A Solar Power System for Electric Vehicles with Maximum Power Point Tracking for Novel Energy Sharing

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***Abstract*— This paper presents a new system architecture which makes efficient use of the power produced from the photovoltaic panels for charging batteries of solar powered Electric Vehicles. The system has the power system for a solar powered Electric Vehicle and the power system for the solar powered grid connected Electric Hub (a large battery bank). Several electric vehicles may be charged from its own photovoltaic panel and from the hub, which in turn is charged by a large capacity photovoltaic panel or by the electric grid in case the power required is more than the power available from the panels. Once all the batteries connected to the system reach a certain maximum charge limit excess energy from the vehicles and the hub is pumped into the grid, thus utilizing the energy that would have been otherwise wasted.**

Keywords—Solar Vehicles; Enery management;Charging station

I. INTRODUCTION

The need to explore new ways to power our homes, vehicles, and businesses has increased dramatically over recent years in fear of fossil fuels running out and their environmental effects. Demand for fossil fuels for running automobiles has been the driving force in utilization and depletion of crude petroleum. Hence there has been an increased focus on Electric Vehicles in recent times. A major limitation of Electric Vehicles is that it is an extra load on the electric grid and since many countries face an energy deficit, it is not currently feasible to use electric vehicles. Another drawback of Electric Vehicles is that it is not entirely emission free. [1] If the batteries are charged using energy generated from fossil fuels, polluting gasses are still formed at the power plant.[2] Hence they only reduce and decentralizes the pollution and do not eradicate it completely. An alternative source of power that is being developed is the use of solar power to run automobiles.

The purpose of this paper is to propose a system which makes efficient use of the power produced from the photovoltaic panels for charging batteries of solar powered Electric Vehicles. It introduces a new charging technique that harnesses the maximum power from the photovoltaic panels and simultaneously shares the charge with the other cars and the Hub thereby not utilizing any power from the Grid until necessary. The excess energy can be sent back to the grid or used locally as per the requirement.

This idea will be useful in making better use of solar energy available to charge car batteries to take a step towards pollution free and sustainable transport system. It will be effective particularly useful shuttle car services for short ranges for tourist places or large campuses. When not in use, the system will generate electricity either locally or for the grid. Therefore it is an ideal place for using the proposed system.

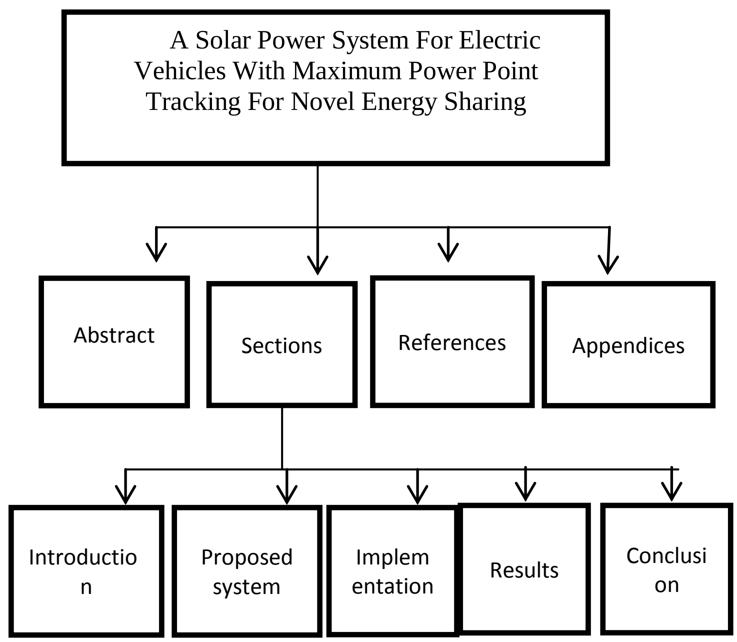


Figure 1: Structure of the paper

A. Technical Background

Currently the electric vehicles are either charged by the grid or separate renewable resources . Otherwise they have their own solar panel and are used for short distances. Charging from the grid produces an extra load on the generation of electricity whereas, renewable sources are unreliable.[7] Only a solar panel on the vehicle is not sufficient to power it entirely.[8], [9].

B. Proposed Solution

Our proposed system utilizes both the grid as well as the energy from photovoltaic panels. The vehicles have their own PV panels. The batteries are charged using both solar power and the energy from the grid which is utilized as the last resort. The system also facilitates power transfer in between vehicles without other energy sources. Hence, it is greener as well as reliable. It also employs MPPT for maximum efficiency. [11]

C. Organization of the Paper

The paper has been organized in the following sections

Section II illustrates the working concept with the block diagram of the proposed system. It has a Hub circuit, a Grid Synchronizer and two solar powered electric vehicles

Section III contains details of the hardware and software implementation of the prototype to test the working principle of the system

Section IV shows the results of the prototype testing

Section V draws a conclusion.

