LFEV Project: Physics Modeling and Cruise Control

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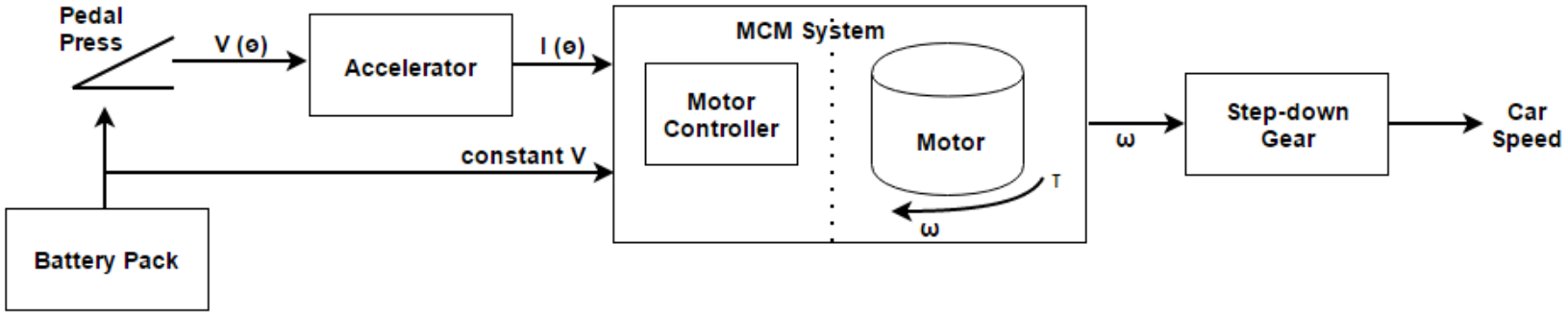
Physical Integration of LFEV

Two approach types:

- Physical model
  - Considers parameters with physical meaning, i.e. load torque, motor speed and supply current
- User (driver) controlled model
  - Considers parameters the driver can access in situ, i.e. throttle controlled by pedal press



Mathematical Relation of MCM I/O

By conservation of power,

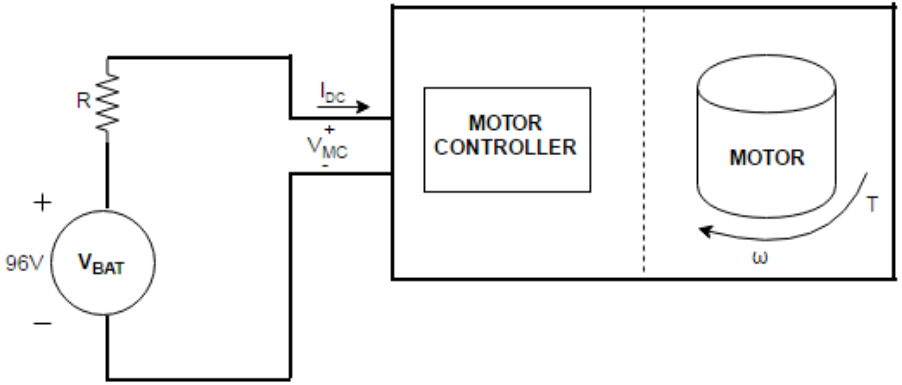
$$vi = \tau\omega$$

Where v (V) is supply voltage, I (A) is supply current , τ is load torque (Nm) and ω is motor speed (rad/s)

$$P_{in} = vi$$

$$P_{out} = \tau\omega$$

Where P_{in} and P_{out} are electrical and mechanical power (Watts) respectively.



