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Quantifying Variability in Detailed Energy Useage on Repeated Trips in the Chevrolet Volt

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Abstract

There is a large quantity of data available on the CAN bus of the Chevrolet Volt that can be obtained through the OBD2 connectors on both the passenger and driver side of the vehicle. Although much of this is not available on the console of the vehicle to passengers, it can be logged and collected to analyse various vehicle performance measures and behaviours as well as charging characteristics. A set of pertinent data has been collected simultaneously for approximately 40 vehicle parameters for numerous trips and charging events for the 2012 Chevrolet Volt. The average energy useage for each trip and the trip length have been summarized to illustrate that for the same trip there are a number of variables that can introduce significant variability in the amount of energy used by the vehicle. Individual trips were logged at a sample rate of ~1000 Hz and as many variables as could be controlled were kept constant to illustrate and compare the effects of driving behaviour on the energy useage. Driving at several different constant speeds for the entire trip was compared for total energy useage. It is noted that there is a significant increase in energy usage for a particular trip travelled at a faster speed.

Keywords: efficiency, energy consumption, environment, EV, vehicle performance

1 Introduction

Electric vehicle technology has evolved to the point where commercial units are available and becoming more popular in the marketplace. Electric passenger cars have many attractions: they run on electricity and thereby may use a variety of primary energy sources such as solar, wind, and nuclear to eliminate dependence on imported petroleum and emissions of carbon dioxide. They are silent, simple in concept and may have minimal service and maintenance requirements. At present, the range is limited by battery technology but the recent introduction of lithium based (lithium ion, lithium polymer, lithium iron phosphate) batteries has increased the range of pure electrics to the point where a very attractive vehicle can be designed with a 100 mile range. The considerations of the past years have also taught the industry that recharging infrastructure at home and on the highway can improve the utility of electric cars to the point where they may make significant inroads into the vehicle marketplace. Further improvements in battery cost, life and specific energy will only enhance the acceptance of these vehicles in the future.

There is a large quantity of data available on the CAN bus of the Chevrolet Volt that can be obtained through the OBD2 connectors on both the

passenger and driver side of the vehicle. Although much of this is not available on the console of the vehicle to passengers, it can be logged and collected to analyse various vehicle performance measures and behaviours as well as charging characteristics. A set of pertinent data has been collected simultaneously for approximately 40 vehicle parameters for numerous trips and charging events for the 2012 Chevrolet Volt. Some of the key parameters are battery voltage, battery current, motor currents, state of charge, engine rpm, vehicle speed, longitude, latitude, altitude, battery power, motor power, etc. The average energy useage for each trip and the trip length have been summarized to illustrate that for the same trip there are a number of variables that can introduce significant variability in the amount of energy used by the vehicle. This has been supported by [1], [2] and even thirty years ago in [3]. The difference today is in the available technology and characterizing a specific vehicle, the Chevrolet Volt. Individual trips were logged at a sample rate of ~1000 Hz and as many variables as could be controlled were kept constant to illustrate and compare the effects of driving behaviour on the energy useage. Driving at several different constant speeds for the entire trip was compared for total energy useage. It has been documented that there is a significant increase in energy useage for a particular trip travelled at a faster speed [4].

2 Results and Discussion

The energy useage of the Chevrolet Volt varies widely depending on the conditions where it is driven and the driving behaviour. Figure 1 shows numerous data points and demonstrates the variability seen in the Chevrolet Volt on energy useage in Wh/mile for a variety of trips totalling 12,000 miles in total distance. It is seen that there is a range between 115Wh/mile up to 562 Wh/mile. The average energy useage over all these trips is 272 Wh/mile. Most of the extreme high energy useages were a result of heating and defrost on cold days. If these cases are removed then the variability is reduced and mostly results from differences in driver behaviour (acceleration and speed) when similar elevations are driven.

