International Journal of Engineering and Techniques - Volume 8 Issue 3, June 2022

RESEARCH ARTICLE OPEN ACCESS

Cost Functions for Efficient Electric Vehicle Drive Systems

Shyju. S.[1]

1(Lecturer in Instrumentation Engineering, Government Women's Polytechnic College, Kottakkal, Kerala.)

Abstract:

This study gives an early arrangement of electric motor degradation cost functions based on energy consumption, energy loss, and work creation in relation to the manufacturer's continuous running rating. Make suggestions. Unlike traditional electric motor degradation indications such as bearing life and insulation-based support parts, these cost functions take into account the quantifiable amount of time in the degradation cycle. Real-time measurements are utilized to assess cost functions over the engine's life. As a result, they provide an incredibly precise indicator that can be used for online regulator modification. Because of the sound construction of a degradation cost capability, the system creator can provide the client with an option between performance and degradation minimization. The proposed cost-likelihood plot has been empirically validated in terms of hardware in recognized electric power train tests and standard drive cycles.

Keywords — **Electric Vehicles, Efficient Electrics Vehicle Drive Systems, Design Parameters, Cost Assessment.**

INTRODUCTION:

The megatrends of electrification and automation are posing new problems for automakers, creating new requirements for future vehicles and paving the way for new, as-yet-undiscovered mobility systems. For example, powertrain electrification offers a cleaner future, whereas autonomous driving will increase safety, availability, and efficiency. These tendencies, however, produce new boundary conditions throughout vehicle development and various cost structures. When compared to internal combustion engine vehicles (ICEVs), the traction battery increases both the weight and the buying price of BEVs. Furthermore, sensors and computers in self-driving cars (AVs) influence auxiliary power usage and acquisition prices. A thorough understanding of new technologies and their prices is essential for automobile manufacturers' capacity to develop future car concepts and ensure market success. [1]

Over the last century, the electric motor has been the industrial workhorse. It has gained prominence in recent decades as a greener and more efficient alternative to the internal combustion engine in the transportation sector. Electric motors are now widely used in a variety of electric vehicles, including plug-in hybrid electric vehicles, series hybrid electric vehicles, parallel hybrid electric vehicles, and combined hybrid electric vehicles. [2]

Diverse optimization strategies are employed in electric vehicle design to enable optimal utilization of diverse device and component capabilities to the benefit of the vehicle construction and its users. Throughout the electric vehicle's operational life, the energy management system ensures that the limited energy onboard is used properly to provide a longer range while giving the desired performance [3].

Electric motors in electric vehicles, like every natural species or artificial entity made, decay, degenerate, and expire. Despite this, the electric motor is regarded as one of the toughest elements in the mechanical power supply chain in process industry applications since its activity is constrained to a narrow operating zone, which is usually around the most efficient, rated operating points.

Model Assumptions:

Vehicle architecture:

Figure 1 depicts a typical CVT-based parallel hybrid arrangement. In a pre-transmission system, an electric machine (EM) is linked to the engine through a disc clutch. In order to meet the pressure demand during pure electric driving, an electric oil pump is used to provide the hydraulic pressure and flow of the CVT hydraulic system. The battery stores the energy required for the EM to work as a motor or generator. The clutch is used to switch between modes. When the clutch is engaged, engine torque can be provided to the driving wheel via the rotor of the EM and CVT, whereas the HEV can be driven in purely electric mode when the clutch is disengaged.

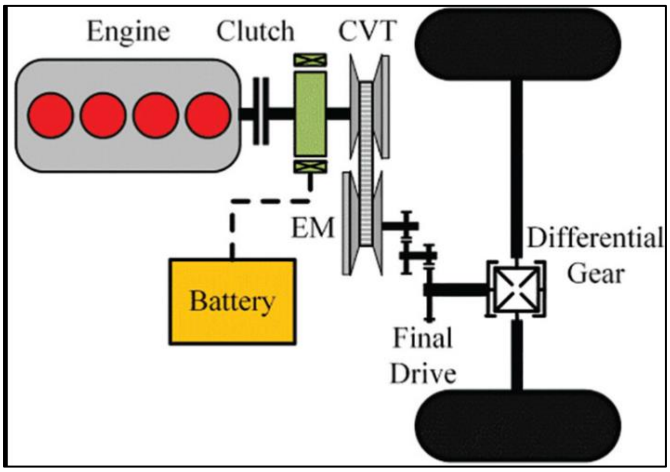

Figure 1: Vehicle Architecture

Vehicle Information:

In today's market, the vehicles chosen for examination are conventional internal combustion engine (ICE) or flex-fuel (FFV), plug-in hybrid electric (PHEV), hybrid electric (HEV), and battery electric (BEV). The model year is set to 2013, although for two of the cars chosen, which were not yet available in 2013, the 2014-year model was used. For comparison purposes, high-end luxury and low-cost autos are included.

Types of Electric Drivetrains:

1. BEVs (Battery Electric Vehicle):

Pure battery electric vehicles (BEVs) are also referred to as battery-only electric vehicles (BOEVs). BEVs have no engine and are propelled by electricity that comes from one or several onboard high-energy batteries. Modern models use a regenerative braking system to save energy. Examples include the Renault Zoe and the Nissan Leaf. The Zoe has a 22 kWh Li-ion battery, and an energy consumption of 14.6 kWh per 100 km, which yields a range of about 140 km to 210 km per battery charge on the New European Driving Cycle (NEDC). The 2015 Leaf comes with a 24 kWh battery (plus a 30 kWh option for the 2016 model), and an official consumption of 15 kWh per 100 km.

Current cost for BEVs:

Even though a BEV has no engine, which implies significant cost savings compared with PHEVs, substantial costs arise from the large battery packs currently required. In a study by Ricardo-AEA (2015), it is assumed that the battery pack determines about 75% of BEV power train cost, due to the relatively high battery cost. The authors of the study calculate additional manufacturing costs of about €12,400 for a lower medium passenger car in 2013, with a 24.9 kWh battery at €375 per kWh. The authors do not specify assumed production volumes for BEVs, PHEVs, and HFCEVs. The report, however, suggests that lower production volumes (in the low thousands) are assumed for HFCEVs, with a significantly higher scale for BEVs.

2. PHEVs (Plug-in Hybrid Vehicle):

Plug-in hybrid electric vehicles (PHEVs) allow both battery-powered electric driving (in charge-depleting mode) and conventional combustion-powered driving (in charge-sustaining mode). They are typically outfitted with an electric motor and a high-energy battery that can be charged from the power grid. Modern PHEVs may be driven in electric mode for different distances before requiring the combustion engine. In electric-driving mode, the propulsion system's energy efficiency is substantially higher, comparable to that of a BEV. The Chevrolet Volt (Opel Ampera in EU markets) and the Toyota Prius Plug-in Hybrid are among the models available. On the NEDC, the 2015 Opel Ampera employs a 16 kWh Li-ion battery and burns 16.9 kWh per 100 km in electric mode. The battery in the 2015 Chevrolet Volt is 16.5 kWh, while the battery in the 2016 model is 18.4 kWh.

To anticipate total life cycle costs (LCC) for transportation vehicles, many vehicle cost models have been utilized. The U.S. Department of Energy's (DOE) vehicle cost calculator and EPRI's total cost of ownership model are two of these models. The vehicle cost of ownership calculator from the U.S. Department of Energy is a web-based tool that compares a variety of vehicle types. Fuel expenditures, operating and maintenance costs, and insurance, license, and registration fees are all factored into the model. However, due to the uncertainty in predicted life and future costs associated with battery replacement, the DOE calculation does not include the cost of a replacement battery for PEVs. [4]

Current Cost for PHEVs:

The National Academy of Sciences assumes that incremental car costs of a 2015 PHEV-30 (with a 30-mile or 50-km drive-cycle range on electric energy) range between €5,100 and €5,800 over a conventional ICEV (NAS, 2013). The authors assume a production of 300,000 units per year and a battery size of 9.8 kWh at €356–€375 per kWh. Ricardo-AEA assumes much higher additional manufacturing costs of about €9,900 for a lower medium PHEV-30 in 2013, with an assumed 10.2 k Wh-rated battery at ~€790 per kWh but without clarifying production scale.

