Fast Charging of Electric Vehicle Using Matlab Simulation

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Abstract- Next generation of transportation in the form of electric vehicles relies on better operation and control of large battery packs. The individual modules in large battery packs generally do not have identical characteristics and may degrade differently due to manufacturing variability and other factors. Degraded battery modules waste more power, affecting the performance and economy for the whole battery pack. Also, such impact varies with different trip patterns. It will be cost effective if we evaluate the performance of the battery modules prior to replacing the complete battery pack. The knowledge of the driving cycle and battery internal resistance will help to make decision to replace the worst battery modules and directly cutdown on user expenditure to replace the battery. Also, optimizing the performance of battery during the driving trip is the challenging task to achieve. The knowledge of energy prices of the grid, internal resistance of the lithium-ion battery pack on the electric vehicle, the age of the battery and distance travelled by the electric vehicle are very important factors on which the cost of daily driving cycle is dependent. In near future, the energy consumed by the electric vehicles will create a major consumer market for the smart grids. The smart grid system is complemented by the renewable energy sources that contribute and support the grid. The electric vehicles are not only predicted as energy consumers but also as dynamic sources of energy. These vehicles can now travel more than 100 miles with a single charging cycle whereas average day to day commute is well below the maximum capacity of these vehicles.

The improvement of the electric grid to the next generation infrastructure i.e. 'Smart Grid' will enable diverse opportunities to contribute the energy and balance the load on the grid. The information about the grid like price quality, load etc. will be available to the people very easily. This information can be useful to make the energy grid more economical and environment friendly. We have used the information for price of energy on the grid to optimize the cost of daily driving cycle. The goal of this project is to accurately predict the battery behavior for the daily driving cycle. The prediction of battery behavior will help the driver to decide the optimum charging patterns, energy consumed during driving and the surplus energy available in the batteries. The prior knowledge of the battery behavior, price of the energy on the grid and the trip travel will help the driver to minimize the cost of travel on daily basis as well as throughout the life of the battery.

I. INTRODUCTION

An ever-increasing need for better and efficient transportation has motivated the auto mobile industry to look for alternative sources of energy in lieu of conventional energy sources. This has led to are surgence of hybrid or electric vehicles in recent years. The electric vehicles are clean, i.e. they have lower CO2, CO and hydrocarbon emissions than conventional energy resources. Vehicles which use non-conventional energy sources are multi-sourced vehicles which use petroleum-battery, diesel-battery or fuel cell-battery etc. The battery forms a critical element for driving non-conventional vehicles. Electric vehicles (EV) require large battery packs with high energy and power densities to become a competitive choice of transport. These batteries have many cells/modules in series and parallel. Acceptance of these vehicles results from better operation and control of large battery packs.

Recently, addressing the problems of green-house effect, clean energy requirements and the need for renewable energy resources, electric vehicles have gained ground. Today, research in electric vehicle design and improved battery technology is an active area of research. The auto-mobile industry is adjusting to the requirements to minimize pollution, to limited availability of conventional energy resources and to minimize the cost of travelling.

In order to move from non-renewable energy resources to renewable energy resources, it is important that we have a very robust grid which can support the energy needs. The grid should be able to support the additional loads from the electric vehicles. Also, it should be able to meet variable energy loads which vary depending on the time of the day and the season. The cost of energy should not increase with an increase in the energy requirements and the grid should also not fail under additional loads.

II. SIGNIFICANCE

This project aims to develop a system which helps to charge the electric vehicle much faster than the present time electric vehicle with more efficiency and help the user to save more time and money. Within 20 years, Bloomberg New Energy Finance predicts that half of all cars sold will be electric. Fossil fuels and the combustion engine are on the way out. EVs are better for the environment. They improve human health (think less smog and air pollution), they are cheaper to maintain, and they are very fun to drive! But right now, there are only about a million EVs on US roads. DC Fast Charging bypasses all of the limitations of the on-board charger and required conversion, instead providing DC power directly to the battery, charging speed has the potential to be greatly increased. Charging times are dependent on the battery size and the output of the dispenser, and other factors, but many vehicles are capable of getting an 80% charge in about or under an hour using most currently available DC fast chargers. DC fast charging is essential for high mileage/long distance driving and large fleets. The quick turnaround enables drivers to recharge during their day or on a small break as opposed to being plugged in overnight, or for many hours, for a full charge.

