Predicting EV Drive Range

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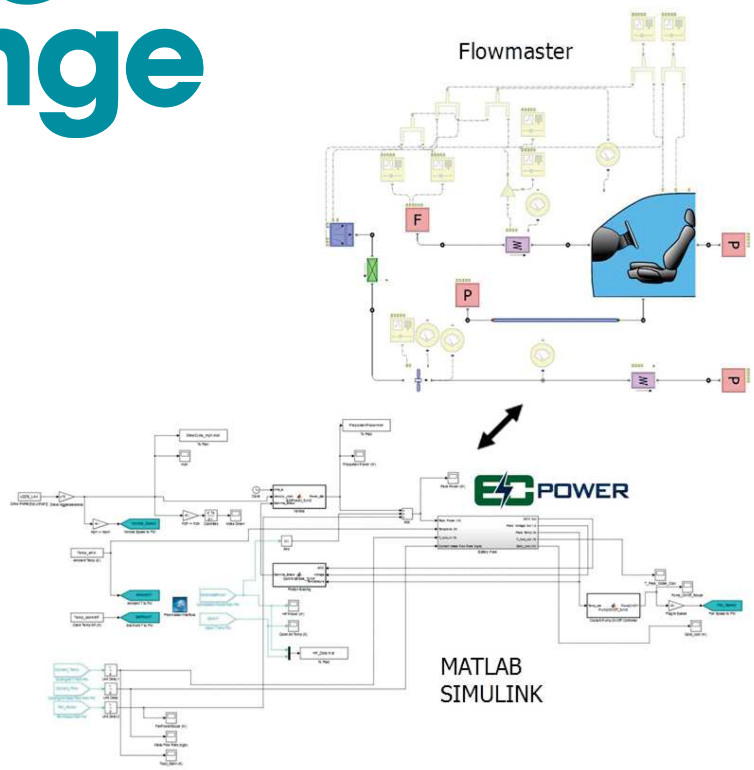

Could the era of the electric car finally be upon us? The answer is yes, but there is still a long way to go. A major concern for consumers of electric vehicles has been that the range of these vehicles has shown to be extremely variable with ambient temperature, [1,2] The ability to understand the effects that potential factors will have to the range of any EV is critical to creating a better design and thus improving the product for customers, ultimately driving increasing adoption. For this reason, the earlier an engineer is able to quantify how different factors will affect the EV, the better, and one of the most efficient ways to do this is through computer simulation.

The purpose of this study was to quantify the ability to capture at least some of these effects using a co-simulation approach to represent different segments of the vehicle. The results were then compared against published empirical data collected by Charged[3] magazine to determine how well the approach fits real world test results. The co-simulation was done using three different software packages to model different parts of the vehicle.

Parameter	Value
Energy	24 kWh
Cells in Series	96
Cells in Parallel	2
Cell Shape	Prismatic
Cathode	70/30 LMO/NMC
Anode	Graphite

Table 1. Battery Design Parameters

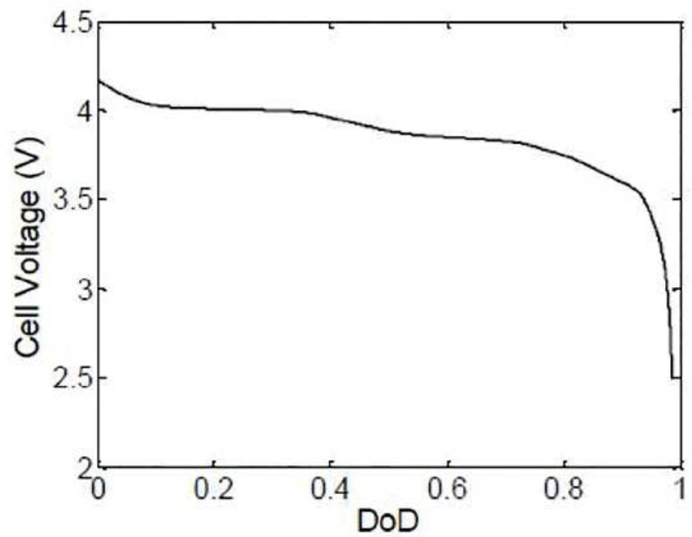

Figure 1. C/3 Discharge Curve for a Single 70/30 LMO/NMC 33Ah Cell

Battery Pack Model

The performance of the battery was modeled using EC Power's AutoLion-ST™. The pack and cells were loosely configured to represent the first generation Nissan Leaf design. The model was responsible for handling three aspects of the simulation, calculating the temperature of the battery pack, calculating the pack voltage, and calculating the State of Charge (SoC).

From the vehicle model, the battery model received a total pack power requirement with the simulation continuing until the battery model reached a SoC state of 20%.

Vehicle Model

The vehicle portion of the model was constructed in MATLAB Simulink®. The vehicle model acted as the platform for the entire co-simulation collecting and distributing data between models. As part of this task, the model also set several of the initial conditions including: ambient, cabin, and battery temperatures; cabin set-point; drive cycle and driver aggressiveness factor.

The vehicle model was also responsible for determining the total power requirement of the vehicle. This included the effects of drag, braking, drivetrain inefficiencies, and propulsion/regeneration from the electric motor. The model also separately determined the cooling fan on/off state with the required power added to the total requirement if necessary.

