Design Energy Efficient Mechanism for Electrical Vehicle Using Power Electronics

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Abstract: *An electric vehicle (EV), also called an electric drive vehicle, uses one or more electric motors or traction motors for propulsion. An electric vehicle may be powered through a collector system by electricity from off-vehicle sources, or may be self-contained with a battery, solar panels or an electric generator to convert fuel to electricity. EVs include road and rail vehicles, surface and underwater vessels, electric aircraft and electric spacecraft. EVs first came into existence in the mid-19th century, when electricity was among the preferred methods for motor vehicle propulsion, providing a level of comfort and ease of operation that could not be achieved by the gasoline cars of the time. Modern internal combustion engines have been the dominant propulsion method for motor vehicles for almost 100 years, but electric power has remained commonplace in other vehicle types, such as trains and smaller vehicles of all types.*

In the 21st century, EVs saw a resurgence due to technological developments and an increased focus on renewable energy. Government incentives to increase adoptions were introduced, including in the India, United States and the European Union. In this paper we have reviewed various research reports in the developments of the components of the Electrical Vehicle in order to provide a solution wherein key developments have been integrated as well as DC/DC converter design and Separate Controller have been proposed to develop optimally efficient Electrical Vehicle.

Keywords: *Electrical Vehicles, Energy Efficient Electrical Vehicles, Controllers for Electrical Vehicles*

I. INTRODUCTION

Just as there are a variety of technologies available in conventional vehicles, electric vehicles have different capabilities that can accommodate different drivers' needs. A major feature of EVs is that drivers can plug them in to charge from an off-board electric power source. This distinguishes them from hybrid electric vehicles, which supplement an internal combustion engine with battery power but cannot be plugged in.

There are two basic types of EVs:

- All-electric vehicles (AEVs)
- Plug-in hybrid electric vehicles (PHEVs)

AEVs include Battery Electric Vehicles (BEVs) and Fuel Cell Electric Vehicles (FCEVs). In addition to charging from the electrical grid, both types are charged in part by regenerative braking, which generates electricity from some of the energy normally lost when braking. Which type of vehicle will fit your lifestyle depends on your needs and driving habits. Find out which BEVs and PHEVs are available to suit your needs.

All-electric vehicles (AEVs) run only on electricity. Most have all-electric ranges of 80 to 100 miles, while a few luxury models have ranges up to 250 miles. When the battery is depleted, it can take from 30 minutes (with fast charging) up to nearly a full day (with Level 1 charging) to recharge it, depending on the type of charger and battery.

If this range is not sufficient, a plug-in electric vehicle (PHEV) may be a better choice. PHEVs run on electricity for shorter ranges (6 to 40 miles), then switch over to an internal combustion engine running on gasoline when the battery is depleted. The flexibility of PHEVs allows drivers to use electricity as often as possible while also being able to fuel up with gasoline if needed. Powering the vehicle with electricity from the grid reduces fuel costs, cuts petroleum consumption, and reduces tailpipe emissions compared with conventional vehicles. When driving distances are longer than the all-electric range, PHEVs act like hybrid electric vehicles, consuming less fuel and producing fewer emissions than similar conventional vehicles. Depending on the model, the internal combustion engine may also power the vehicle at other times, such as during rapid acceleration or when using heating or air conditioning. PHEVs could also use hydrogen in a fuel cell, biofuels, or other alternative fuels as a back-up instead of gasoline.

II. RELATED WORK

In [1] Fabio Crescimbini, Stefano Bifaretti, Marco Di Benedetto, Alessandro Lidozzi, Sabino Pipolo and Luca Solero proposes use of Variable Speed Diesel Electric Unit with Power Electronic Converter and PM Synchronous Generator instead of Fixed Speed Diesel Engine with Rotor Field Winding Synchronous Generator with results which shows that Variable Speed Systems are most applicable where the difference between Peak Power Generation capability and required average load is large. The proposed system is controlled by a combined ARM – MuP FPGA structure which regulates the output DC link voltage and the prime mover speed according to the DC link requested power.

In [2] Markus Henke and Tim-Hendrik Dietrich are applying Alternating Magnetic field in the primary coil system which leads to an Inducted voltage in the secondary coil. The output current of the secondary coil flows through specially designed serial compensation unit and is rectified to supply the DC link of the DC-DC converter. Contactors were used to disconnect the Induction Charging System.

In [3] Anurag Khergade, S. B. Bodkhe and Ashwani Kumar Rana proposes the use of AFPM BLDC motor to avail high torque and wide speed range. The use of AFPM BLDC motor also reduces the overall size of the EV due to its compactness. To achieve accurate speed control, closed loop control using microcontroller is proposed in this paper. Microcontroller is used to drive the motor by sensing rotor position using Hall sensors. The effective braking scheme is also proposed.