- Fast charging aims to recharge EV batteries within a short period similar to that for gasoline refueling of conventional vehicles.
- The time necessary for fast charging is about 20 minutes for charging up 80% capacity.
- EVs convert over 77 per cent of the electrical energy from the grid to power at the wheels. Conventional gasoline vehicles only convert about 12 per cent – 30 per cent of the energy stored in gasoline to power at the wheels.
- This will help people to waste less time at charging stations.
- It decreases the traffic at the charging stations.

Future scope of the project includes Development of electric vehicles station The EV charging station market is expected to grow 5 to 7 times in the next 5 years. It was valued at 5 billion dollars in 2020 and optimistic predictions see it reach around 35 billion by 2026, which would make EVs represent 15% of all car sales worldwide within 5 years. In the past decade the increased interest in sustainable transportation has been pushing the EV manufacturers, infrastructure developers and charging station makers to constantly innovate and improve the century-old technology. The race is on for a better drive range, efficient charging, superior battery capabilities and of course outstanding customer experience.

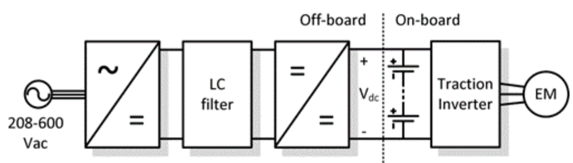
Motivated by their efforts to decrease CO2 emissions, many governments (mostly European) introduced incentives for EV owners. These measures not surprisingly led to a significant surge of EV sales, which in turn generated demand for charging stations. Today, the future seems bright for the EV Charging market. Let’s take a look at what lies ahead and, more importantly what market players can already do to win the race against their competitors.

III. OBJECTIVES

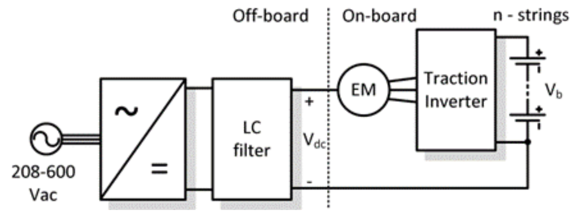
The energy storage system is an essential component of the electric vehicle (EV) that has a major influence on its efficiency, drive range and performance. The modern electric vehicle typically employs a single battery pack, which is sized to primarily meet the drive range specification of the vehicle. Batteries have significantly higher energy densities compared to their power densities, and their recommended peak-to-average power ratio is between0.5 to 2. This poses a challenge to the electrification of road vehicles where the peak-to- average power ratio based on real-world drive cycles.

A simple solution to increase the power capacity of the energy storage system is to use a larger battery pack. An alternative to oversizing the battery pack is energy storage hybridization, where a high-power density source is used together with the high energy battery. Examples of secondary energy sources are supercapacitors, batteries of another electrochemical composition, and fuel cells.

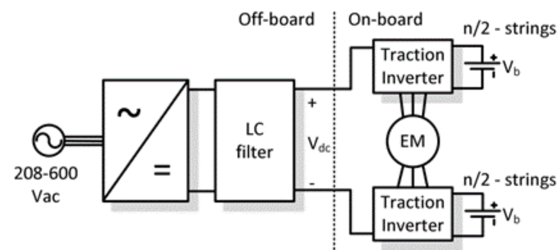
To integrate a secondary energy source having a differing electrochemical and/or physical property, additional interface power electronic converters are utilized. The most well-established topology integrating mixed energy storage media. The DC/DC and DC/AC two stage traction system has been heavily investigated.



By connecting the secondary energy source to the battery via a DC/DC converter, power from each energy source can be freely controlled. A drawback of this system is that the DC/DC converter introduces additional electrical loss as well as inductive elements on- board the vehicle. When the secondary energy source is a supercapacitor, this configuration is particularly inefficient under low-speed urban driving conditions where the drive inverter must use a high step-up ratio to perform regenerative braking while a high step-down ratio is required for the DC/DC converter to transfer this braking energy into a depleted supercapacitor.