Experiments and LFEV maintain constant supply voltage, resulting to changing of both τ and ω

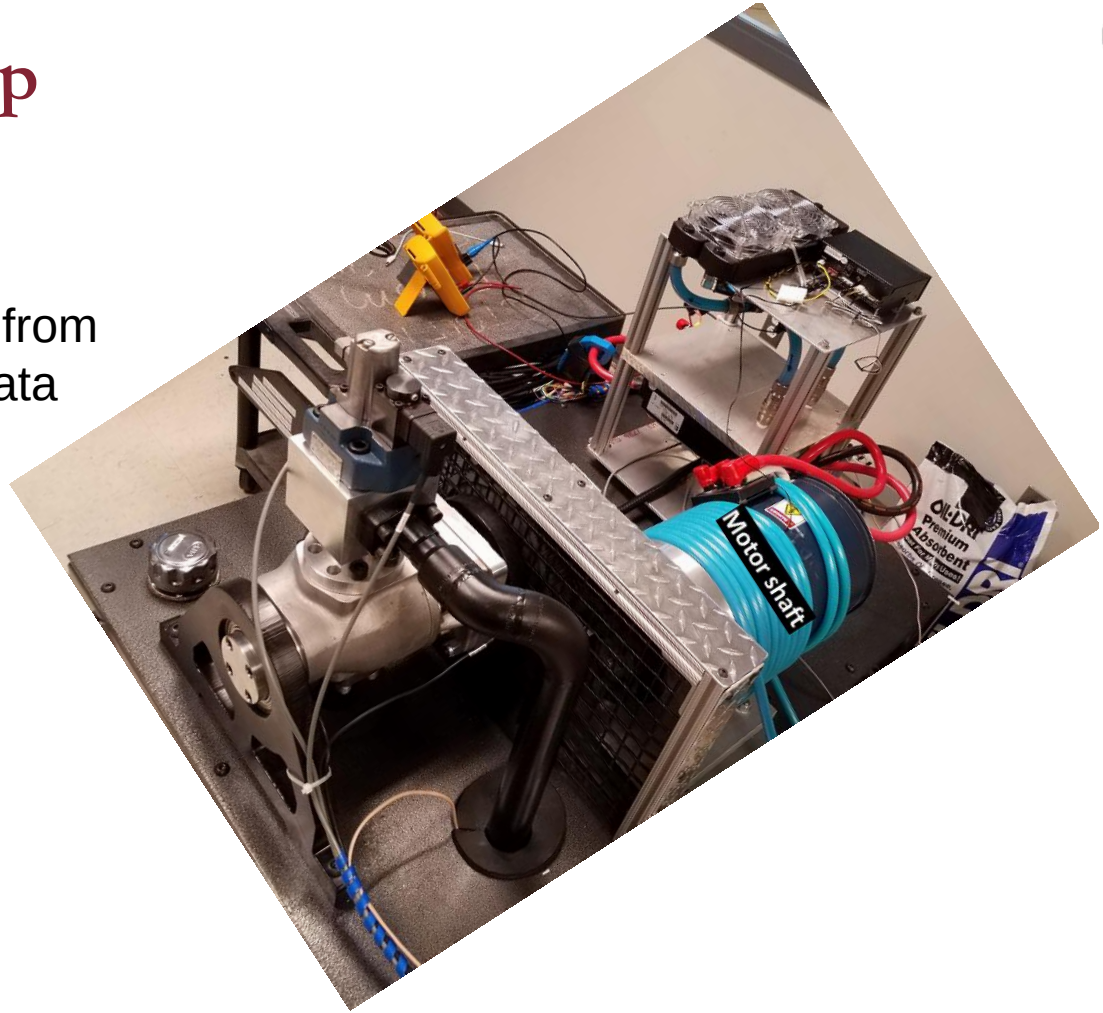
$$P_0 = ki \qquad \text{Eq.4}$$

$$P_0 = \tau\omega \qquad \text{Eq.5}$$

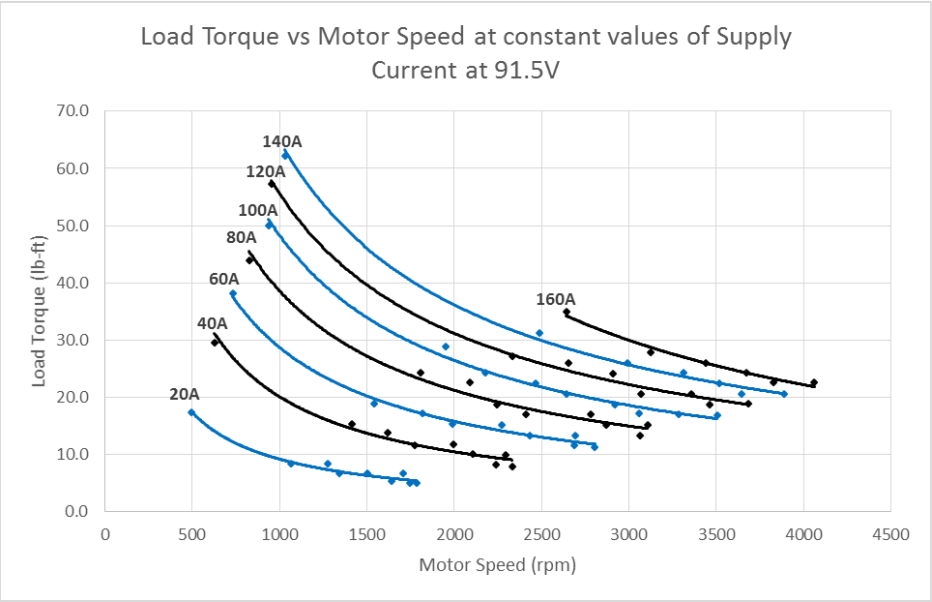
For constant power P_0, I (A) is directly proportional to P (W) with constant voltage k (Eq.4), while ω and τ exhibit hyperbolic relationship (Eq.5). T and ω change at different degrees, thus to analyze changing current effect, one of the mechanical parameters is held constant.

