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Low power consumption and high thermal capability of electric car battery design

Ola Hussein Abd Ali Alzuabidi
Dijlah University College, Computer Engineering Techniques, Iraq

ABSTRACT

This paper presents the design of low power consumption and thermal capability of electric car battery. Different drive cycle, lawmaking, official real word and measurements have been study and investigated depend on their acceleration and velocity contents. The power consumption, acceleration performance, and power consumption of power train, comprise traction motors, batteries, and power electronic module were analyzed and determined for drive cycle. Additionally, the consequence on drive cycles fulfillments, acceleration performance, and power during scaling of electric drive system has study. Through the power train sizing regard power and torque, the requirements of acceleration turned out to dominate over requirement of top velocity, and grade level. The electrical powers trains down scaling resulting in energy consumptions downward to 80% of unique power train sizes. The little slot geometries have high speed loss through drive cycle and average cycle had low loss for many cycles. This results in amalgamation with high velocity torque lower material cost and very involved options as electric car traction motors.

Keywords: Electric Car Battery, Power Consumption, Thermal Capability

Corresponding Author:

Ola Hussein Abd Ali Alzuabidi
Computer Engineering Techniques
Dijlah University college, Iraq
E-mail: ola.hussien@duc.edu.iq

1. Introduction

The main challenge in the worldwide society nowadays is to decrease the negative collision of transportations that has environments because of greenhouse gas and toxic emotion [1-4]. This type of emission from cars is legally synchronized on general and local level. To fulfill with predictable prospect, more strict regulation and manufacturing are required to spend in different fuel economy techniques [5-9]. This could lead to increasing interested in electric car or leading hybrid electrical car that will decrease the fuel consumption to traditional cars except battery electric cars which provide higher power train efficiencies with no tailpipe production. That's why they are so far considering CO2 accepted in regulation [10-15]. Battery electric cars have probable to provide an emanation free of used in case of charged with electricity that generate relic free and renewable source [16-20]. In current time, great part of main automotive manufacturing in the world has been develop their battery electric cars model which have seen increasing annuals enlargement speed as high as 90% through the period of 2012 to 2020 [21-27]. The battery still relates drawback of relative short drive range due to award constraint which collective long time of charge. Forbid battery electric cars as of captivating up the profitable competitions by means of fuel energize on great level immediately so far [28-35]. Hence, it becomes more important to examine the effect on power efficiencies and performance of many designs. Regarding to this design, the drive systems come of different components in power train. An additional interested researches feature to examine the possibilities to intend the derived systems depend on specific types of use and then to assessment of consequences on power and energy performances and efficiencies [36-40]. Furthermore, because of limited space for driving system component in the cars, the selected of peak torque versus thermal capabilities for convinced electric machines sizes which become high imperative [41-45]. In this area, many researchers have been proposed and evaluate the tailpipe emanation and fuel utilization of traditional burning cars, different drive cycle have been developed over last few decades. They have been conducting the related types of cycles with their acceleration and speed performances to introduce level of energy consumptions as in [46-55]. Hence, the speed influence and measuring of acceleration on the power consumption for battery electric cars is in available literatures. Numerous interesting publication reports simulated or measured result regard to battery electric cars energy consumptions per drive distances, efficiencies, and range through different drive cycle. In this work, the calculation and investigation the relation between energy consumption and component sizes has been introduced. Whilst, accounting booth consideration care design and fairly full drive coverage depend on an extensive numbers of existing battery electric cars.

2. Materials and methods

2.1 Battery electric car power train scheme

In the cars applications, normally described to keep the electric machines physical volume down. This could be achieved by design high velocity level of cars as a reasonable compromising is maximum velocity from 12 000 to 16 000 RPM given that the serves as great compromising among performance and volume. Through usual on street drive, the cars velocity range might vary from zero to 130 km/h or high at time. That's mean the wheel determination rotate to about 1100 rpm or more. Hence, the decrease gears relation toward the controls is inherent required. To provide the right and left tractions wheel chances to spin slightly deferent velocities through turning. Additionally, there is a need for differential to connect between wheels which is sometime a different include in final gear ration. Figure 1 shows the typical battery drive system with the suggested schematic system of power train.

