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Charging Electric Car with Solar Energy

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ABSTRACT

In a world where environment protection and energy conservation are growing concerns, the development of electric and hybrid vehicles (EV/HEV) has taken on an accelerated pace. The dream of having commercially viable electric/hybrid vehicles is becoming a reality. EVs and HEVs are gradually available in the market. This chapter reviews the present status of electric and hybrid vehicles worldwide and their state of the art, with emphasis on the engineering philosophy and key technologies. The importance of the integration of technologies of automobile, electric motor drive, electronics, energy storage and controls, and the importance of the integration of society strength from government, industry, research institutions, electric power utilities and transportation authorities are addressed. The challenge of EV commercialization is discussed.

INTRODUCTION

It's certainly clear that fossil fuels are mangling the climate and that the status quo is unsustainable. There is now a broad scientific consensus that the world needs to reduce greenhouse gas emissions more than 25 percent by 2020 and more than 80 percent by 2050.The idea of harnessing the sun's power has been around for ages. The basic process is simple. Solar collectors concentrate the sunlight that falls on them and convert it to energy. Solar power is a feasible way to supplement power in cities. In rural areas, where the cost of running power lines increases. Solar power, a clean renewable resource with zero emission, has got tremendous potential of energy which can be harnessed using a variety of devices. With recent developments, solar energy systems are easily available for industrial and domestic use with the added advantage of minimum maintenance. Solar energy could be made financially viable with government tax incentives and rebates. An exclusive solar generation system of capacity 250KWh per month would cost around Rs. 20 lakhs, with present pricing and taxes (2013). Most of the developed countries are switching over to solar energy as one of the prime renewable energy source.

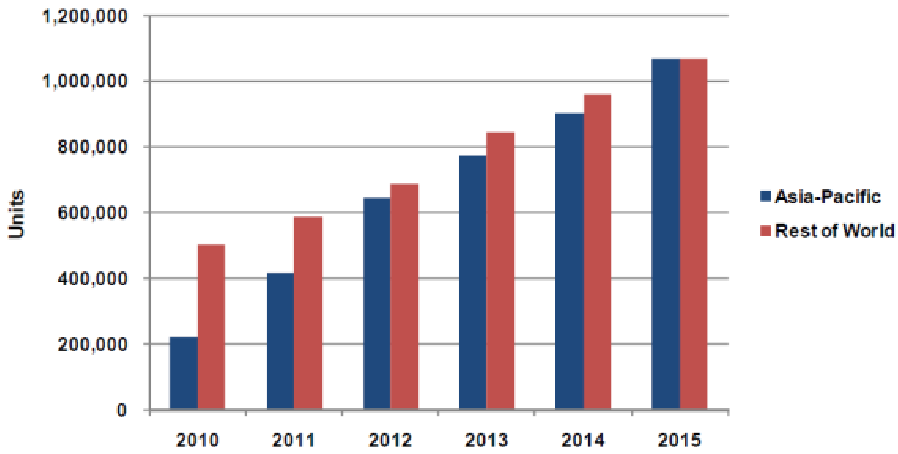

Fig 1.1 Graphical Representation of Electric Car Consumption

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Adoption of electric cars especially in developing nations of Asia-Pacific is showing a healthy increase over the past few years. The trend of vehicle units sold versus year is shown in Figure 1.1. The vehicle is analytically calculated with the help of its technical specifications. Detailed analytical calculation of EV is demonstrated in literatures . The analytical calculation and simulation model will be developed in this paper. The results will be summarized in forms of various tables for reader. The vehicle will be simulated for various velocity inputs such as constant speed and various driving cycles. Electric vehicle (EV) is a road vehicle which involves with electric propulsion. With this broad definition in mind, electric vehicles may include battery electric vehicles (BEV), hybrid electric vehicle (HEV) and fuel cell electric vehicle (FCEV). Electric vehicle is a multi-disciplinary subject which covers broad and complex aspects. However, it has core technologies, namely chassis and body technology, propulsion technology and energy source technology. The article begins with reviewing the status of BEV and HEV, then focusing on the engineering philosophy of EV development. Subsequent to the illustration of the configurations of both BEV and HEV, it discusses rather detail the major technologies, namely the propulsion technology, energy source technology and infrastructure technology. Finally the commercialization aspects are discussed. The conclusion summarizes the state of the art and the challenges of BEV, HEV and FCEV.

For our study of the core aspects of electro mobility, we have chosen the areas of environment, politics, economy, society, infrastructure and technology. It is not possible to completely separate the content of these areas because there are complex relationships between them. Climate change and the conditions for the use of fossil resources (limited availability, price) are causing countries to change their climate and energy policies and are causing changes to their national societies. Politicians are responding to these changes with national emissions limits that unfortunately vary at international level. As a rule, these limits cover direct emissions of CO2 or other environmentally harmful gases. Electric vehicles do not produce direct emissions in the form of CO2.

In order to meet the increase in power demands and to reduce the global warming, renewable energy sources based system is used. Out of the various renewable energy sources, solar energy is the main alternative. But, compared to other sources, the solar panel system converts only 30–40% of solar irradiation into electrical energy. In order to get maximum output from a PV panel system, an extensive research has been underway for long time so as to access the performance of PV system and to investigate the various issues related to the use of solar PV system effectively. This method help to increase utility of electric system in car to dandify the less use of fuels.