Experimental setup

Dyno setup *pseudo LFEV* from which Physics Modeling data was collected remotely through a CAN bus.

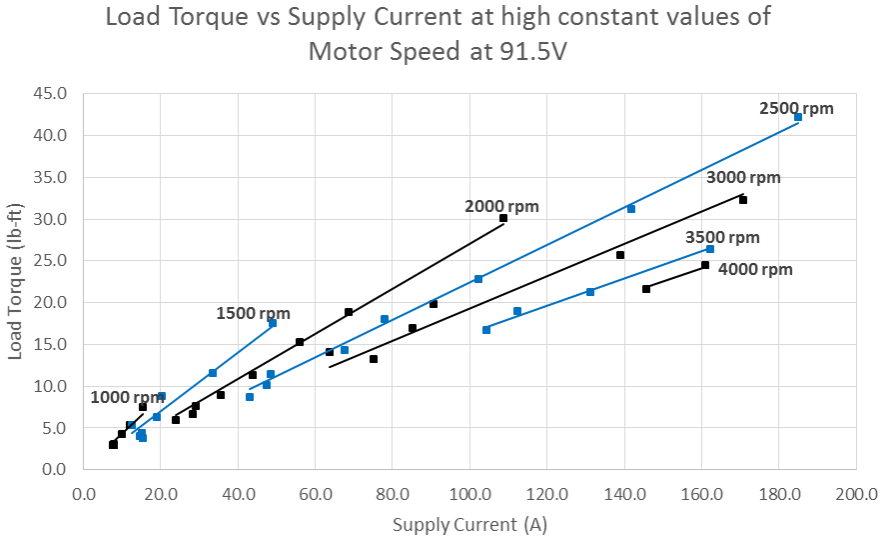


Electric Motor Plausibility for LFEV



At constant current, motor speed self-adjusts at a set load torque value to meet the power which the current is proportional to, resulting in hyperbolic relationship

At constant motor speed, a set increase in load torque results to an increase in supply current to maintain the given constant motor speed.