The dual inverter drive is a multilevel topology that overcomes these limitations without the use of DC/DC power converters or additional inductive elements, thus offering an efficient and light-weight solution attractive for electric vehicles. The basic components of the dual inverter drive are the energy storage units, two DC/AC converters



Proposed integrated charger using the dual inverter drive

IV. METHEDOLOGY

Modeling and simulation of the battery needs to know mathematical relationship between battery input and output parameters and simulator. The simulator for battery has been developed using MATLAB and Simulink software tool. The results of these tools are given at appropriate sections of the thesis. The mathematical battery models are explained as in the following section. The open circuit voltage (v) changes with state of charge (SOC). In case of lithium-ion battery, open circuit voltage is directly proportional to the state of charge of the battery. Figure 3.1is highly useful even though it does not explain dynamic behavior of the battery and this equivalent diagram is considered for the modeling purpose. The battery capacity used in electric vehicles is usually quoted for some hours discharge. The electric cell shave nominal voltages E, which gives approximate voltage when cell delivers electrical power. The internal resistance i.e. R, the current I is f lowing out of the battery. The open circuit voltage V

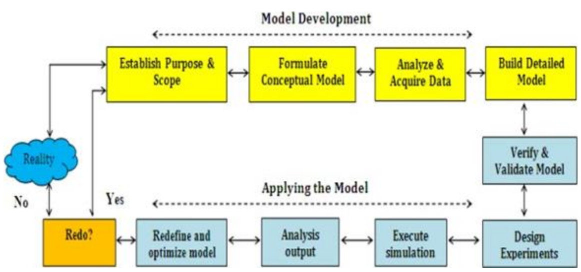
can be written
$V = E - I \times R$

Where, $R = R1 + R2$

This equation gives proper prediction of the battery voltage during the electrical load. The voltage E is not constant and also affected by state of charge (SOC) and other parameters such as temperature. Mathematically, the open circuit voltage is written as

$$E = n \times 2.15 - DoD \times 2.15 - 2.00$$

Where n is considered as number of cell consist in the battery. For Nickel type of battery, this formula is not suitable because voltage or state of charge curve is not linear. In this formula temperature parameter term is not included. If temperature term is included in the formula, then it would give strong impact on modeling of the battery.



To model this proposed battery MATLAB® software is used to simulate the battery behavior. The functions for calculation of E have been written in MATLAB software tool for Li-ion batteries. The function programs are executed before execution of main MATLAB program. A battery with low in internal resistance delivers high current to the system as per demand of the energy. High resistance causes the battery voltage to collapse and the equipment cuts off, leaving energy behind in the system.

This is the general block diagram of development and optimization of the model for specific purpose. In this project, it is planned to study the above process of development and application of model. Here, different battery models are to be studied and simulate it in MATLAB and Simulink software to understand behaviour of the battery. The model development consists of formulation of conceptual model, analysis, acquire data and building model. Whereas in applying model includes simulation, result analysis, redefining, model optimization and verification and validation. The mathematical formulation is needed for the planed so that dependent and independent parameters could be identified and used in software system. After analysis the specific model is represented and used for simulation experimentation, the simulation is executed and generated results are again analyzed. In case the simulated results are not validated with reality system in optimization or redefinition then model modification is necessary and required otherwise no modification in the prescribed model. With the help of MATLAB or Simulink we can mathematically models for estimation and prediction the behavior of the systems.

- Battery Equalization

The electric vehicle battery pack consists of large number of cells which are packed in modules. These modules have variable voltages. The power quality of the battery is good if the battery is operated at one specific voltage. Hence to maintain the whole battery pack at one energy level and voltage energy is transferred from higher energy battery module to the lower energy battery module. Battery equalization is the process to balance the energy levels of the modules of lithium-ion battery pack.