In [4] Florin Dumitrache, Marius Catalin Carp and Gheorghe Pana presents a way of designing and implementing an electronic module for an e-Bike. The paper shows how a low power, 8-bit microcontroller can be used to drive such a motor and also manage other useful functions on an e-Bike.

In [5] Anif Jamaluddin, Fengky Adie Perdana, Agus Supriyanto, Agus Purwanto; Inayati, and M. Nizam presents a Wireless Battery Monitoring System (WBMS) for electric vehicle, developed for monitoring voltage, current and temperature of battery. Their proposed system consists of hardwares (sensors, a microcontroller, a bluetooth module, an Android smartphone) and software. It was designed on a low cost microcontroller ATMEGA 328 (Arduino UNO). Voltage, current and temperature data are transferred to microcontroller, then data of battery is transferred using bluetooth communication to display. In this research, data of battery monitoring are displayed on Personal Computer (PC) with LabVIEW programme and android smartphone. The monitoring system was able to show real-time data of voltage, current and temperature and display data on android smartphone and PC simultaneously.

In [6] Vatsal Shah, Vipin Shukla, and Amit Sant presents the design methodology and performance analysis of a single passenger prototype battery electric vehicle (EV), named Vidyut. The main objective of this paper is to demonstrate the performance of a Lynch motor based propulsion system for a prototype EV. Lynch motor is an axial gap permanent magnet (PM) brushed dc motor which offers the merits of higher torque to weight ratio, higher power density, and lower cost as compared to the PM brushless dc motors. This results in elimination of dc-ac conversion system, and consequently reduces power and signal electronics, related losses, cost. On the other hand, the overall reliability, energy savings and compactness are positively impacted. The prototype consists of a 24 V lithium ion battery storage system, MOSFET based synchronous buck dc-dc converter, and an ARM microcontroller for implementing the control algorithm.

III. PROPOSED SYSTEM

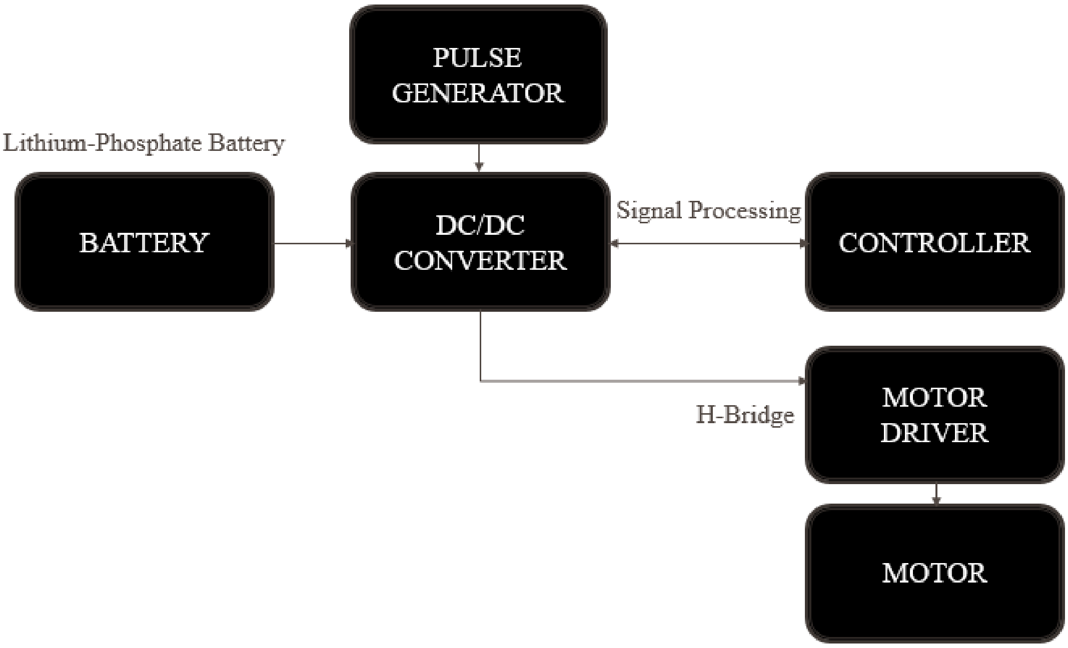


Fig- 1 Proposed System

The different configurations of EV power supply show that at least one DC/DC converter is necessary to interface the Battery module to the DC-link.

In electric engineering, a DC to DC converter is a category of power converters and it is an electric circuit which converts a source of direct current (DC) from one voltage level to another, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components (capacitors).