NOVEL STRATEGY OF EFFICENT ELECTRIC VEHICLE CHARGING USING MPPT

SYSTEM DIAGRAM

A solar car is an electric vehicle powered by energy from the sun via on-board photovoltaic cells that charge the batteries for a more driving extent [2]. The solar car is designed with three main electrical components connected in parallel: the solar panel array, the energy storage system and the electric motor drive system. The proposed storage system can be charged by the PV array, and both can provide power to the motor to drive the car at desired speed [9]. Table I shows the basic electrical and mechanical components of solar cars. Note that only the electrical components and their design will be discussed in this system.

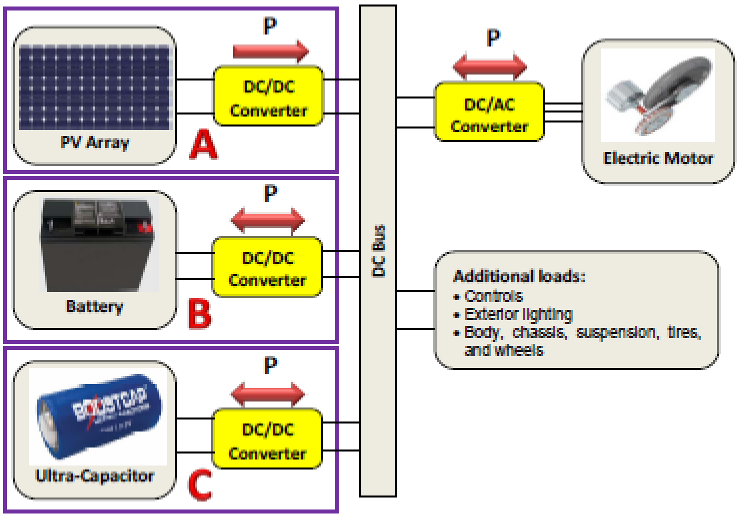

Fig 3.1 Electric Car Charging System

Table 3.1 Basic Components of Solar Car

Electrical components	**Mechanical components**
Photovoltaic cells(solar arrays)	Exterior lighting
MPPT	Body
Energy storage system	Chassis, suspension
Electric drive motor	Tires and wheels

3.1.1 Basic Principle

An Electric car is powered by an Electric Motor rather than a Gasoline Engine. The Electric Motor gets its power from a controller. The Controller is powered from an array of rechargeable batteries.

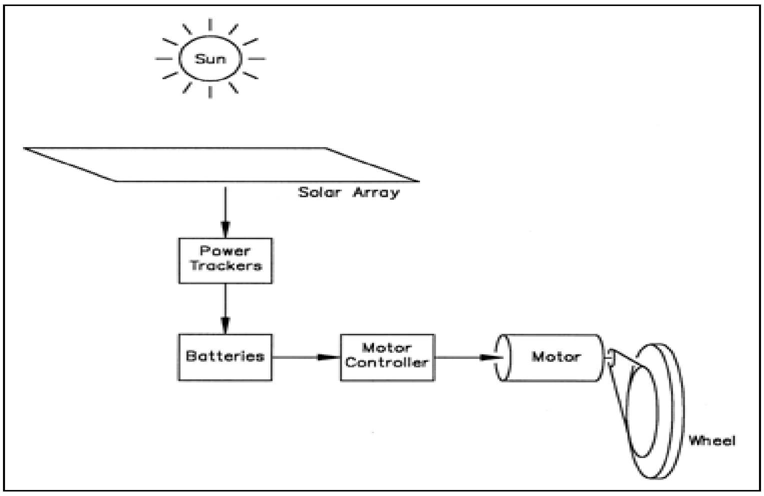

Fig 3.2 Block Diagram of Electric Car with Solar Cell

PROPOSED DC-DC CONVERTER FOR MPPT INTERNAL

The basic function of any switch mode DC-DC converter, in any PV system, as an Intermediate power processor is that it changes the current and voltage level such that maximum power can be extracted from PV array .Changing voltage and current levels is nothing but converting a given fixed load to a variable load. The connected load may be of stand-alone sink type, battery, up-stream converters or combination of these.

The analysis is carried out under the following assumptions:

1. Switching elements (MOSFET and Diode) of the converter are assumed to be ideal.
2. The stray capacitance and equivalent series resistance of the capacitance are considered.
3. Passive components of the converter (R, L, and C) are assumed to be linear, time invariant and frequency independent.
4. Converter operations assumed to be operating in continuous inductor current mode of operation. Figure 3:shows the block diagram implementation of MPPT using Boost converter. A boost converter can also be called as the step-up converter because the DC voltage output is higher than the DC voltage input.

