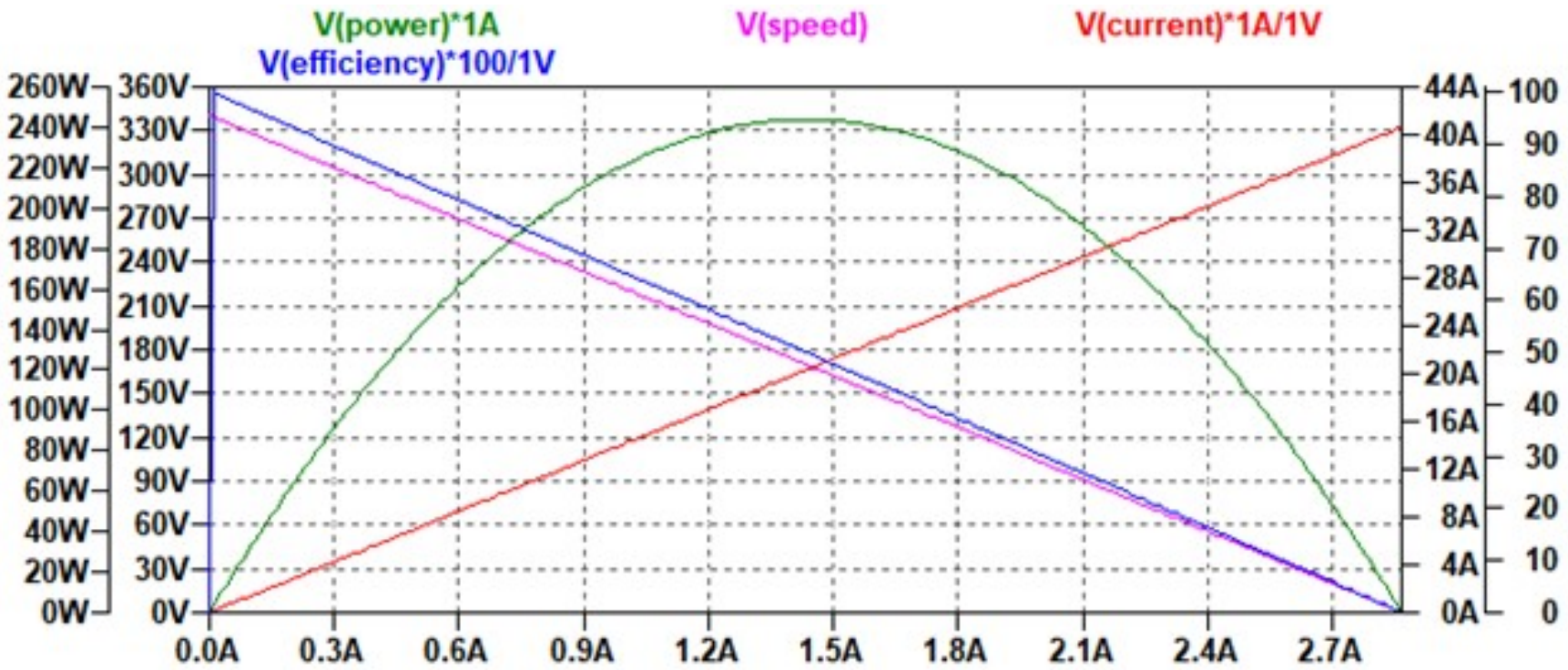

Figure 5: Sim plots

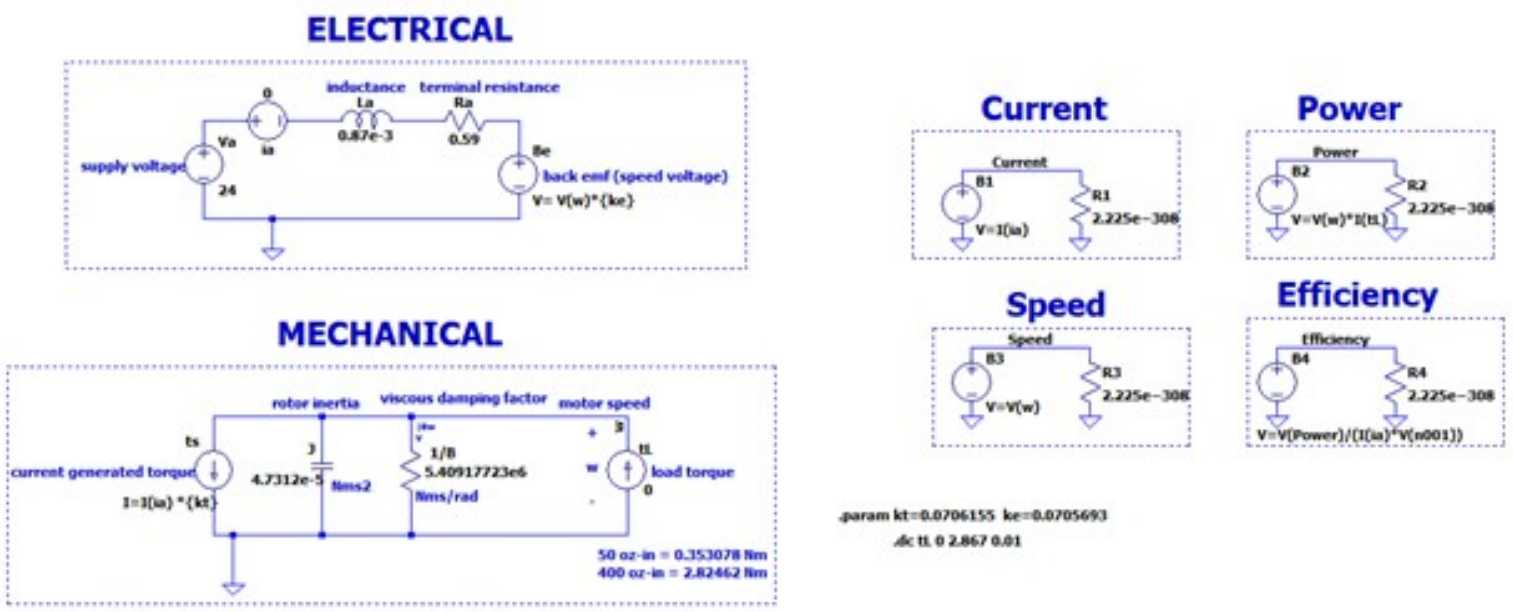

Figure 6: ltspice