Road load Model Based Energy and Range Estimation for Eco-routing Navigation of Electric Vehicles

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Chapter 7

Conclusion and future scope

7.1. Summary

Electric vehicles are being termed the frontiers of sustainable mobility. In an effort to beat global warming and create a green environment, EVs seem to be a viable solution to fight climate change and reduce air pollution issues. With advancements in various associated technologies and increased awareness among the masses, the world is on the cusp of a major transition from gasoline powered vehicles to electric vehicles. In spite of all the advantages that EVs offer, challenges still prevail. Energy efficiency and the driving range of electrified vehicles are areas of concern that require extensive research. Minimization of the energy consumed and proper information on the remaining range of the EV during a manoeuvre will definitely enable better adoption. Therefore, this research emphasises the concept of eco-routing navigation, which conceptualises energy minimization by choosing an energy-efficient route for drivers.

Eco-routing is an innovative strategy aimed at optimising energy efficiency by identifying the most energy-efficient route, taking into account different constraints related to vehicle characteristics and customer preferences. It is a relatively new topic, and research is being carried out. Most prevalent eco-routing systems are proprietary and unavailable for researchers or academicians. Also, they are fuel consumption-based and not solely developed for electric vehicles. Hence, an energy consumption estimation technique based on a road load model, specifically for electric vehicles, was proposed in this work. The model is a prerequisite for developing an eco-routing navigation system. The results from the model have been used for the demonstration of an eco-route and also to calculate the range of an electric vehicle in motion. In the process of estimating the energy consumed, there are a few other aspects that have been focused on in this work. An electric vehicle prototype has been developed and used as a dynamic test bed. The factors influencing energy usage in EVs were also identified and studied. The EV powertrain was analysed, and an experimental set-up to estimate the torque-speed characteristics of DC motors has also been presented. In addition, the role of battery sources in EVs was highlighted, and a technique to measure the coulombic efficiency of batteries has also been discussed. The main contributions of this research work have been recapitulated in this chapter.

Chapter 2 summarises the fundamentals of electric vehicles and introduces the concept of eco-routing navigation systems in EVs. Range anxiety and energy consumption in EVs have been studied. Factors that influence energy consumption in vehicles have been identified and addressed. Existing eco-routing prototypes and generalised models that are used to calculate energy consumption have been reviewed. The relationship between energy use and the battery source has also been explained. Chapter 3 emphasises the importance of vehicle dynamics and motors in an EV eco-routing navigation system. The determination of an eco-route in real-time requires information on various parameters on board a vehicle when it is traversing. A test electric vehicle prototype was therefore designed and developed for implementation purposes. It is a neighbourhood battery electric vehicle and weighs around 120 kg. It is independent rear wheel driven and has PMDC motors attached to it for propulsion. To attain the main aim of calculating the energy consumption of an EV, parameter extraction was performed with the help of different sensors installed in the prototype. Individual extraction and estimation methods were used to obtain the data which was then used in the road-load based model to find the energy consumption and range of the test EV. A productive electric vehicle drive consists of motors providing efficient traction. A smooth and energy-efficient drive demands the economic and unfaltering use of the electric motors used in the vehicle. A system for the extraction of DC motor parameters was therefore developed. The experiment uses a motor-generator coupled technique for obtaining motor parameters in real-time. The torque speed characteristics of the motors used in the EV prototype have been extracted using this set-up, from which the correct operating range of the PMDC motors has been determined. In Chapter 4, a road load model has been presented that is based on vehicle dynamics and road-dependent factors. Special emphasis has been given to the road gradient present on roads. The tractive effort of an EV along with its power consumption was simulated using this model. This model has been further used on a test electric vehicle for energy demand estimation as well as the determination of an eco-route. No electric vehicle is complete without the use of a power source, which is usually batteries. Chapter 5 studies batteries and their role in electric vehicles. A simple electrical circuit battery model was also simulated, which helps understand the battery behaviour of lead acid batteries. Battery capacity and charge-discharge cycles are important for range estimation in EVs, for which a technique for estimation of battery parameters and Coulombic efficiency has been proposed and analysed. In Chapter 6, an energy consumption model has been developed and used for measuring the energy consumed during a trip. The estimation involves all major factors affecting energy usage in EVs and is based on the road-load model that was discussed in Chapter 3. The energy obtained is then used for the determination of eco-routes in cases where there is more than one route available to reach the destination. Evaluation of the model has been performed using real-time data obtained from on-road tests of the EV prototype. The remaining range of EVs has also been determined, which are essential parts of eco-routing navigation systems. Additionally, a neural network model was developed using data from the test EV to predict the usage of energy during the trip.