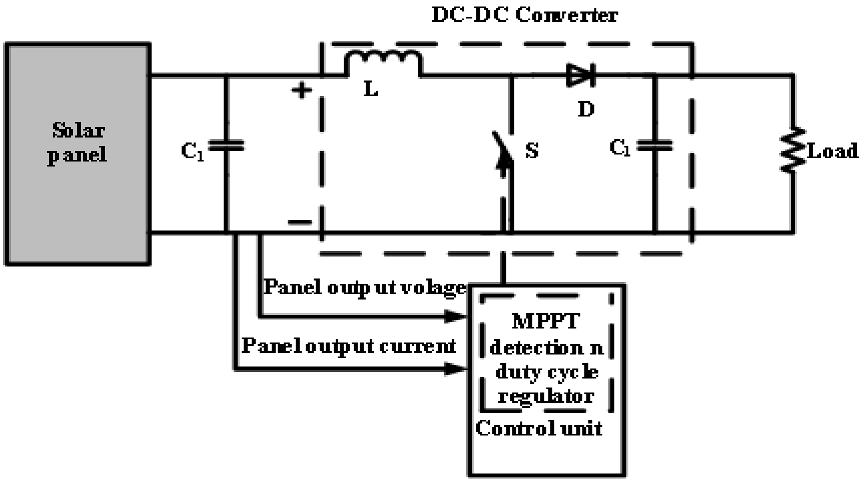

Fig 3.6 Solar Panel with DC-DC Converter for MPP Tracking

3.2.1 Boost Converter

A boost converter is designed to step up a fluctuating or variable input voltage to a constant output voltage of 24 volts with input range of 6-23volts in. To produce a constant output voltage feedback loop is used. The output voltage is compared with a reference voltage and a PWM wave is generated, here Spartan 6 FPGA kit is used to generate PWM signal to control switching action. A DC to DC converter is used to step up from 12V to 24V. The 12V input voltage is from the battery storage equipment and the 24V output voltage serves as the input of the inverter in solar electric system. In designing process, the switching frequency, f is set at 20 kHz and the duty cycle, D is 50%.Here we want to introduced an approach to design a boost converter for photovoltaic (PV) system using microcontroller. The converter is designed to step up solar panel voltage to a stable 24V output without storage elements such as battery.

It is controlled by a FPGA unit using voltage-feedback technique. The output of the boost converter is tracked, measured continuously and the values are sent to the microcontroller unit to produce pulse-width-modulation (PWM) signal. The PWM signal is used to control the duty cycle of the boost converter. Typical application of this boost converter is to provide DC power supply for inverter either for grid-connected or standalone system. Simulation and experimental results describe the performance of the proposed design. Spartan 6 FPGA is used to perform tasks in the proposed design. As stated in the introduction, the maximum power point tracking is basically a load matching problem. In order to change the input resistance of the panel to match the load resistance (by varying the duty cycle), a DC to DC converter is required. It has been studied that the efficiency of the DC to DC converter is maximum for a buck converter, then for a buck-boost converter and minimum for a boost converter but as we intend to use our system either for tying to a grid or for a water pumping system which requires 230 Vat the output end, so we use a boost converter.

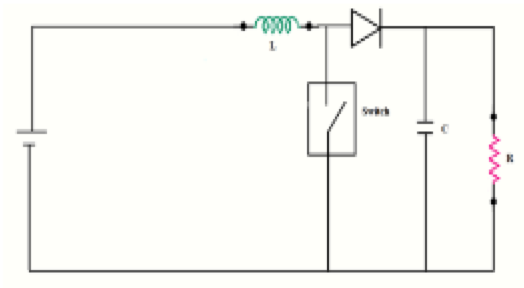

Fig 3.7 Circuit Diagram of a Boost Converter

3.2.1.1 mode 1 operation of the boost converter

When the switch is closed the inductor gets charged through the battery and stores the energy. In this mode inductor current rises (exponentially) but for simplicity we assume that the charging and the discharging of the inductor are linear. The diode blocks the current flowing and so the load current remains constant which is being supplied due to the discharging g of the capacitor.

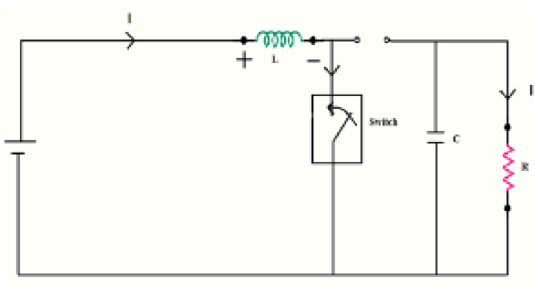

Fig.3.8 Mode1 Operation of the Boost Converter

3.2.1.2 mode 2 operation of the boost converter

In mode 2 the switch is open and so the diode becomes short circuited. The energy stored in the inductor gets discharged through opposite polarities which charge the capacitor. The load current remains constant throughout the operation. The waveform for boost converter are shown in figure.