DC/DC converters can be designed to transfer power in only one direction, from the input to the output. However, almost all DC/DC converter topologies can be made bi-directional. A bi-directional converter can move power in either direction, which is useful in applications requiring regenerative braking.

The amount of power flow between the input and the output can be controlled by adjusting the duty cycle (ratio of on/off time of the switch). Usually, this is done to control the output voltage, the input current, the output current, or to maintain a constant power. Transformer-based converters may provide isolation between the input and the output. The main drawbacks of switching converters include complexity, electronic noise and high cost for some topologies.

In case of interfacing the Fuel Cell, the DC/DC converter is used to boost the Fuel Cell voltage and to regulate the DC-link voltage. However, a reversible DC/DC converter is needed to interface the SCs module. A wide variety of DC-DC converters topologies, including structures with direct energy conversion, structures with intermediate storage components (with or without transformer coupling), have been published.

Each converter topology has its advantages and its drawbacks. For example, The DC/DC boost converter does not meet the criteria of electrical isolation. Moreover, the large variance in magnitude between the input and output imposes severe stresses on the switch and this topology suffers from high current and voltage ripples and also big volume and weight. A basic interleaved multichannel DC/DC converter topology permits to reduce the input and output current and voltage ripples, to reduce the volume and weight of the inductors and to increase the efficiency. These structures, however, cannot work efficiently when a high voltage step-up ratio is required since the duty cycle is limited by circuit impedance leading to a maximum step-up ratio of approximately 4. Hence, two series connected step-up converters would be required to achieve the specific voltage gain of the application specification. A full-bridge DC/DC converter is the most frequently implemented circuit configuration for fuel-cell power conditioning when electrical isolation is required. The full bridge DC/DC converter is suitable for high-power transmission because switch voltage and current are not high. It has small input and output current and voltage ripples. The full-bridge topology is a favourite for zero voltage switching (ZVS) pulse width modulation (PWM) techniques.

IV. SIMULATION RESULT

Simulink Model:

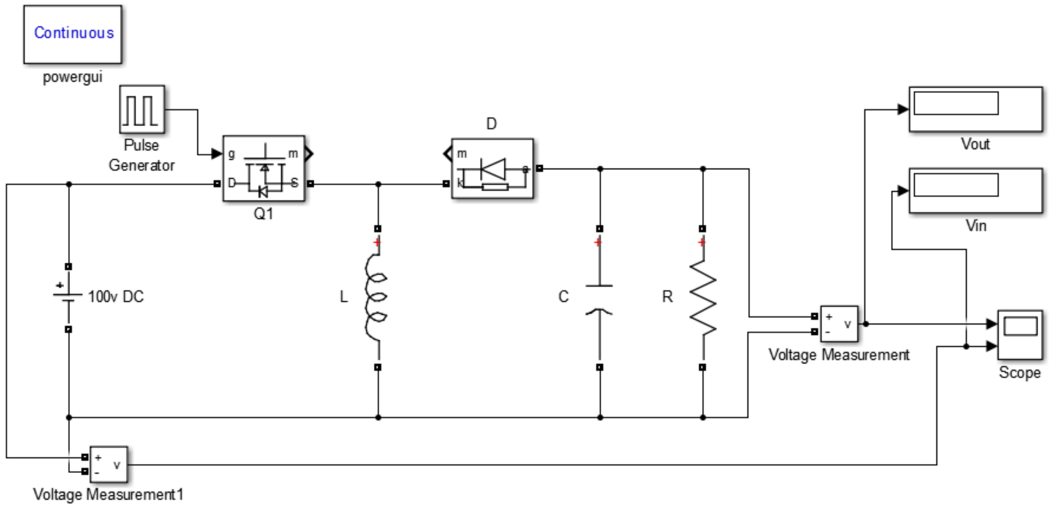


Fig 2 - Simulink Model for DC-DC Buck Boost Converter (Final Version)

Parameters:

DC Voltage = 100 V; L = 1mH; C = 47uF; R = 10 ohms; Pulse Generator Amplitude = 10; Pulse Generator Amplitude = 50 KHz; Pulse Generator Pulse Width (Duty Cycle) = 20, 50 & 80

Operation:

Here, I have modelled the Buck-Boost DC-DC Converter with 100 V input voltage and simulated the results for different duty cycles.

At duty cycle = 20 the DC-DC converter works in the Buck Mode and gives results of approximately 24 V in the output.

At duty cycle = 50 the DC-DC converter works in the Idle Mode and gives results of approximately 98 V in the output.