HFCEVs:

A fuel cell, which creates energy from hydrogen and air, powers HFCEVs. The electricity generated by the fuel cell powers the electric motor that drives the wheels and can also be used to recharge the battery pack if necessary. A battery pack is included in modern fuel cell vehicles to capture regenerative braking energy and assist with acceleration while the fuel cell stack is warming up. The size of the battery is often comparable to or somewhat larger than that of hybrid electric vehicles (HEVs). HFCEVs have a higher conversion efficiency than ICEVs but at a higher cost. Refueling HFCEVs is much faster than charging batteries. In the United States, the Toyota Mirai and Hyundai Tucson are commercially available models.

Fuel cell System:

HFCEVs rely heavily on the fuel cell system. It primarily consists of a fuel cell stack and a variety of supporting components, often known as balance of plant (BOP). One cell stack has several cells. The polymer-electrolyte or proton-exchange membrane (PEM) fuel cell stack is the most common form of fuel cell stack used in cars. Hydrogen is stored in an on-board storage tank, which functions similarly to a fuel tank in an ICEV. Hydrogen is currently kept as a compressed gas using current technologies. The fuel cell generates electricity using an anode-cathode concept similar to that of a battery. The anodes are powered by hydrogen from the onboard storage tank, while the cathodes are powered by oxygen from the surroundings. Electrons from hydrogen are compelled to follow an external circuit, resulting in an electric current flow. [5]

Hydrogen Production:

Hydrogen can be created in a variety of ways, including electrolysis and reforming. Currently, hydrogen is primarily produced on a small scale in small generators by reforming natural gas. Other methods of generation include water electrolysis and biofuel reformation. Future large-scale facilities could manufacture low-cost hydrogen utilizing a variety of technologies, such as natural gas reforming or coal gasification. The most cost-effective method of producing hydrogen, which is also utilized in industry, is currently based on fossil fuels. In the United States, for example, natural gas accounts for 95% of hydrogen production. [6]

OBJECTIVES:

1. To study Cost functions for efficient electric vehicle drive systems.
2. To study types of Electric Drivetrains.
3. To Analysis of LCC simulations.
4. To study of Summary of investment costs for electricity and hydrogen chargers by station type.

RESEARCH METHODOLOGY:

Books, educational and development magazines, government papers, and print and online reference materials were just a few of the secondary sources we explored to learn about comparative public policy studies. The internal and external validity of comparison research determines their quality. The amount to which inferences may be taken correctly from the study setting, participants, intervention, measures, analysis, and interpretations is referred to as internal validity. The amount to which the conclusions can be generalized to different circumstances is referred to as external validity.

Data from the literature on costs and emissions has been collected, analyzed, and pooled. The cost of batteries, fuel cells, and charging infrastructure has been estimated based on the data gathered. Furthermore, the powertrain expenses of BEVs, PHEVs, and HFCEVs.

REVIEW OF LITERATURE:

Researchers (He, Y.; Venkatesh, 2012) created EV smart parking lot models and used a variety of optimization strategies to plan EV charging. All such EV scheduling approaches in EV smart parking lots have at least one of the following goals: (a) maximize the number of EVs charged in a given amount of time; (b) maximize the smart parking lot profit; (c) minimize the EV owner's charging cost; and (d) reduce peak demand by participating in DR. [7]

M.S. Kuran; A.C. Viana; L. Iannone; D. Kofman; G. Mermoud; J.P. Vasseur, 2015 A sophisticated parking lot management system for scheduling electric vehicle charging. The authors examine the subject of EV charging schedules from the perspective of smart parking lot operators and EV owners in IEEE Trans. Smart Grid 2015, 6, 2942-2953. The optimization objectives were to maximize the number of EVs charged and the overall revenue of the smart parking lot while minimizing the EV charging expenses for the EV owners using quadratic problems. Similarly, Zhang, L., game theory is utilized to schedule EV charging in order to maximize smart parking lot utilization by increasing the number of EVs to be charged. As a result, a larger number of EV owners can be accommodated. However, the authors did not take into account the stochastic aspects of energy price fluctuations or the EV's driving patterns. [8][9]