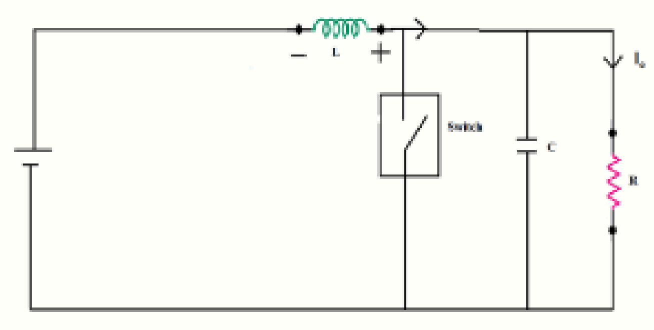

Fig 3.9 Mode 2 Operation of the Boost Converter

3.2 .1.3 Design approach of proposed boost converter

The design of the converter is performed to step-up the input voltage of 12V to an output voltage of 24V. The following parameters are required for the design of the Boost converter:

- Input voltage (VS) = 12V,
- Output voltage (VO) =24V,
- Switching frequency (fess) = 20 KHz,
- Maximum load current (Imax) = 2A,
- Maximum inductor current (Imax) = 4.25A,
- Minimum inductor current (Liming) = 0.5A,
- Ripple in the output voltage (do) = 1.2V,
- Ripple in the output current (do) = 0.03A,
- Load resistance (R) = 20 ohm.

We get the value of parameters from equation (1) and (2) as:

L=80µH

C=42µF

LC=62.5µH

Also the converter operates in continuous conduction mode as L < LC

Duty Cycle:

The duty cycle can be found using the following relation

$$D = 1 - \frac{\text{Vin}}{\text{Vout}}$$

Inductor value:

The value of inductor is determined using the following relation

Limn=D (1-D2)*R/2*Fs

An inductor is practically designed using the following parameters

Formula for inductor design, L $= \frac{(d2n2)}{(1+0.45d)}$

Required dimensions of inductor

Coil length, l = 8.1 cm

Diameter, d= 6.3 cm

Inductance value required, L = 151 uh.

Number of turns, n = 64

Where L is inductance in micro Henrys,

d is coil diameter in meters,

l is coil length in meters, and

n is number of turns.

Capacitor value:

The value of capacitor is determined from the following equation

$$C = \frac{D}{Fs * R * Vr}$$

Where is the minimum value of capacitance,

D is duty cycle,

R is output resistance,

Fs is switching frequency, and

Very is output voltage ripple factor

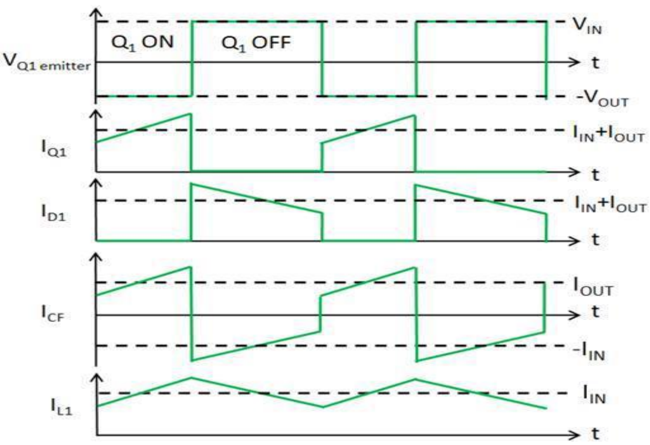

Fig 3.10 Boost Converter Waveform

RESULT AND DISCUSSION

4.1 SIMULATION

LT spice IV version 4.23i 2016 simulation programs are used to simulate the considered Boost switching converter. DC-dc power converters are employed in a variety of applications, including power supplies for Personal computers, office equipment, spacecraft power systems, laptop computers, and telecommunications equipment, as well as dc motor drives. The input to a dc-dc converter is an unregulated dc voltage Vg. The converter produces a regulated output voltage V, having a magnitude (and possibly polarity) that differs from Vg.

The dc-dc converter is a dc power supply that is small, lightweight & highly efficient, and uses a semiconductor switching element. It can response quickly and suitable to changes in input voltage within the scope of normal operating conditions to return to the normal operating state. It is comprised of (I) switching power supply unit which, can turn ON/OFF switching elements that can be turned ON/OFF at high frequency to convert a dc input voltage VIN into a dc output voltage VOUT, and (ii) a control unit, which is used to control the ON/OFF operation of the switching element of said switching power supply unit.[5]

LTspice IV is a high performance SPICE simulator, schematic capture and waveform viewer with enhancements and models for easing the simulation of switching regulators. Our enhancements to SPICE have made simulating switching regulators extremely fast compared to normal SPICE simulators, allowing the user to view waveforms for most switching regulators in just a few minutes.

LTspice IV is freeware computer software implementing a SPICE simulator of electronic circuits, produced by semiconductor manufacturer Linear Technology (LTC). LTspice IV provides a schematic capture and waveform viewer with enhancements and models to speed the simulation of switching regulators Supplied with LTspice IV are macro models for 80% of LTC's switching regulators and operational amplifiers, transistors, MOSFETs, and passive components.[1] It shows the Spice models of the Boost switching

Table 4.1 Comparison Boost Converter

Parameters	Design	Simulation
Input voltage	12V	12V
PWM voltage	5V	5V
Output voltage	24	23.12
Ripple in output voltage	1.2V	1.09V
Ripple in inductor current	3.75A	3.702A
Maximum inductor current	4.25A	4.142A
Minimum inductor current	0.5A	0.44A
Output current	1.2A	1.156A
Ripple in output current	0.03A	0.036A