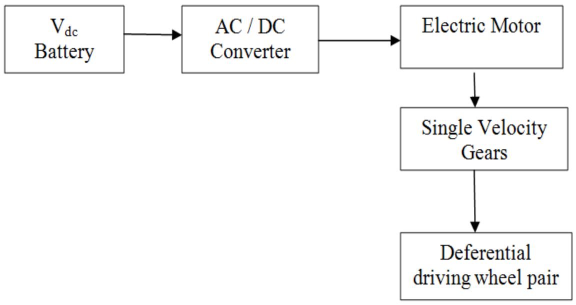

Figure 1. Battery electric Car power train scheme

The dynamic aim of cars is to describe ability of vehicle movements on the road surfaces under force influence among tire and road and aerodynamic gravities. Basic knowledge in cars dynamic through power train design phase is essentially reveal load and its level which require coping with driving. Vehicle dynamic understand is equivalent important whilst examine of power train is impact of on cars performance, which it might be instance to speed up or regular power expenditure for every drive coldness. The design of several entity of systematic car could model with much level of details according to major occurrence that is under taken to study. For dynamic study types, the power train load level and power consumption will analyze reasonability to assume the cars body is rigid. Therefore, this design could be modeled as lump mass at cars center of gravities and only the dynamic in one direction is involved under assuming car constancy is not under situation desecrated. The corresponding electric circuit modeling used dynamic methods is illustrated in Figure 2.

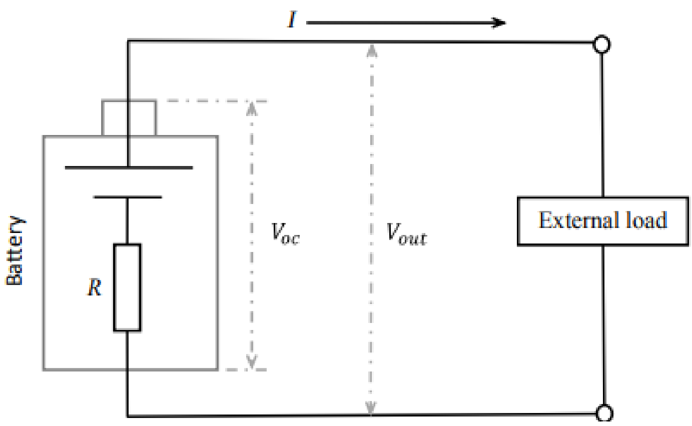

Figure 2. Modeling of equivalent circuit

The d-axis or direct physically could be represented in redial axis cross the center line of magnetic indirect in the route of magnetically flux as of magnetic whilst the quadreture of Q-axis could be represented in an axis cross between two magnet. Typically, the DC/AC converters is utilize power electronic switch device to convert between battery DC voltage to 3-phase AC electrical energy which is required via the electric motor. Every switch in automotive applications contain of one IGBT chip in parallel with diode chip according to current rate. Through the operation, the major loss in the converter is because the switching and conduction in the diodes and transistors. The loss could be representation as in [37] and the sinusoid idea of pulse width modulation in 3-phase voltages can be assumed properly. The dissipated loss in the driver circuit is because of capacities and inductive parasitic are assuming negligible. One condition, revolve on, and twist off for IGBT loss are consider whilst the average block loss are assumed very small. In the same way for diode, turn off and on state are consider whilst turn o loss is neglect because of an assuming fast diode in turn on processing. Typically, the IGBT converter module is intend to withstanding definite voltage level of about 600 volt, 1200 V and so on. The number of slight different module is available at every voltage levels with various current rates as 200A, 400A and so on. Given that the loss to great part based on current size and rating involve is how big temperatures increase because of loss that cool systems are talented to grip with no risks over heating of the diode chips or transistors chip.

2.2 Modelling of battery

The easy circuit's mode of electrochemists batteries is illustrated in shape 3 wherever V_{oc} represents the idea of unload battery voltage, R_{dis}, and R_{ch} are represents the interior resistance through charge and discharge of the batteries by currents I_b, which leads to load based on incurable voltages V_t.

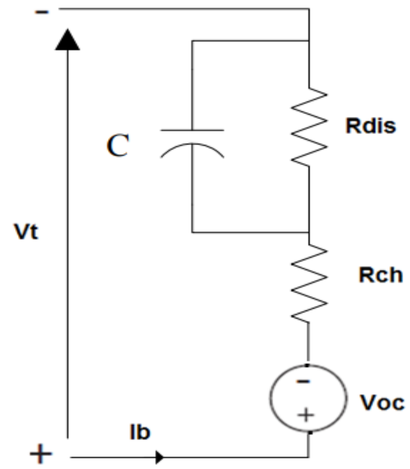

Figure 3. Simplifying model of battery

The equation of terminal voltage through the discharge state could be expressed as following formula:

$$V(t)= V_{(oc)} - R_{(dis)} \cdot I_{(b)} \quad \ldots\ldots(1)$$

The contented of charges in the batteries is frequently explain by the terms status of charges (SOC) that changed by means of the batteries current in excess of instance as in the below formula:

$$SOC(t) = SOC_{init} - \frac{\int_{t0}^{t} I_{b}(\tau)d\tau}{Q_{tot}} \quad \ldots\ldots(2)$$