Cabin Thermal & Battery Cooling Model

The cabin and battery cooling air portions of the model were constructed in Mentor Graphics 1D Computational Fluid Dynamics tool, Flowmaster. The primary purpose of the Flowmaster model was to calculate the power required to maintain the given set-point temperature of the cabin at the different ambient temperatures and vehicle velocities. To accomplish this, the Automotive 1D Cabin component was used to calculate the average cabin temperature as a function of inlet airflow rate, air temperature, and vehicle velocity. The model was able to account for the difference in external heat transfer based on when the vehicle was moving or stationary as well as the heat input due to solar radiation.

The HVAC system was modeled as a simplified heating or cooling generation component. This component added or removed heat to the airflow entering the cabin based on the feedback from Flowmaster's PID controller. A Coefficient of Performance (CoP) of two was used to account for the inefficiencies in the HVAC system.

The Flowmaster model was also responsible for calculating the temperature of the battery pack cooling air and the cooling fan power requirement. If the temperature rose high enough, the vehicle model would signal that the fan should be running. Under these circumstances, Flowmaster would calculate the heat added to the airflow due to the fan inefficencies as well as the power the fan required. The overall Flowmaster power requirement fed back to the vehicle level model to be included in the total power requirement of the battery.

Factor	Values
Driver Aggressiveness	0.8, 1.0, 1.2
Cabin Set Point Temperature	15, 20, 24 (°C)
Ambient Temperature	-10, 0, 10, 20, 30, 40, 50 (°C)

Table 2. Study Factors and Values

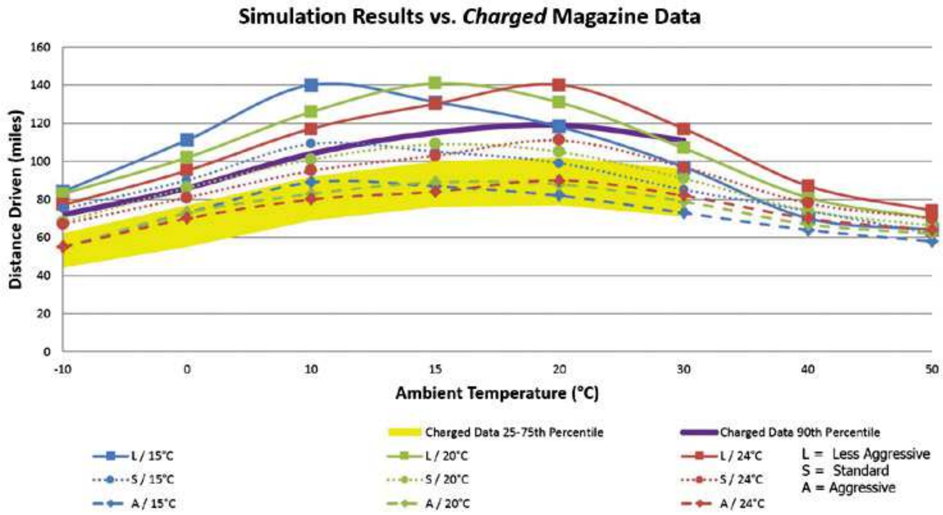

Figure 2. Predicted Drive Range for different Ambient Pressures vs. Published Data

Results and Conclusions

The purpose of the study was to understand how different factors effected the overall drive range of the vehicle through simulation. The three factors chosen for the study were driver aggressiveness, cabin set point temperature, and ambient temperature. Several values for each factor were used in the study as a full factorial study:

Each co-simulation ran for between five and ten minutes ending once the SoC of the battery model reached 20%. In total, the seventy-two studies were run over two days requiring approximately eight hours of engineering time.

The results can also be shown against the data publish in Charged magazine. In figure 2, the yellow band represents the middle 50% of test data collected while the solid purple line represents the longest 10% of drive ranges.

Overall the trends seen from the analysis, are what was expected before the study began. As shown in figure 2, the results were on the upper end of what was seen by Charged magazine as part of their data collection. Further refinement to the estimates for drive cycle and driver aggressiveness could improve this correlation. The model could also be further developed, including more accurate data for the cabin materials as well as the performance of the HVAC system.

With improvements to the model the spread of distance results would likely decrease to be more consistent with test data. The study showed that while drive range information can be determined through test, using a co-simulation approach, a reasonable approximation was possible from a full factorial of driving scenarios in less than one engineering day.

Literature

[1] Heather Hunter, AAA News Room, "Extreme Temperatures Affect Electric Vehicle Driving Range, AAA Says," March 20, 2014 http://newsroom.aaa.com/2014/03/extreme-temperatures-affect-electric-vehicle-driving-range-aaa-says/

[2] Consumer Reports News, "Winter chills limit range of the Tesla Model S electric car," February 15, 2013. http://www.consumerreports.org/cro/news/2013/02/winter-chills-limit-range-of-the-tesla-model-s-electric-car/index.htm

[3] "FleetCarma Goes Deep into the Data", Charged. Pg. 56-61. Jan/Feb 2015.

[4] Kolak, D., Shaffer, C., Marovic, B., Sinha, P.

Prediction of EV Drive Range Reduction under Extreme Environmental conditions using Computer Aided Engineering Tools

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