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Analysis of Detailed Electric Vehicle Data in Electrical Engineering Education

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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. 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. This data has been used as a learning tool in the electrical engineering classroom for senior students in both advanced machine courses and in sustainable energy courses. Through analysis the students develop a better understanding of general electric vehicle operation principles and energy useage and management. They also develop problem solving skills and experience with analysing large data sets (certain trips have over 15 million data points) and using appropriate tools to perform large but repetitive tasks.

Keywords: education, energy consumption, EV, efficiency

1 Introduction

The introduction and growing popularity of the Chevrolet Volt and Nissan Leaf have increased the interest level in electric vehicle technology in electrical engineering programs, especially in the power and sustainable energy areas. The increasing availability of other electric vehicles such as the Ford Focus, Toyota RAV 4 and a number of other newer models is serving to increase the interest and the need for study in engineering programs. The use of detailed electric vehicle data analysis as a learning tool provides an interactive and learn by doing method to develop a deeper understanding of general electric vehicle operation and quantification of energy useage and management. Engineering students can be taught a broad variety of disciplines using electric car systems as a laboratory exercise. Among these are vehicle dynamics and energy usage, controls, communications systems, electric power systems, renewable energy themes, traffic and mission optimization, thermal and battery management systems, and economic/environmental analysis. Until now the test hardware for such laboratory study has been very expensive (e.g. Tesla roadster at $120,000) or very primitive (mostly vehicles converted inefficiently from conventional cars). Now however, the introduction of the Chevy Volt and the Nissan Leaf has changed the situation so that highly sophisticated electric vehicle systems are now available at a very moderate cost (~$40,000 and ~$32,000 respectively). Electric vehicle simulations have been used in [1-3] to provide a similar learning environment but analysing data from an electric vehicle driven in the local area provides students a more direct and engaging learning exercise.

2 Description of Analysis Exercises

Students were provided several sets of data from unknown situations and were asked to provide a complete description of what was happening with the electric vehicle over the course of the data set. The data was presented in a standard comma separated value text file with identifications for each column of data. Some data sets had over 15 million data points which required the students to consider effective ways to take a look at various sections of data quickly in order to get a basic understanding of what was occurring with the electric vehicle. MATLAB was most often chosen as the most effective way to manipulate and graph data to illustrate various vehicle operations, although many chose Microsoft Excel. Those who maintained their analyses throughout in excel noticed they were performing the same tasks over and over and that they needed to invest a significant amount of time each time they performed the task. Those who used MATLAB were able to perform multiple analyses very quickly once they had written scripts for graphing and data organization. For students that had difficulty deciding which data to view, simple questions were asked to aid them in finding a direction. Some of the possible questions are: Where is the vehicle?, Is the vehicle moving?, How much power is the vehicle using?, Is the altitude constant?, Is the speed constant?, and Is the vehicle accelerating/decelerating? Students were also asked to think about possible vehicle activities and to determine what key data characteristics would help them identify a particular activity. For instance a student may be asked to describe what the data would look like if a vehicle was travelling uphill at a constant speed versus downhill at a constant speed. Students are asked to consider the conditions under which a vehicle might require a considerable increase in power or the conditions under which a vehicle might accelerate.

3 Sample Student Results

Figure 1 and Figure 2 represent a partial sample student analysis of two different types of data. Figure 1 is data from a typical 20 mile commute over 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. This particular set of data provides many different subsets where students can analyse causes of increased power consumption that can vary widely as well as long periods of regenerative breaking as well as start and stop characteristics. Figure 2 is a data set from the beginning of a charge event where the student can observe battery voltage and current changes as the charge cycle progresses. Some students go beyond the required exercise to obtain a deeper understanding of the relationship between state of charge and energy useage. Figure 3 shows a sample student analysis attempting to relate state of charge with energy useage and battery power over the duration of a trip. Overall, the students viewed the set of open ended exercises as a valuable and engaging experience that demonstrated electric vehicle technology as well as developing large data set analysis techniques and problem solving and hypothesis testing skills.

More advanced problems were also posed to the students such as what is the most energy efficient speed to travel up a steep hill and how can the total energy consumed be determined from the available data set. These questions require much more computational power and a basic understanding of manipulating these data sets before a meaningful investigation can be initiated.