wherever

$SOC_{(init)}$ ………..initials SOC levels

Q_{tot} ……......whole charges capacities in batteries

To build the replica in Figure 3, a spot further progress the unload voltages could exist model as a meaning of batteries states of charges. Through operation of battery energy contents are drained that lead to decrease the unload voltage downward to convinced level at small SOC levels wherever the unload voltage case abruptly drops quickly. The losses of major powers in the batteries are because of interior resistances which could be model as RI^2 conductions loss. Through the usual cars operations, the propulsion and secondary load numbers will drain the energy battery which are fed by low voltages circuits. This load might be fan, air conditioner, pumps, lights, wiper, and radio with various controls system in the cars. These types of load might demand relatively high peak energy level as a part from an overall increased power consumption from the batteries. Depend on [24], the electrical air conditions systems are design for crest powers of 6:5 kW with the nonstop energy of about 4 kW. The difference of temperatures in electric machine and gradient arises because of inherent internal heat source ant this is losses mechanism. The difference in regional temperatures produce is rising to transfer of heating or energy of thermals from warmers region to colder during three processing of convection, radiation, and conduction. Even at short duration of time, at right load, there is a exact danger to break the electric mechanism limit with instant shortage or breakdown of lifetime. Hence, in order to envisage the temperature allocation in electrical machine through unreliable loads state such as classically arise in battery electronic cars, the heat transfer rate for different mode should be included and estimated into thermal model of machines. The lumped thermal parameters networks are known to produce sensible correctness in temperatures allocation still with relative short numeral of node. Then, the heat transfer in electric machine is intrinsically three dimensions and could model in fewer dimension understatement of dimension interdependence. The accurate thermals mode should be captures the major flow of warmth transfer in the mechanism which could be complete logically in the lump parameters networks or numeric using finite element analyze with computation liquid dynamic techniques. The main efforts lie in forming the applicable networks wherever the chief warmth transport pathways are symbolized. To get appropriate estimation of warmth transport rate, finite element analysis and CFD programs could be used to analyze the details and complex machine geometry. Hence, both models put up in addition to weight points implementation could be occasion consumption. The software of thermal finite element program is imperfect to progress the correctness transmission opinion for radiation and convection with same guess which will be used in lumped parameters networks. In this section, a typical level of acceleration and speed has been attempted to identified with different road type and high velocity motor drive. To find appropriate BEV power train criterion of design according to torque velocity and energy, a distinctive daily drive distance shall be examining since the range is significant design factor for BEV.

3. Results and discussion

3.1 . Duration of acceleration

The duration of time of all deceleration acceleration is determined for logged and test cycle. The resultant cumulate frequency allocations are illustrated in Figure 4. Generally, the period of acceleration is longer than period of deceleration which is typically 80% of all acceleration are 12 second to 12 seconds or less for test cycles with about 9 seconds or less for logged cycles. In addition, 50% of all test cycles acceleration are 5 seconds to 6 seconds or lesser with logged cycle of about 4 seconds

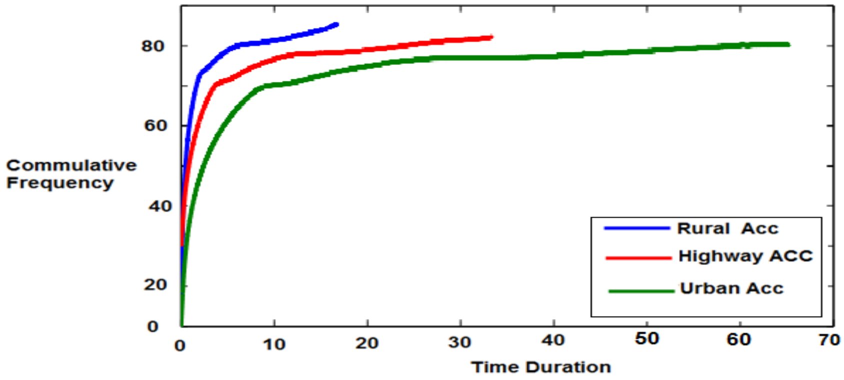

Figure 4. Increasing frequency allocation period of every decelerations and accelerations, Counting among zero-crosses, for the Logged plus Test cycle

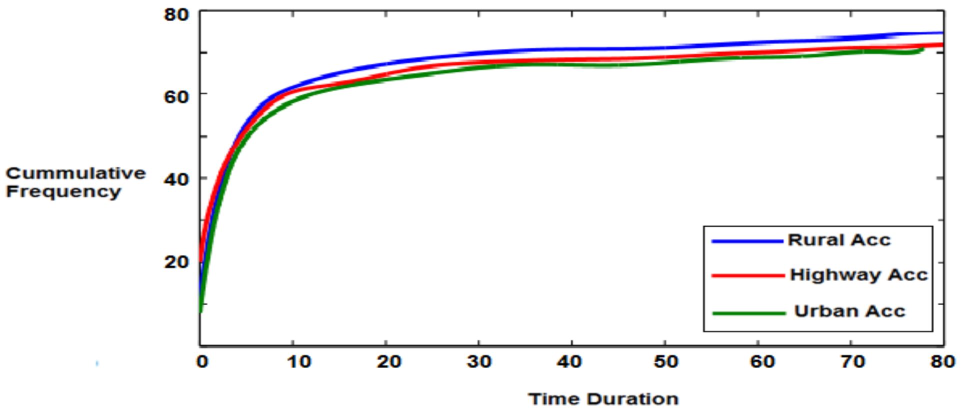

Figure 5: increasing frequency allocation of the time period of every deceleration and acceleration counting among zero-crossings, for the Logged and Test cycle