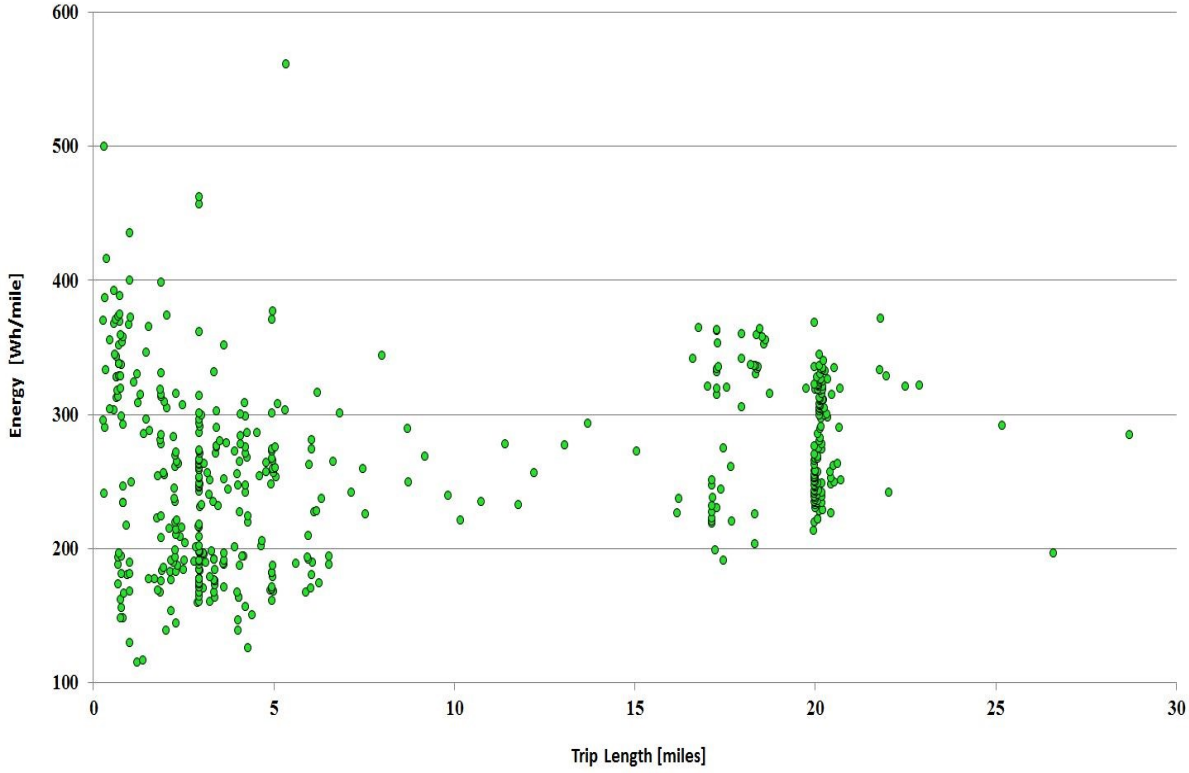

Figure 1: Variability of Energy Use per mile for different trips. Shorter trips on average tend to have a lower energy use per mile. It is also clear that for the particular vehicle that the majority of trips are in the 20 mile range (commute to work) or short trips between 3to 4miles.

In figure 1 it is clear that there is a clustering of trips around 20 miles which represent a work commute and another cluster of very short trips in the 3-4 mile range for local travel. The elevation of the last 17 miles (first three miles are city driving) of the typical 20 mile commute is shown in Figure 2. The trip involves mostly highway conditions with demanding elevation increases (1000 feet) and elevation decreases (1500 feet). It can be seen that the battery power reaches peaks of 110kW and also periods of 50kW regeneration from the large downhill slope. Half of the 20 mile trips seen in Figure 1 are below 300 Wh/mile as they benefit from the significant drop in elevation. The other half of these trips exceed the 300 Wh/mile as the demanding climb, although handled with ease by the Volt, demands significantly more energy for the same distance. This breaks these two groups of trips into separate categories for energy use as the terrain is significantly different depending on the direction of travel. In the shorter in town trips, the difference is less pronounced such that the dominant factor influencing energy use is the driver behaviour.

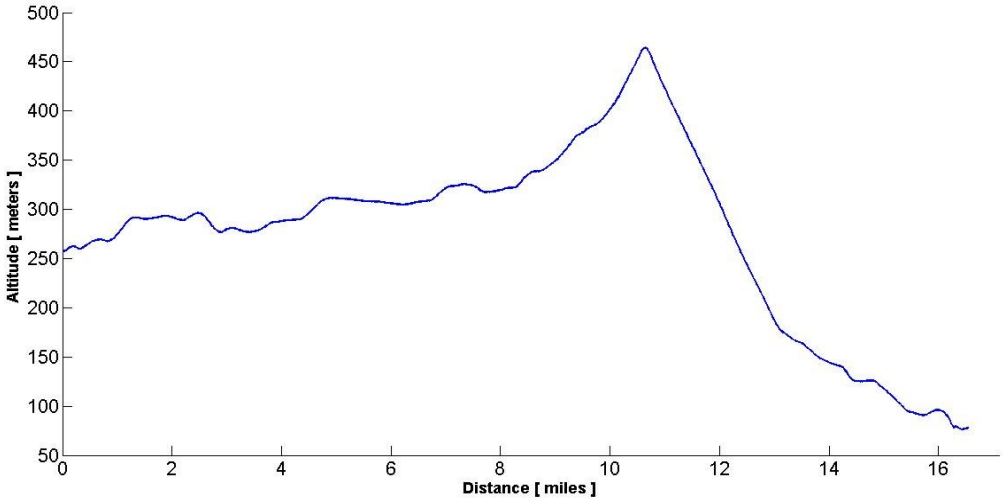

Figure 2: Elevation profile of commute trip.