MILP and fuzzy linear programming (FLM) are employed in [Ansari, M.; Al-Awami, A.T.; Sortomme, E 2015] to maximize the smart parking lot profit by effectively optimizing the EV charging schedule. [Han, S.], a linear programming (LP) technique and dynamic programming (DP) model are utilized to maximize smart parking lot profit and minimize EV charging costs. The challenge with LP is how to handle both real numbers and integers at the same time; so, MILP is more appropriate than LP. The DP lacks a generic formulation, and each problem must be addressed individually. Furthermore, the DP uses more memory when storing the outcomes of intermediate steps, which MILP does not. [10-12]

For the near-term functions, we estimate IGBT costs using Hodkinson (1997) and consulting with an electronics industry specialist to determine current and projected near-term IGBT cost declines. Hodkinson (1997) investigates wire bond, lead frame, and intelligent power module type IGBTs for 70 kW (peak) AC induction and BPM drive systems, concluding that wire bond packaging has the lowest silicon cost for EV motor controllers. He estimates that the current silicon cost for a 70 kW AC induction inverter is $300, based on three 1200-volt, 100-amp six-pack IGBT modules, and $200 for a 70 kW BPM inverter, based on two such modules. Because silicon prices scale to current capacity (i.e., we assume constant system voltages), we normalize these cost estimates to the 70-kW system and then scale them linearly for different inverter power ratings. Our 2,000 and 20,000 per year estimates are based on current IGBT module pricing, while the 200,000 per year estimate incorporates a slightly lower cost estimate that represents an anticipated 20% decrease in IGBT costs over the next 2-3 years, compared to current costs (Harvey, 1998). [13]

RESULT AND DISCUSSION:

The LCC tool uses a template to perform all necessary calculations.

Simulation Results:

One of the other factors evaluated by the LCC simulations was the effect of different miles per year traveled by the individual vehicle. For this case, runs of 10,000, 20,000, and 30,000 miles per year driven were made for the three vehicles – Leaf, Elantra, and Volt. These results are plotted in Figure 2, which shows average annual costs versus miles per year. The case for 12,330 miles is also noted in Figure 2. From Figure 2, it can be observed that the curves are linear, except at the 10,000 to 12,000-mile range for the Nissan Leaf and Chevrolet Volt for the 10- and 15-year simulations. Because the Leaf and Volt are totally battery-driven at this mileage range, the curve is practically horizontal. Because the lines are linear, the effect of miles traveled each year does not influence the relative locations of the three automobiles. greater mileage results in greater annual costs, as expected. The equations for the 10-year simulation are provided to emphasize the efficiency differences between the all-electric Leaf, PHEV Volt, and Elantra ICE automobiles. Given the assumptions employed in this analysis, the Leaf is more than twice as efficient as the other vehicles.