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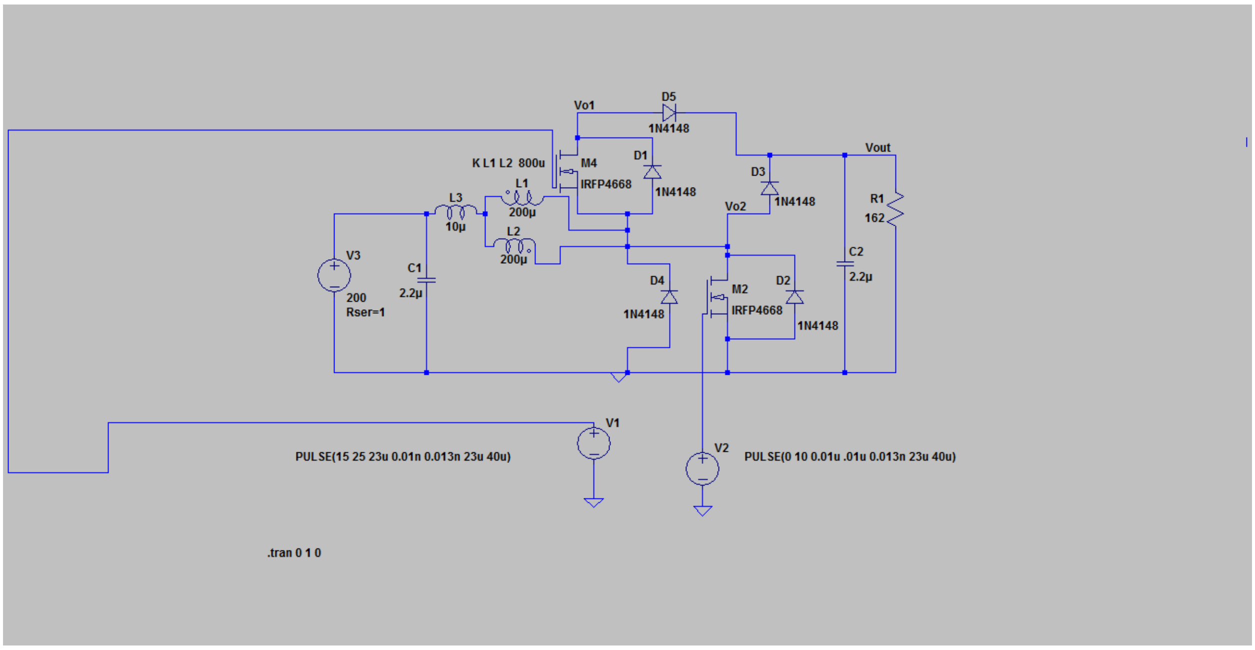

Fig 4.1LT Spice Simulation Of Boost Converter

4.2 RESULTS

In this project, the analysis and simulations of 12v/24v Boost switching converter is presented. The converter performance such as load voltage, capacitor and inductor currents, voltages and currents ripples, etc. are analyzed and derived theoretically under continuous operation.