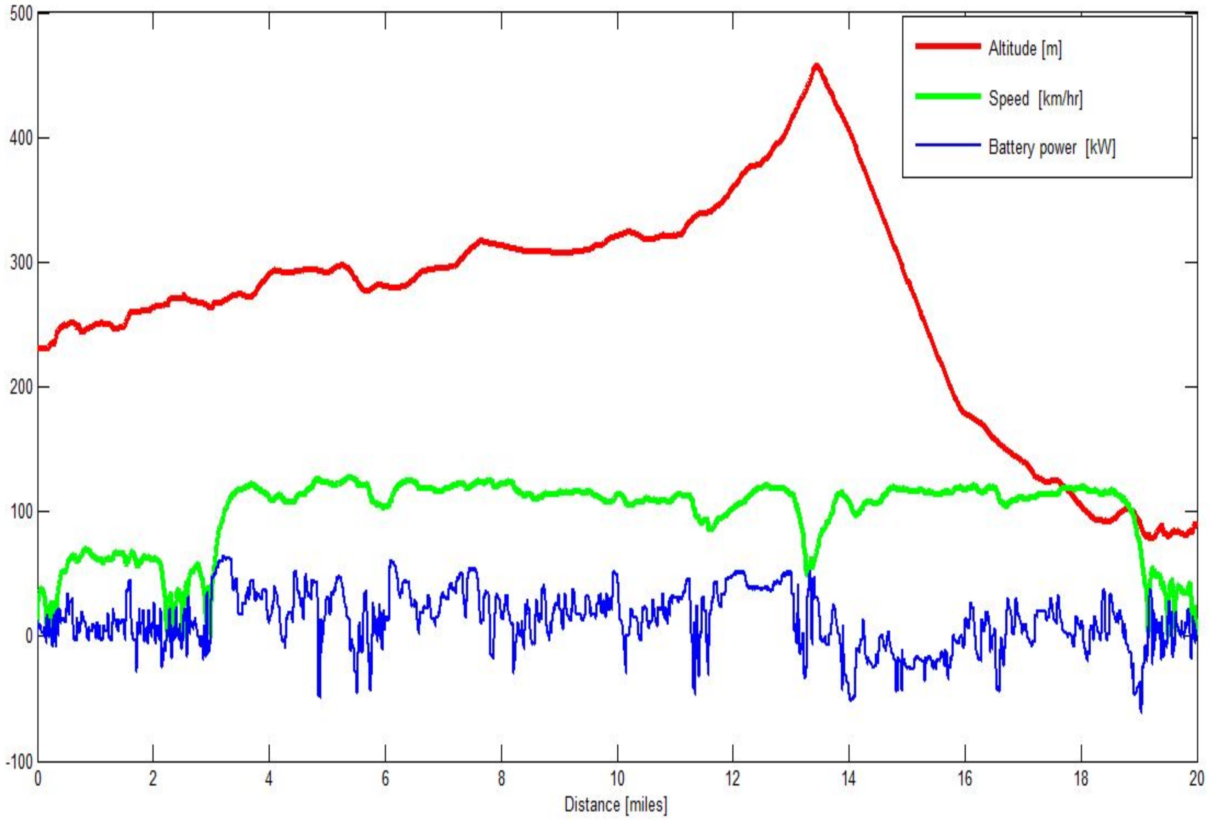

Figure 1: Sample Student Analysis of Speed versus Battery Power and correlating power useage with elevation.