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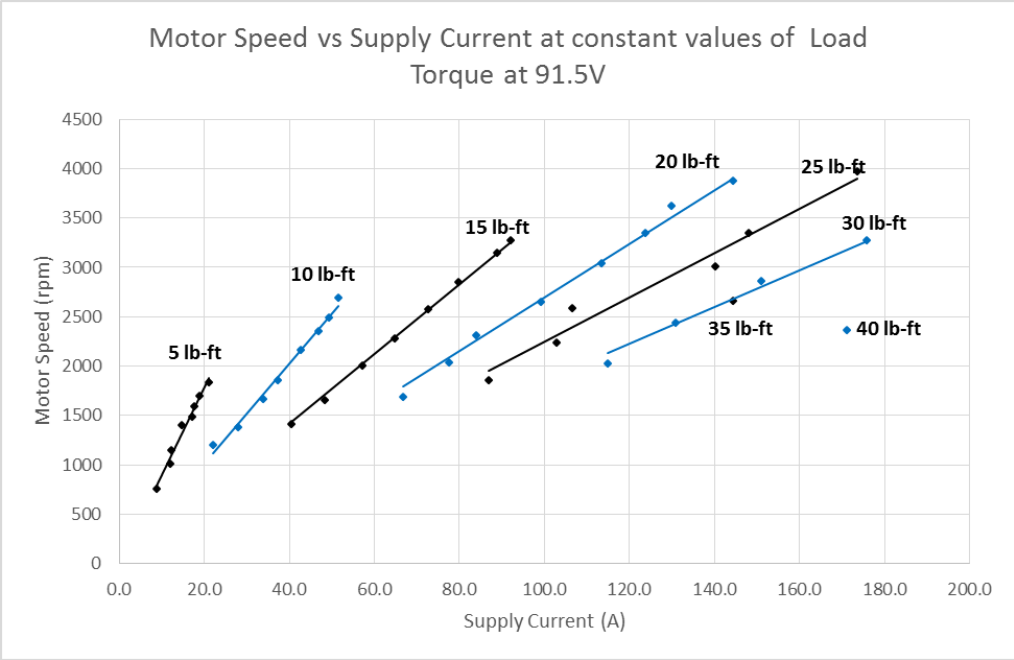
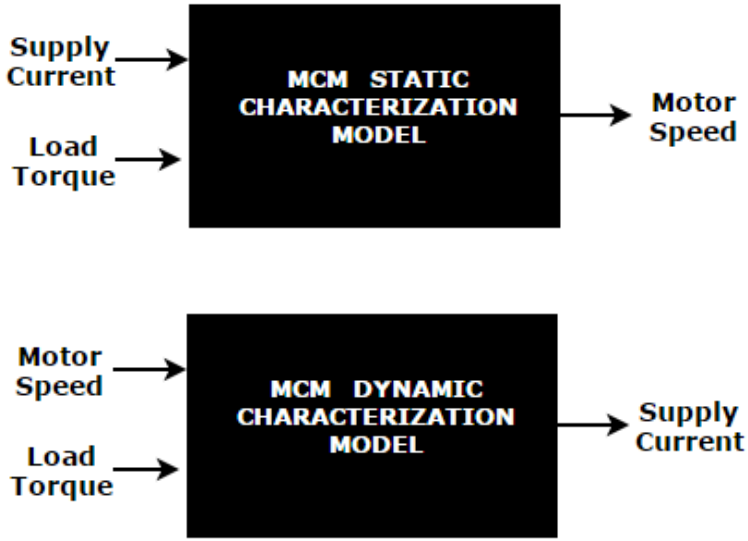


Physical Parameter	Working Range
Load Torque (lb-ft)	0 – 70
Motor Speed (rpm)	0 - 4000
Supply Current (A)	0 – 185 (limited by PS)

At constant load torque, a set increase in motor speed results to an increase in supply current to maintain the given constant load torque.