The battery pack has limitation on the its maximum current to charge or discharge, maximum and minimum operating voltage, quantization error and noise. This is addressed with equalizing the battery pack. The energy from higher energy module is transferred to lower energy module. The high energy modules have lower internal resistance whereas the lower energy modules have higher internal resistance. The energy level of the battery is equalized to minimize the loss of energy. The battery pack is operated at equalized module as a benchmark and not the lowest energy module as the benchmark.

A control scheme to equalize battery modules based on open circuit voltage estimation. A novel cell equalization approach was proposed to achieve a low-cost operation, large current exposure and high efficiency. A practical approach to solve the cell equalization problem is with a voltage equalization scheme. Voltage based power electronics scheme for cell equalization is a practical solution for electric vehicles and plug-in hybrid electric vehicles.

- Electric Vehicles in Smart Grid Market

The major hurdle in penetration of electric vehicles in the market is energy carrying capacity of batteries. Though performance of the lithium-ion batteries has improved, it does have limitation on miles per charge. Charging the batteries on the residential grid is a widely accepted solution in near future applications. The batteries should penetrate in the residential grid in coordination, arbitrarily charging the batteries can adversely affect the performance of the grid. One of the solutions to charge batteries faster is by charging them with a higher current. This, however, has adverse effect on battery health. As the charging current increases, the internal resistance of the battery rises over a period of time. There is a trade-off between the charging the batteries with higher current level sand the health of the batteries. The charging current for lithium-ion battery and the battery degradation is optimized by Bashashetal (S. Bashash,2011).

- Thermal Modeling of Lithium-Ion Batteries

A factor limiting widespread use of electric vehicles is performance of the batteries. The lithium-ion batteries explode at high temperatures. Their performance drastically degrades if their operating temperatures are high (Millner, 2010). The thermal behavior of the lithium ion battery is modeled by Caietal (L.Cai,2011).The battery temperatures change with the application of the loads. The temperature of the battery rises with the operation of the battery. Proper cooling system should be implemented to keep the battery temperature within the operating range.

Though a lot of research has been conducted in the field of battery modeling, battery equalization and performance of electric vehicle batteries, there are specific issues that need to be addressed. The battery performance can be improved by knowing its state of health and state of charge. Accurately identifying the internal resistance of the battery pack helps us to predict the behavior of the batteries. There viewed literature directs to use voltage equalization scheme which is a robust technique to equalize batteries.

Modeling and Simulation of Battery Performance Parameters

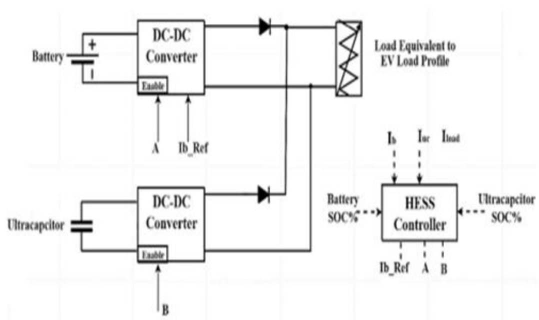
Battery performances and characteristics at diverse operating conditions are critical in its applications particularly in Electrical Vehicles (EVs) and Hybrid Electrical Vehicles (HEV). With a precise and competent battery model it can be predict and optimize battery performance mainly under practical runtime usage such as Battery Management Systems (BMS). An accurate method for estimating the battery parameters is needed before constructing the reliable battery model. There are three famous battery models; battery equivalent circuit, Thevenin and second order Battery modes are commonly used for battery modeling.