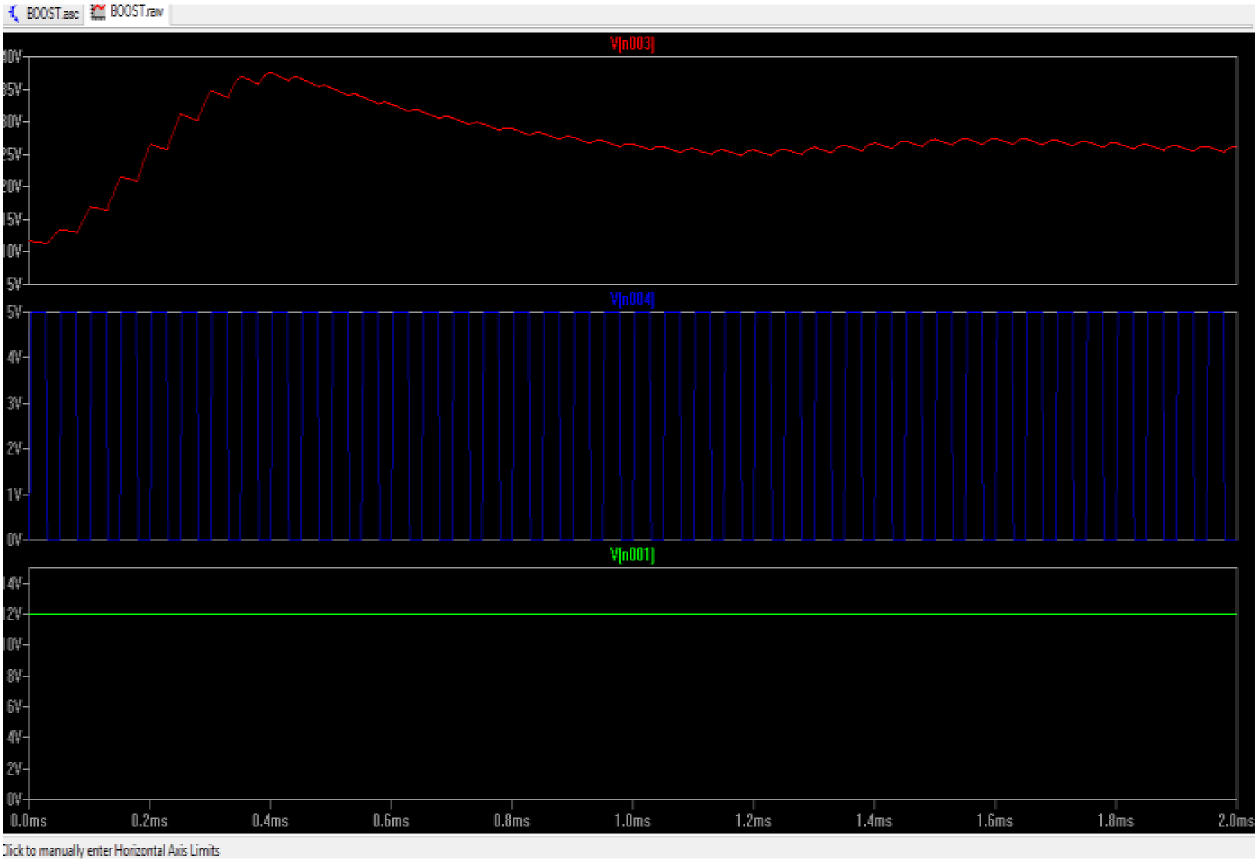

Fig 4.2 : Simulation waveforms of the output voltage, pulse width modulation voltage and the input voltage

The design of the converter is performed to step-up the input voltage 12v to an output voltage of 24v. Allspice IV programs are used to simulate the switching converter using a very high speed MOSFET as a switch with 20 KHZ switching frequency. The simulated waveforms are consistent with the theoretical waveforms and the percentage error between simulated and theoretical results is found to be very small. Fig 4.2 shows the simulation waveforms of the output voltage, pulse width modulation voltage and the input voltage of the simulated Boost converter. It can be noted that the simulated waveforms are similar to each other and consistent with the theoretical waveforms. The response of the output voltage is under damped and reaches its steady – state voltage in about 1.4 ms. The simulated output ripple voltage is about 0.75 V. The average output voltage is found to be 23.151V compared with the theoretical of 24V.

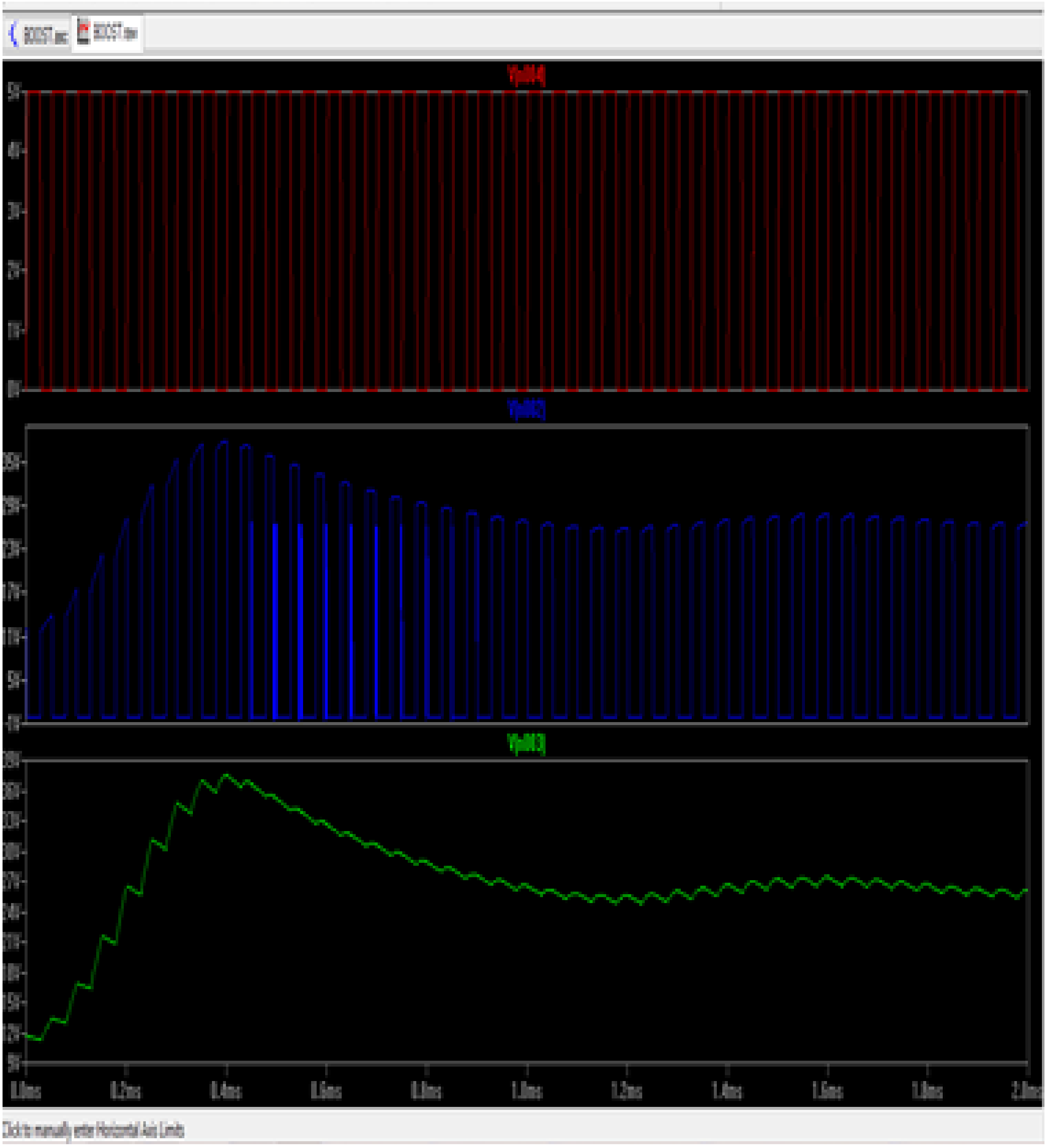

Fig 4.3 Simulated waveforms of the pulse width modulation voltage, inductor voltage and capacitor voltage