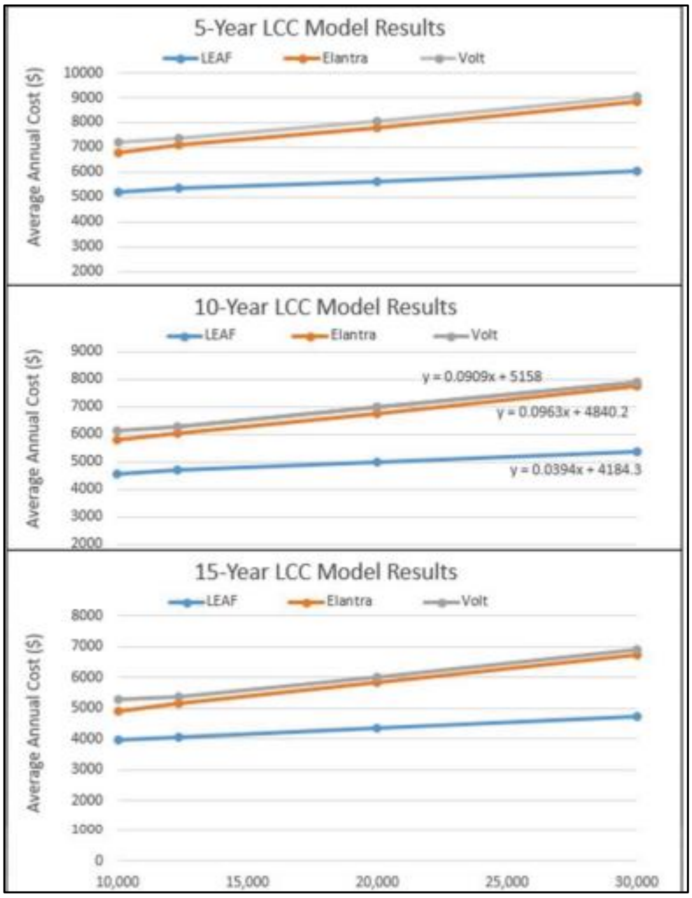

Figure 2: LCC Analysis for 5, 10 and 15-Years

The costs listed above do not include the new charging infrastructure required for EV deployment. Cost estimates differ significantly per charger type, owing in part to the inclusion or absence of numerous cost components such as planning, installation, authorization, signposting, and so on. [14]

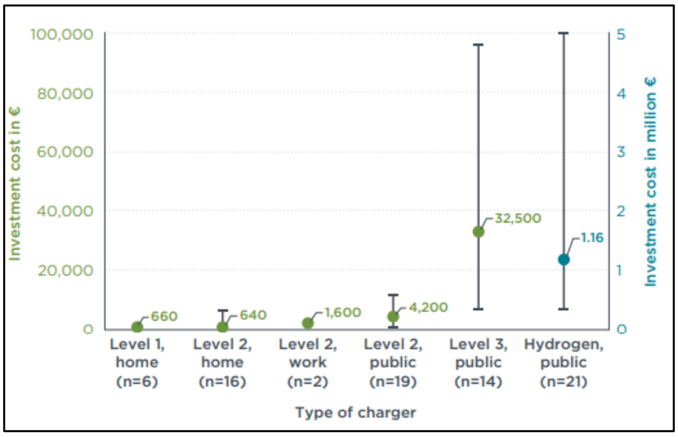

Figure 3: Investment costs for electricity and hydrogen chargers by station type

To assess the component costs associated with different electric power trains over a conventional vehicle, a bottom-up cost approach is utilized. Using the Ricardo-AEA BEV cost numbers, and updating with a more recent battery cost estimate of €250 per kWh, a BEV-100 (with a drive-cycle range of roughly 100 miles/160 km) costs about €5,700 more than a normal passenger car. [15]

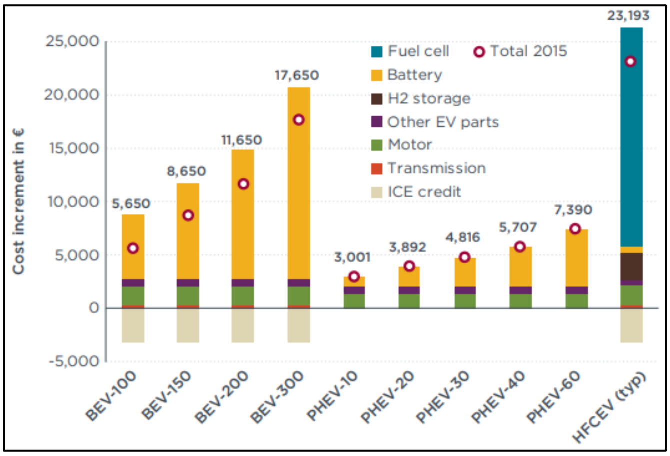

Figure 4: Cost breakdown of different electric power trains

Cost subtractions are made for the non-existing combustion engine, exhaust pipe, and conventional transmission and are referred to as ICE credits. [16]

CONCLUSION:

The LCC model incorporates car expenditures such as purchase price (including any federal subsidies), salvage value, fuel consumption (electricity and liquid fuel), tyres, insurance, maintenance, state tax, and financing interest payments. In comparison to ICEs that run on petrol, ethanol, or diesel, hybrid, plug-in hybrid, and battery-electric vehicles are being studied. Although the traction battery replacement costs for PEVs are difficult to estimate, they are included in the analysis by changing the batteries in the 11th year to investigate the battery's impact on overall expenses. Economic elements employed in LCCs include varying rates of inflation, discount, and fuel escalation, as well as battery deterioration in PEVs to account for battery energy loss over time. The LCC is carried out over a 5-, 10-, or 15-year timeframe. Furthermore, the powertrain costs of BEVs, PHEVs, and HFCEVs have been estimated using a bottom-up technique. Aside from recent cost reductions, power train expenses for all three types are predicted to fall by 50%-70% between 2015 and 2030.

REFERENCES:

1.Trommer, S.; Kolarova, V.; Fraedrich, E.; Kröger, L.; Kickhöfer, B.; Kuhnimhof, T.; Lenz, B.; Phleps, P. Autonomous Driving. The Impact of Vehicle Automation on Mobility Behavior; Institute for Mobility Research: Munich, Germany, 2016

2. N. Mutoh and S. Member, Driving and Braking Torque Distribution Methods for Front and Rear Wheel Independent Drive Type Electric Vehicles (FRID EVs) on Roads with Low Friction Coefficient, IEEE Trans. Ind. Electron., vol. 59, no. 10, pp. 3919,3933, 2011

3. J. Lemmens, S. Member, P. Vanassche, J. Driesen, and S. Member, Optimal Control of Traction Motor Drives Under Electro thermal Constraints, IEEE J. Emerg. Sel. Top. Power Electron, vol. 2, no. 2, pp. 249,263, 2014

4. Alexander, M. & Davis, M. (2013). Total Cost of Ownership Model for Current Plug-in Electric Vehicles. Electric Power Research Institute. Palo Alto, CA.

5. Dunn, J. B., Gaines, L., Kelly, J. C., James, C., & Gallagher, K. G. (2015). The significance of Li-ion batteries *in electric vehicle life-cycle energy and emissions and recycling's role in its reduction.*

6. Edwards, Larivé & Beziat, 2011

7. He, Y.; Venkatesh, B.; Guan, L. Optimal scheduling for charging and discharging of electric vehicles. IEEE Trans. Smart Grid 2012

8. Kuran, M.S.; Viana, A.C.; Iannone, L.; Kofman, D.; Mermoud, G.; Vasseur, J.P. A smart parking lot management system for scheduling the recharging of electric vehicles. IEEE Trans. Smart Grid 2015, 6, 2942–2953.

9. Zhang, L.; Li, Y. A game-theoretic approach to optimal scheduling of smart parking lot electric vehicle charging. IEEE Trans. Veh. Technol. 2016

10. Ansari, M.; Al-Awami, A.T.; Sortomme, E.; Abido, M.A. Coordinated bidding of ancillary services for vehicle-to-grid using fuzzy optimization. IEEE Trans. Smart Grid 2015, 6, 261–270.

11. Jin, C.; Tang, J.; Ghosh, P. Optimizing electric vehicle charging with energy storage in the electricity market. IEEE Trans. Smart Grid 2013, 4, 311–320

12. Han, S.; Han, S.; Sezaki, K. Development of an optimal vehicle-to-grid aggregator for frequency regulation. IEEE Trans. Smart Grid 2010, 1, 65–72

13. R.L. Hodkinson, Toward 4 Dollars per Kilowatt, Orlando, FL (1997)

14. Internal Revenue Service. (2014). Plug-In Electric Drive Vehicle Credit (IRC 30D)

15. Alexander, M. & Davis, M. (2013). Total Cost of Ownership Model for Current Plug-in Electric Vehicles. Electric Power Research Institute. Palo Alto, CA.

16. Alternative Fuels Data Center, U.S. Department of Energy. (2013b). Vehicle Cost Calculator Assumptions and Methodology