Battery Power and Energy for the Charge-Sustaining HEV Mode

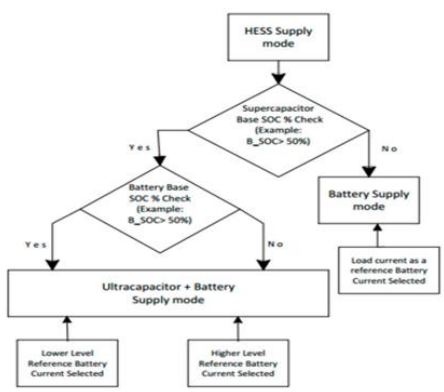
- In an HEV when the battery is depleted, that is, discharged to a certain SOC. Most HEVs operate in a charge-sustaining mode around a predefined SOC. During CS HEV operation, the battery has to meet the discharge and regain power with available energy around this SOC.
- The power requirements for the 10-mile and 40-mile ranges discussed above are higher than the targets set for maximum and minimum power-assist HEVs, respectively.
- After looking at the power capabilities of tested lithium-ion batteries at various SOCs, the Work Group determined that if a battery system meets the peak power targets, it also would meet the HEV needs, so no additional peak power target for a HEV was selected.
- The available energy requirements for the HEV mode were selected to be 500 Wh for a 10-mile (high P/E ratio) battery (the same as maximum power-assist) and 300 Wh for a 40-mile (high E/P ratio) battery.
- The total energy is the available energy/SOC window and depends on the battery technology.

- HESS System Configurations

HESS can be defined on the basis of the connection of the storage unit to the DC link of the EV. HESS system configurations are passive, semi-active and active. There is no connected converter between the energy storage unit and the DC link in a passive HESS configuration. In a semi-active HESS configuration, only one energy storage unit is connected to the DC link via a DC-DC converter; the other storage unit is connected directly. In most cases, the battery is connected directly to this configuration. The configuration in which the energy storage is connected to the DC link, having a bidirectional DC-DC converter between them, is known as an active HESS configuration. Figure below depicts a block diagram of HESS with DC-DC converters linked to a DC bus modulated by the HESS (Hybrid energy storage system).



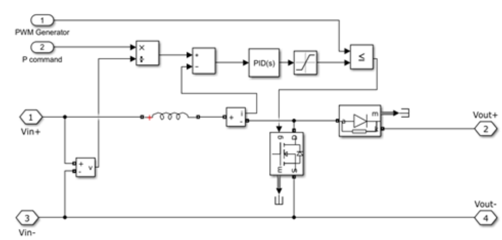
- HESS control scheme algorithm.



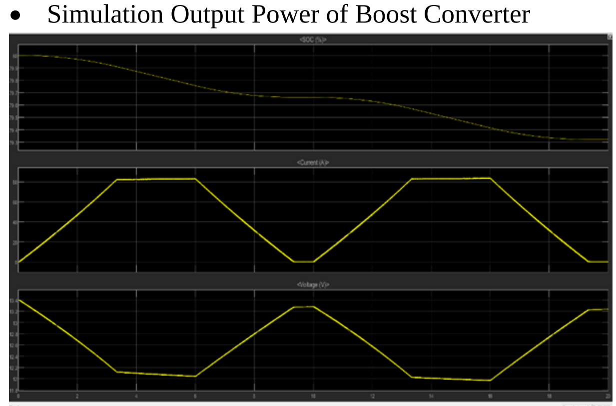
- Boost Converter

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). Boost converters are highly nonlinear systems and a wide variety of linear and nonlinear control techniques for achieving good voltage regulation with large load variations have been explored.

Power for the boost converter can come from any suitable DC source, such as batteries, solar panels, rectifiers, and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC-to-DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power ( ) must be conserved, the output current is lower than the source current.