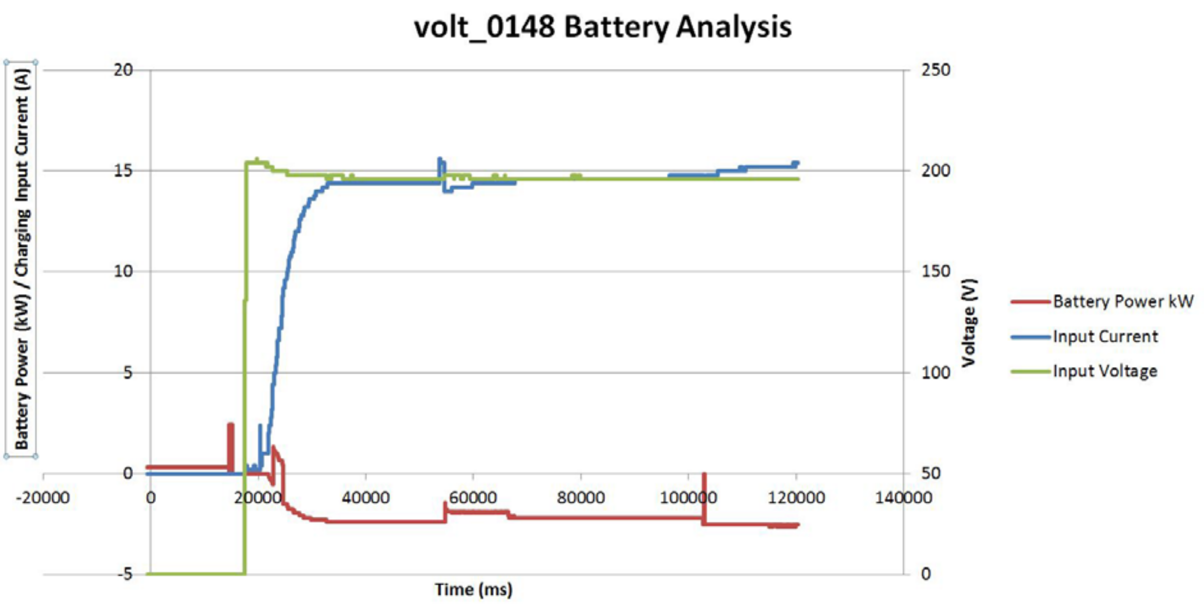

Figure 2: Sample Student Analysis of Charging Event.

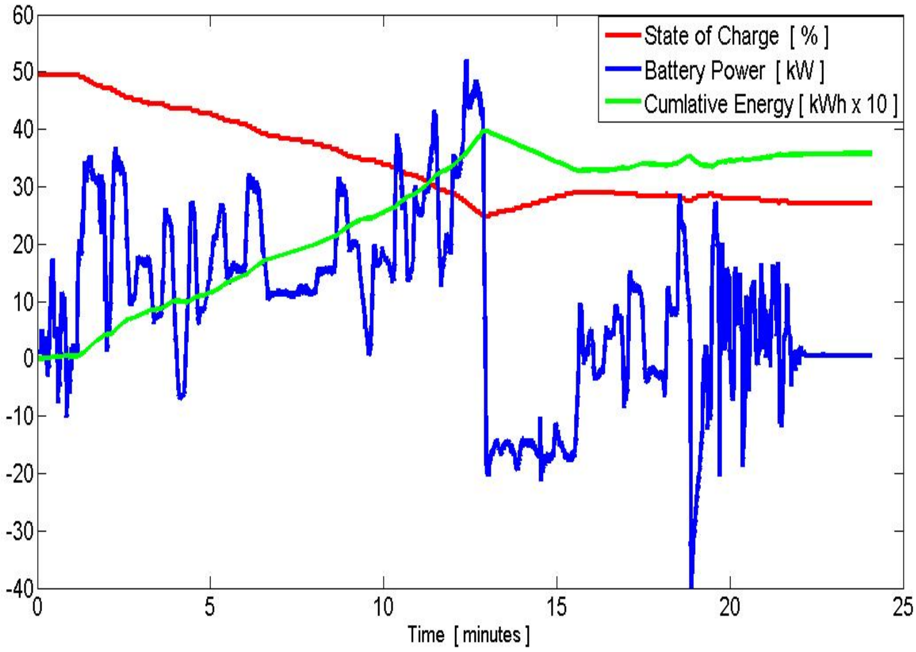

Figure 3: Sample Student Analysis of SOC (state of charge) and cumulative energy useage over the duration of a trip.

4 Conclusions

Student interest in electric vehicle technology is continuing to grow within electrical engineering programs and especially in power system and sustainable energy programs. Analysis of local, student collected electric vehicle data has proven to be an effective tool in both teaching students important electric vehicle operation principles as well as continuing the improvement in problem solving skills and experience with managing large data sets to extract pertinent information.

Acknowledgments

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