7.2. Future scope of work

This section briefly discusses the interesting and prospective aspects of this work that are worthy of being further researched based on the findings of this work.

a. Design of dynamic test bed

In this work, a dynamic test bed was designed to achieve experimental objectives. The test BEV that was developed is only at prototype level and was developed in such a way that the energy efficiency of the vehicle can be calculated onboard the vehicle in real-time. However, the mechanical design of the prototype can be enhanced in order to reduce associated losses and offer the EV at a product level. The commercial value of the EV can be increased by using a superior drivetrain, cutting-edge sensors, and a dedicated data collecting system on board, making it a favoured option for neighbourhood electric vehicles.

b. Parameter extraction of DC motors

This research work includes a system that proposes the extraction of parameters from a DC motor using an electrical load. The technique adopted is semi-automated and is used to determine the torque speed characteristics of the motors that are used in the prototype vehicle. Future scopes include full automation of this procedure so that the system can be used in the EV for obtaining the torque-speed characteristics of the motors in real-time, thereby also enabling drivers to choose the optimal operating region while driving. The system can also be upgraded for testing alternate current (AC) motors. In doing so, however, dedicated circuits and sensors must be used to obtain satisfactory results.

c. Coulombic efficiency estimation of batteries

In this thesis, an estimation method for batteries has been proposed wherein a motor-generator coupling technique is used for determining the coulombic efficiency of lead acid batteries. Battery parameters important for EV applications like charge-discharge current, voltage,etc. were also extracted. But the system was tested only for lead-acid batteries. Future work includes testing the system with other battery types, like the lithium-ion battery. Automatization is another area where this research can be pursued. The results obtained from this system can be included in the development of the eco-routing system for acquiring more precise results on energy usage and energy efficiency of the EV. CE in EVs decline during acceleration.The additional current that is required can be supplied through a super capacitor. An analysis can be also conducted in this field of work.

d. Energy consumption estimation

One of the main contributions of this thesis is the evaluation and analysis of energy usage in EVs. The results of energy consumption can be further used in the development of an effective eco-routing navigation system. The proposed method can be developed as a portable system that can be universally used in any electric vehicle for the extraction of parameters in real-time, which will help detect an eco-route. The input to the vehicle was a driving cycle, which controlled the vehicle speed. The ministration of a PID controlled input will enable the automatic generation of driving cycles required for manoeuvring an EV. Furthermore, the inclusion of GPS techniques along with preferences from the driver will ensure finer eco-routing navigation. The shape factor was not much emphasised because the model has been tested on an NEV. This factor can be included in the model to further study energy consumption when an EV is travelling at higher speeds. A neural network model was also presented in this thesis. Incorporation of more random, non-linear factors as well as factors that indirectly affect energy use and are physically immeasurable can strengthen the model. Testing the model with data from commercially available EV models will enable better verification and result in a precise prediction of energy consumption in electric vehicles. Additionally, the concept of hydroplanning can be incorporated in this energy consumption model to analyse its influence on energy use.

It can therefore be inferred that the research conducted in this thesis and its outcomes will hold practical significance and contribute to the development of creative applications in the field of electric vehicles. EV technology continues to face several obstacles and unresolved issues that require careful consideration. The experimental methodologies that have been presented possess the potential to enhance the efficacy of this technology. The work was divided into discrete components that could be integrated to create a cost-effective, smart and universally applicable eco-routing navigation system for electric automobiles.

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