Fig 4.3 shows the inductor voltage is a square wave while the capacitor voltage is the same wave of the output waveform.

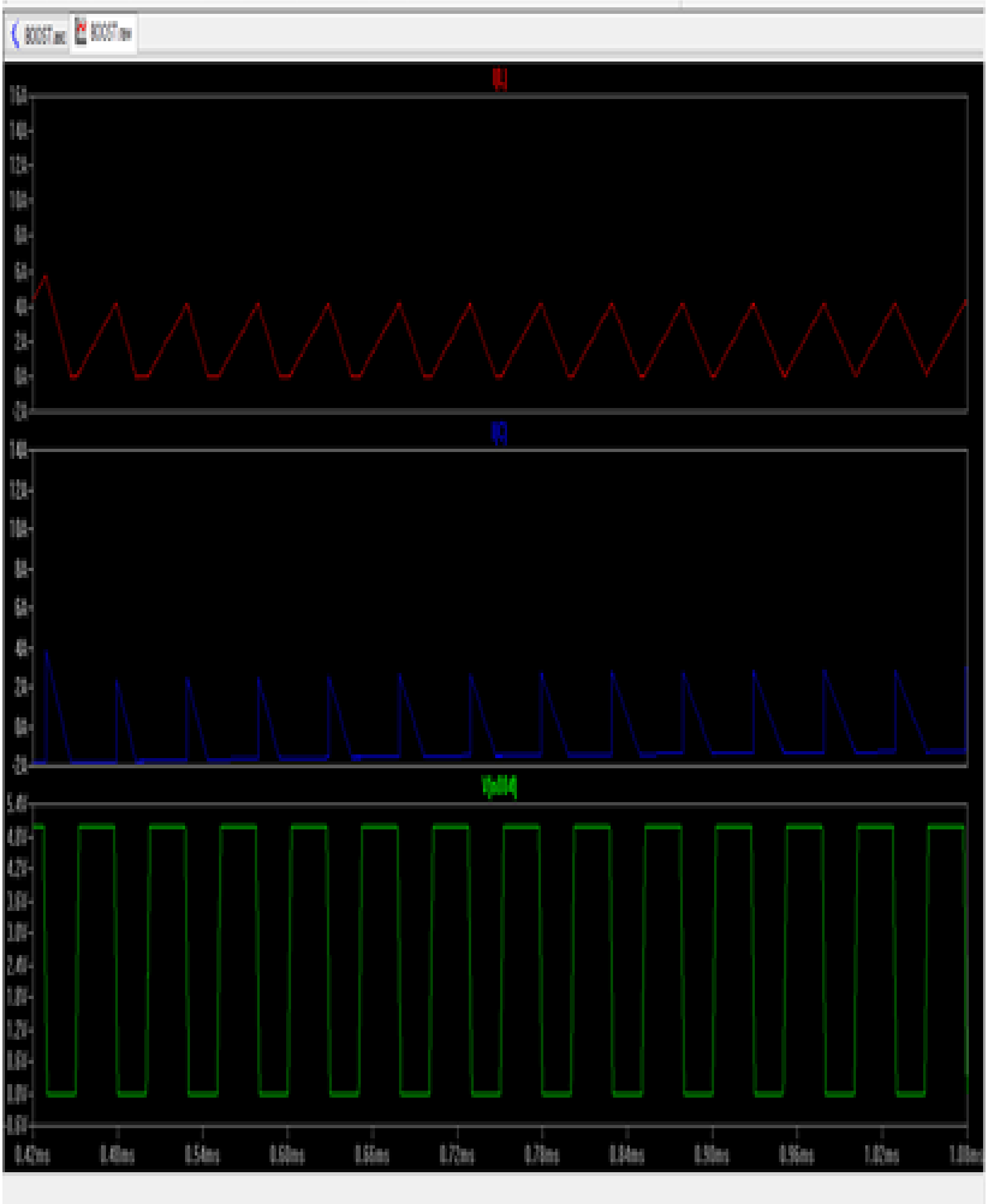

Fig4.4 Expand view of the inductor and capacitor currents along with the switching pulses

Fig-4.4 shows expand view of the input inductor and output capacitor currents along with the switching pulses. The input inductor current is under damped with maximum value of 4.2A and minimum value of 0.6A with a ripple current of 3.6A and therefore the percentage error with the theoretical results are very small.