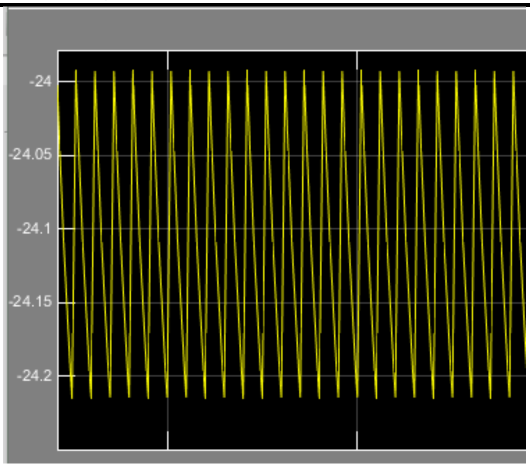
At duty cycle = 80 the DC-DC converter works in the Boost Mode and gives results of approximately 328 V in the output.

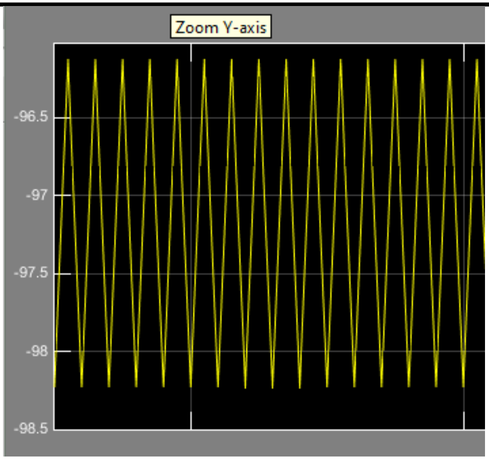
Hence, we can increase or decrease the output voltage by changing the duty cycle of the switch Q1 i.e. MOSFET in this case from 0 to 100.

Simulink Output:

At Duty Cycle = 20

At Duty Cycle = 50





At Duty Cycle = 80

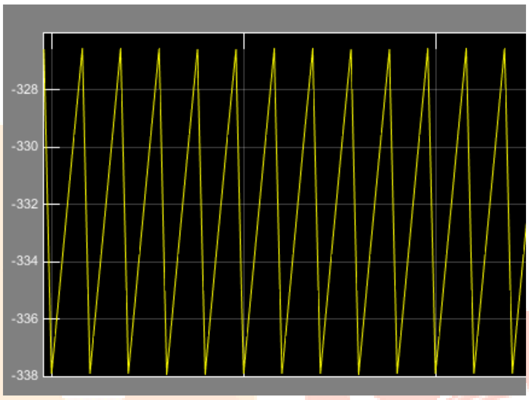


Fig 3 - Simulink Output for DC-DC Buck Boost Converter (Final Version) with various Duty Cycles

V. HARDWARE RESULT ANALYSIS

Per the outcomes of the literature analysis, we worked on speed comparison of BLDC motor using simple Li-Polymer battery and advance Li-PO4 battery along with Arduino Uno Atmega 328 controller.

Using controller we have provided the PWM signals to the motor terminal via DC to DC converter and analyzed the results.

Results:

Sr. No.	Voltage at Motor Terminal (v)	Motor Speed (RPM)	Duration
1	O	0	0 to 2 ms (ON time)
2	0.5	5	0.2 – 1.8 ms
3	1	10	0.4 – 1.6 ms
4	1.5	15	0.6 – 1.4 ms
5	2	20	0.8 – 1.2 ms
6	2.5	25	1.0 – 1.0 ms
7	3	30	1.2 – 0.8 ms
8	3.5	35	1.4 – 0.6 ms

9	4	40	1.6 – 0.4 ms
10	4.5	45	1.8 – 0.2 ms
11	5	50	2.0 – 0 ms

Table 1 – Result Analysis

Per our analysis, we have successfully achieve speed comparison with different PWM signal and terminal voltages. Here we have also compared the controller output with conventionally used PID controller as well. The PID controller is an analog controller and have certain limitation in terms of response time as compared to Atmega 328 controller. The PID controller have large sampling time and hence large response time. Also the PID controller have poor performance during nonlinear operations.

The issues of the PID controller including the nonlinearity has been resolved successfully with our controller – DC to DC converter combination.

VI. CONCLUSION

Increasing level of pollution is the key issue of the moment for almost every country in the world and with increasing population of fossil fuel powered transportation mediums, the issue is rising rapidly as it accounts for the major percentage of overall pollution. However, we saw a gap between the individual research on the EV components and integration of the same into one complete system with few modification/development to make them more efficient. This research is our humble try to fill this gap and we would like it to be appreciated. Although there is still fair amount of development scope available in this field, we have touched few important technical development scope during our research tenure which we felt needs to be addressed immediately.

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