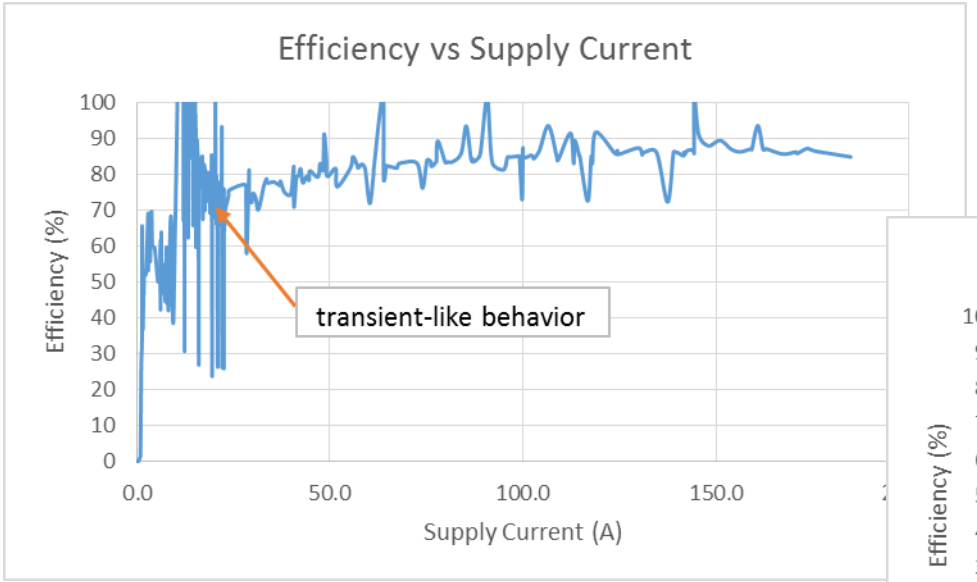
Dynamic and Static Model Lookup Table

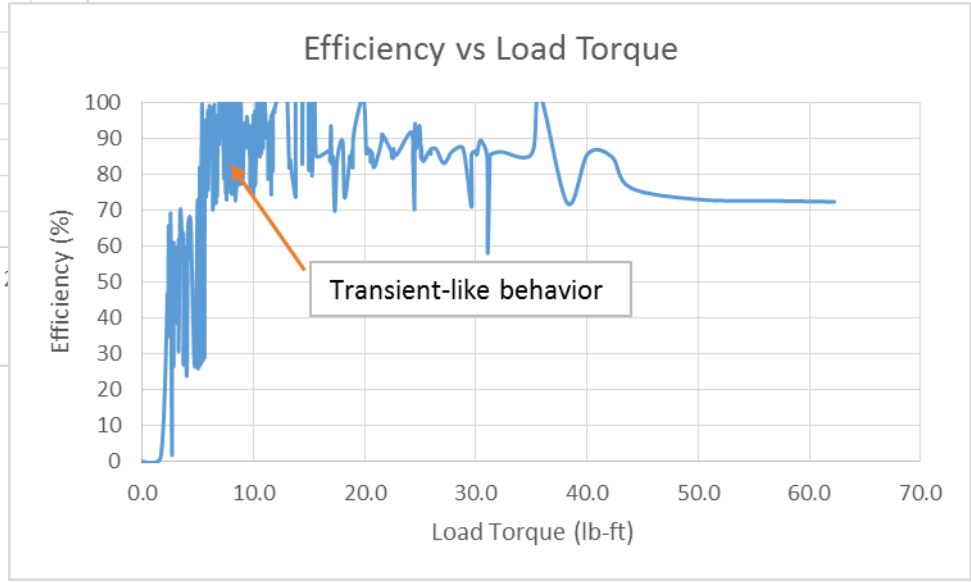


ID Number	τ (lb-ft)	*i (A)*	ω (rpm)	% load	*v (V)*	P_Elec (W)	New_i (A)
Zainab_4-6-2017	2.3	3.1	493	20	91.5	284.6	3.1
Zainab_4-5-2017	17.3	19.0	494	50	91.5	1738.5	19.0
Zainab_4-6-2017	2.7	3.5	510	0	91.5	321.2	3.5
Zainab_4-6-2017	2.5	2.9	510	5	91.5	264.0	2.9
Zainab_4-6-2017	2.4	3.4	518	25	91.5	311.1	3.4
Spring_2016	2.8	3.9	540	100	89.7	356.9	4.0
Diego_3-31-2017	24.5	30.8	570	0	89.6	2818.2	31.5
Spring_2016	2.8	5.3	613	100	89.7	485.0	5.4
Zainab_3-31-2017	2.8	4.5	614	0	89.6	411.8	4.6
Zainab_4-5-2017	29.6	40.7	629	50	91.5	3724.1	40.7
Spring_2016	3.0	5.7	644	100	89.7	521.6	5.8
Spring_2016	3.0	6.0	690	100	89.7	549.0	6.1
Spring_2016	3.1	6.2	721	100	89.7	567.3	6.3
Spring_2016	3.1	6.4	722	100	89.7	585.6	6.5
Spring_2016	3.1	6.3	722	100	89.7	576.5	6.4
Spring_2016	3.1	6.2	722	100	89.7	567.3	6.3