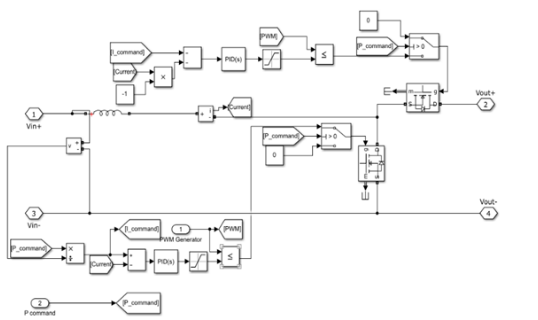


- Simulation Output Power of Boost Converter

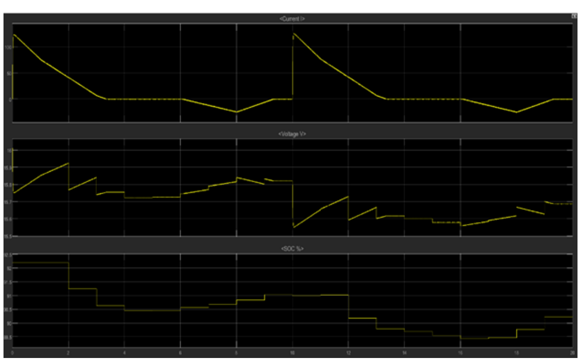


- BUCK/BOOST CONVERTER

The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a flyback converter using a single inductor instead of a transformer. Two different topologies are called *buck–boost converter*. Both of them can produce a range of output voltages, ranging from much larger (in absolute magnitude) than the input voltage, down to almost zero.

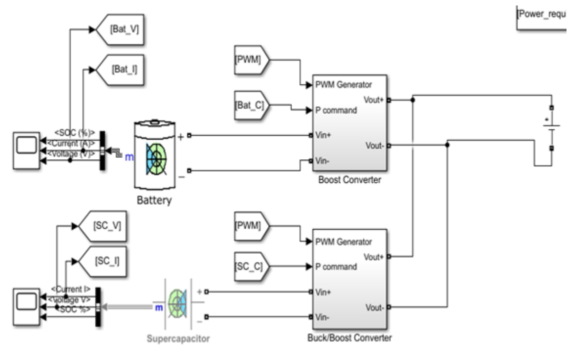


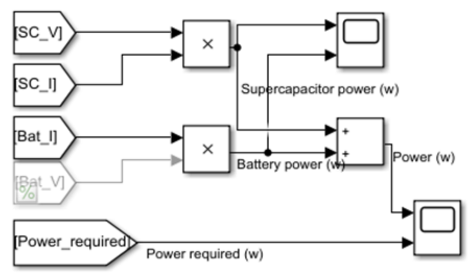
In the inverting topology, the output voltage is of the opposite polarity than the input. This is a switched-mode power supply with a similar circuit topology to the boost converter and the buck converter. The output voltage is adjustable based on the duty cycle of the switching transistor. One possible drawback of this converter is that the switch does not have a terminal at ground; this complicates the driving circuitry. However, this drawback is of no consequence if the power supply is isolated from the load circuit (if, for ex, the supply is a battery) because the supply and diode polarity can simply be reversed. When they can be reversed, the switch can be on either the ground side or the supply side.

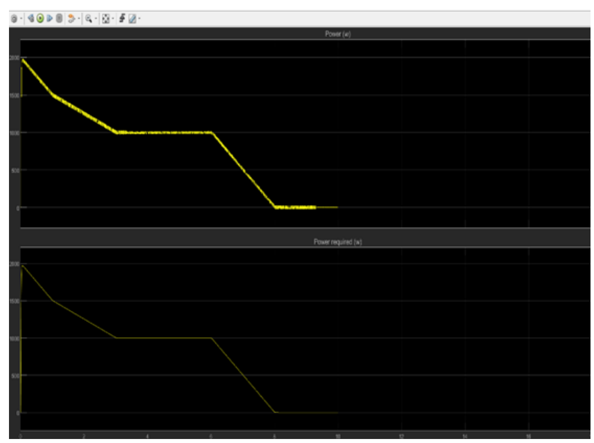


Simulation Output Power of Buck/boost converter

- Circuit Diagram







Simulation of Total Output Power Vs Required Power

The SOC level of an ultracapacitor is generally taken as 50% due to its efficiency being drastically reduced below this level of SOC. In the case of a battery, SOC rules can be changed according to application and user needs.

CONCLUSION

The main contribution of this project is the reconfiguration of the dual inverter traction system for integrated fast charging. The concept is to eliminate the DC/DC power stage of off-board battery chargers by performing DC/DC power conversion using traction hardware. As a result, the existing EVSE is reduced to a single AC/DC power stage, which itself can potentially be shared amongst multiple EVs.

This work proposes a fast-charging method which leverages high-current traction drive and existing powertrain components in the dual inverter drive, thus enabling rapid charging functionality without additional equipment.

This topology supports flexible battery voltage range, current ripple reduction, and reduces the complexity of the electric vehicle supply equipment.

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