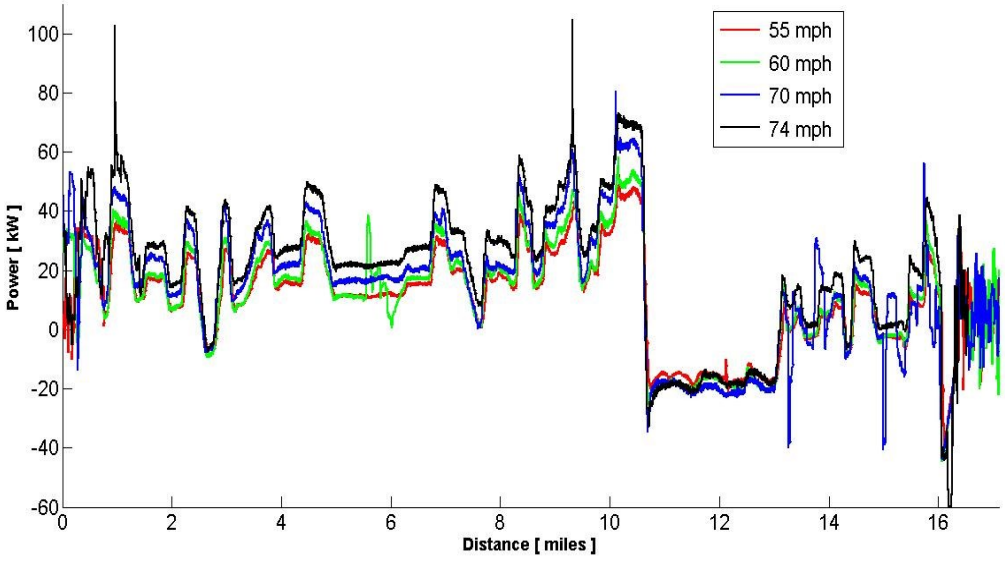

Figure 3: Vehicle power required to travel at different speeds over the elevation profile of Figure 2. The four speeds displayed are 55 mph, 60 mpg, 70 mph and 74 mph. The speed is maintained at a constant rate from mile 1 until mile 16.

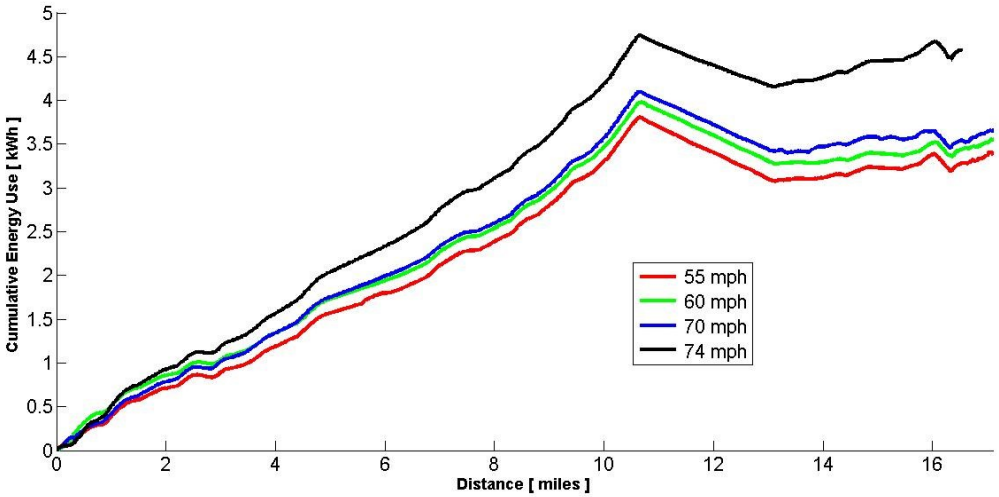

Figure 4: Variability of cumulative energy use for same trip travelled at four different speeds.

Figure 3 shows the power used by the vehicle to travel the decreasing elevation commute at 4 different speeds: 55mph, 60mph, 70 mph and 74 mph. It should be obvious that the faster speeds will require more power since even if they used the same total energy per trip it would be expended at a faster rate. Figure 4 shows the less obvious cumulative energy used over the trip. It is seen that travelling at 74 mph requires significantly more energy than at 55 mph with the intermediate speeds requiring intermediate quantities of energy. In another study on flat terrain it was determined that travelling at 55 mph required 261 Wh/mile while travelling at 75 mph required a 41% increase of 369 Wh/mile [4]. In this one particular case for the 20 mile trip at 55 mph and 74 mph the increase was 37% which shows general agreement with the previous study.

3 Conclusions

Although the Chevrolet Volt is often expected to deliver a specific range, it has been shown that the energy useage of the vehicle can be highly variable depending on trip profile and driver behaviour. This has particular importance in determining appropriate remaining range algorithms such that each driver is given a reasonably accurate prediction of the remaining range of their vehicle. With appropriate understanding of the factors that affect energy useage and the degrees to which they will alter the range of the vehicle, drivers can make informed choices to achieve the desired performance from their vehicles. The energy useage for the majority of trips ranged between 200 Wh/mile to 400 Wh/mile depending on terrain, and driver behaviour (speed and acceleration). Shorter trips using the heater and defrost can lead to a higher energy useage but are a relatively small influence on the overall energy useage of the vehicle which achieves and average of 272 Wh/mile over a total distance of 12,000 miles.

Acknowledgments

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