The time period of all downward and upward cycles segmentations are determined for logged cycle and the resultant cumulative frequencies allocations is highlight in Figure 6. Clearly, the time period is longest for highway cycle with 80% of upward occasion in rural and urban cycle. The time period is about 25 second or less in the highway cycle. In addition, for 50% of 25 seconds or lesser, it is 38 seconds or less for highway case and the time is 10 seconds to 14 seconds or less. The concluded time period of score climb is further than two times the time period of accelerations.

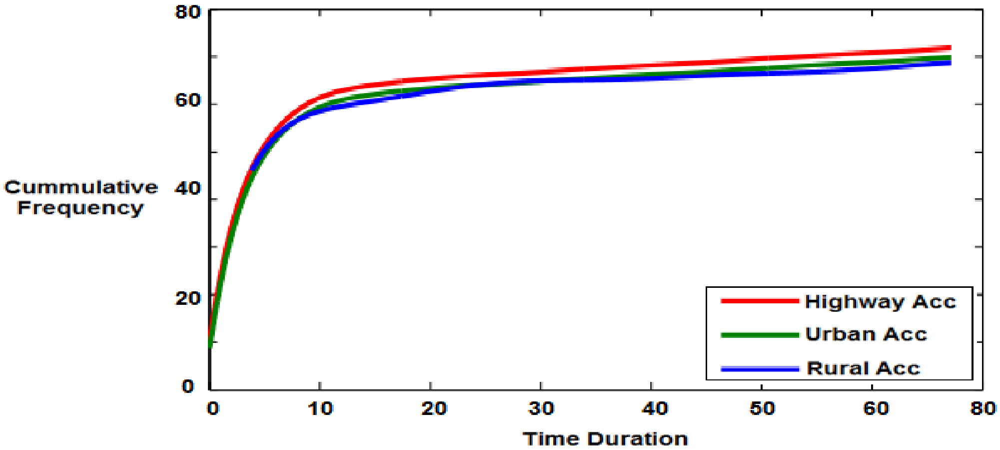

Figure 6: increasing frequency allocation of the time period of every climbing and downward Counting between zero-crossings for the Logged and Test cycle

To find appropriate drive range for electrical cars, it is necessary to gained data how distant driving generally traveled. Presumptuous the specific instance to charged is in excess of nights, then one could think data according to travel distances daily. Around the world, many countries try during survey to map archetypal people mobile habits traveling by many commodities.

3.2 Analysis of wheel load

The force levels of wheel load analysis are a power and velocity at the wheel is estimated depend on state quantity of cars requirements. By using the data collected in many experiments regarding to cars dynamic, the force due to aerodynamic drag is 2.2, road grad 2.4, rolling resistances 2.3, and acceleration 2.1 which are determined for all cars concepts by assume constant of gravitation of g=9.8, density of air is 1.2 kg. The forces of road load include rolling resistance and aerodynamic drag for every idea of battery electric cars is predictable at velocity level inside specifies velocity range. Because of aerodynamic drags, the force of the wheel shows tough reliance on velocity. The insisted of sport cars is bigger wheel force at convinced velocity level compare with other cars and city cars demand which is lowest. The process of sizing and modelling in the city cars and the sport with highway cars has been implemented and examined. Clearly, two slight different approaches are utilizing, were some step is independence whilst other guild on previous step.

4. Conclusion

This paper introduced different drive cycle and official real word measuring within frames of this research which have study and characterize in term of acceleration, velocity, and cycle parameters. Additionally, velocity allocations and acceleration are examined correctly. The most lawmaking drive cycle were developed and investigated. Through the map of current battery electric cars it was originate that there is widely increase regarding pinnacle speed and acceleration routine and drive variety. It was finding that the car of city has strong velocity reliance than other two types because of relative high aerodynamic drags. The required wheel power and force is accelerated up to 100km/h and take off at 25% grads and driving at highest grads. Moreover, where find that the instance to acceleration could be offered by means of much combination of early utmost forces and powers. The battery loss accuracy and dynamic voltage model could be improved by implement capacitive term and perhaps different battery cell should be modelled in future with more data.

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