Spring_2016	3.1	6.2	722	100	89.7	567.3	6.3
Spring_2016	3.1	6.2	722	100	89.7	567.3	6.3

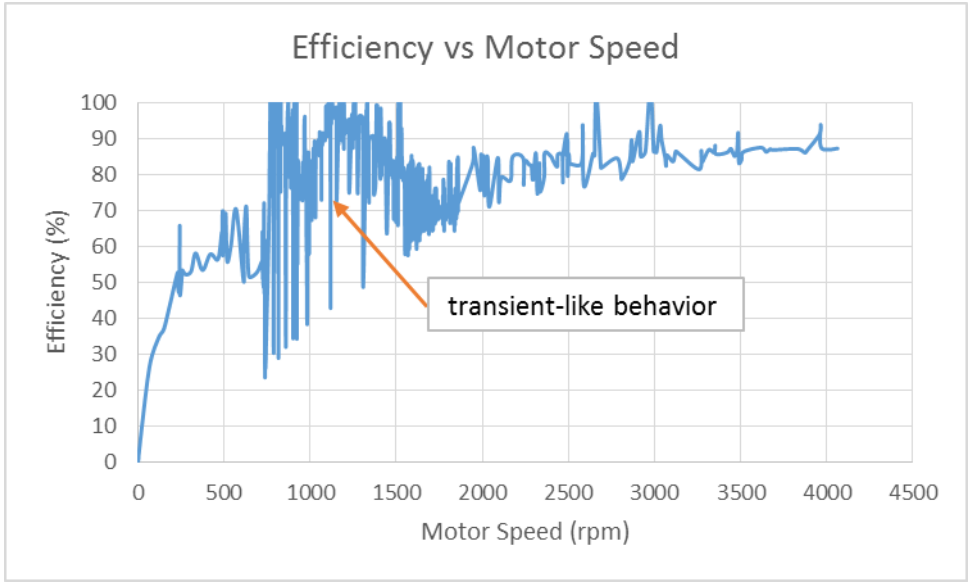
Sample section of the lookup table specific to the HPEVS AC50515X Motor used for the LFEV

MCM Efficiency





MCM Efficiency



Transient-like behavior possibly caused by:

- Motor unstable at the given physical parameter low range
  - Working range of motor specified excluding the transient.
- Data for plot is from all combined data collected.
  - Experimental data collected in spring ‘17 had irregularities cleaned. Spring ‘16 used as raw (no documented irregularities for data collection)

Conclusion

- Observed throttle (physically represented by pedal press) translation to supply current as direct proportionality.
- Determined electric motor plausibility for LFEV
- Accurate Physics model a good foundation for cruise control

Future Work

Cruise control Simulink simulation building from the physics model