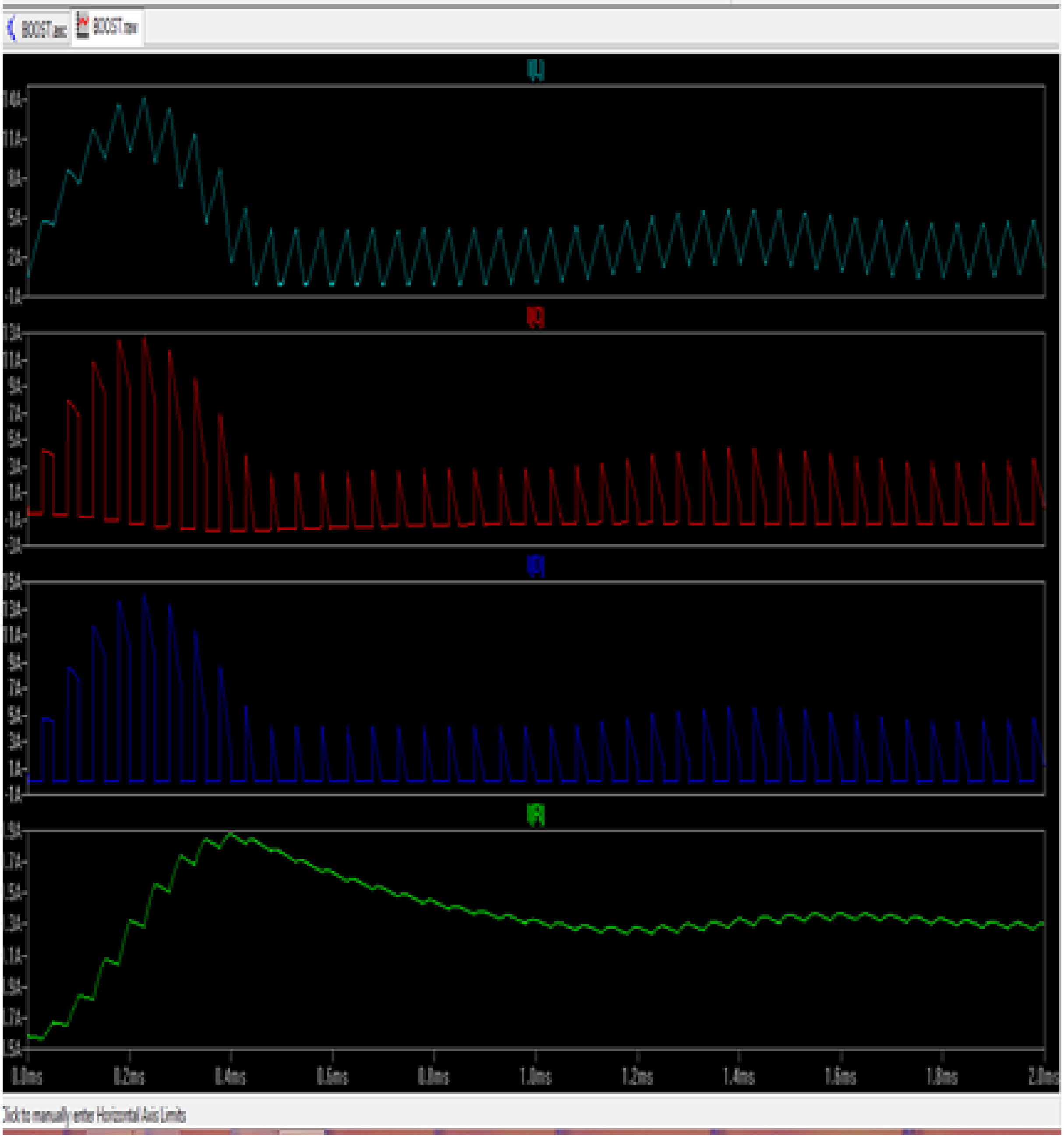

Fig4.5 Simulated waveforms of current passing through inductor, capacitor, diode and output current

Fig4.5 shows the waveforms of current passing through inductor, capacitor, diode (Id), and output current (Io). It can be noted that the output current reaches its steady state value of 1.156A after 1.5ms and has a very small ripple of 0.036A.

CONCLUSION

Solar car racing has raised the interest of energy issues and research topics in the public domain. To achieve the best system optimization, it is highly required to understand the system vehicle electrical system. The aim of this project is to design efficient power converters that will be used to develop the energy management system of a solar powered car that includes three different sources to transfer power according to the 24v output. . In solar races, it is very important to select PV modules with high efficiency; however, there is a trade-off between efficiency and cost.

Weight and capacity are the most important criteria for solar car battery selection, since more weight increases the rolling resistance, hence more power will be needed to drive the car. A more practical way is using a battery with ultra-capacitors to improve the performance of a solar powered vehicle, where each energy storage device will perform its own duty based on its characteristics and the current circumstances

Electric-drive vehicles have the potential to make major contributions to the electric supply system, as storage or generation resources, or both. The already-launched battery-powered EVs are a good initial bridge to a vehicle fleet integrated with the electrical system, since battery-powered vehicles must be connected to the grid anyway, for charging. Our analysis suggests that there would be substantial economic benefits for most electric utilities to insure that the connection to the electrical distribution system allows battery EVs to function as storage resources.

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