II. PROPOSED SYSTEM

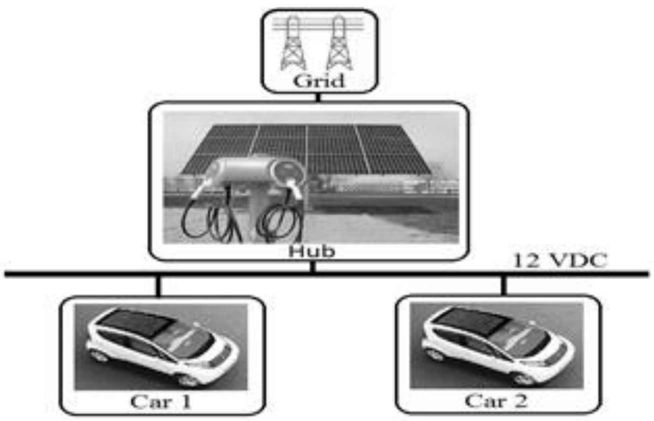


Figure 2: Block diagram of the proposed system

Figure 2 illustrates the diagrammatic representation of the proposed system. It attempts provide a new architecture for charging electric vehicles using power from photovoltaic panels. This not only allows charging of electric vehicles but also provides energy to the grid at times without harming the environment or increasing load demand of energy from the grid. For this system, we have only considered electric vehicles having their own photovoltaic panel on the roof or the body. The charging station or the Hub consists of a large battery bank and a large photovoltaic panel. The Hub is connected to the grid to either pump the extra energy into the grid or draw energy from it in case the energy required is more than the energy required by the batteries. To extract the maximum power produced from the photovoltaic panels, a Maximum Power Point Tracking algorithm was used on all vehicles as well as on the hub.

The system may be envisaged as having two parts:

A. The power system for the solar powered electric vehicle

Figure 2.1 shows the block diagram of the solar powered electric vehicle. It shows that the system on the vehicle is designed to optimally charge the batteries both in running and stationary conditions. It consists of a photovoltaic panel on the vehicle body. The power from the panel is controlled through a

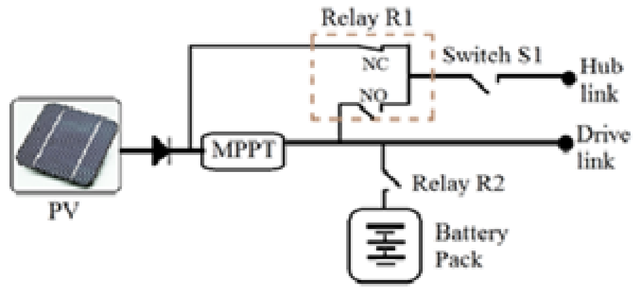


Figure 2.1: Block diagram for solar powered electric vehicle

buck boost converter which is switched using the MPPT controller for achieving maximum power output. The microcontroller is used for the measurement of battery voltages and for switching relays. The vehicle's system is connected to the hub through the relays which are controlled by the microcontroller. Current sensors are used to sense the current from the output of the converter to send the feedback to the MPPT module. A voltage diver circuit is being used to approximately measure and feed the battery voltage to the microcontroller which decides the mode of operation. The relays are operated accordingly. This battery charge level approach has been adopted for simplicity. Using the state of charge method is a more accurate scheme for measurement.

The operation of the car can be split into four modes:

1. *M1 (Standalone) –*

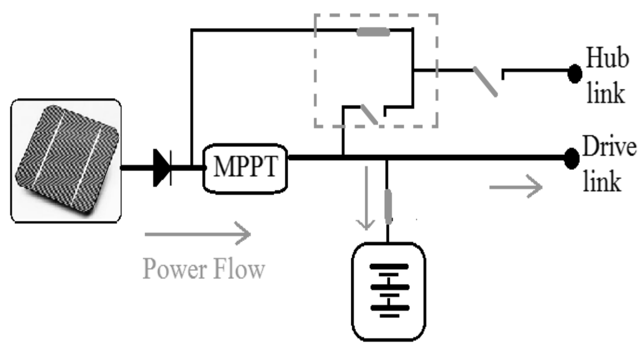


Figure 2.2: Block diagram for vehicle in M1

Figure 2,2 shows the block diagram of the vehicle in mode 1.This mode occurs when the vehicle is being driven or is parked separately. The power generated from the panel is used to charge the battery or directly to the drive.

2. *M2 (Charging from Hub) –*

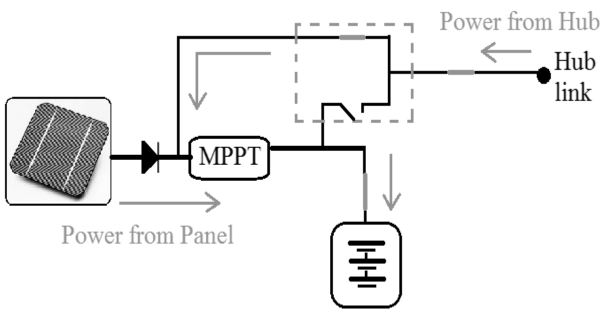


Figure 2.3: Block diagram for vehicle in M2

Figure 2.3 illustrates the block diagram for the vehicle in mode 2 operation. This mode occurs when the battery is not fully charged. The battery is charged using the photovoltaic panel of the car as well as the hub. The hub is connected in parallel with the photovoltaic panel of the car and the total power is fed to the buck boost converter of the vehicle. The MPPT module controls the combined power from the hub and panel.

3. *M3 (Discharging to the Hub) –*

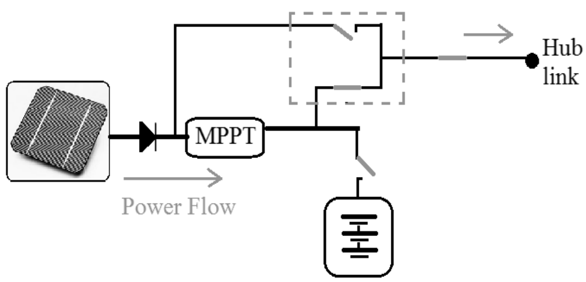


Figure 2.5: Block diagram for vehicle M3

Figure 2.5 shows the working of the vehicle when it is operating in mode 3.When the battery is charged above a preset percentage, the power from the panel is pumped back to the hub. The energy can then be used for charging batteries of other vehicles or can be pumped back to the grid through the hub.

4. *M4 (Discharging/Charging to another vehicle) –*

If a vehicle is stranded and needs to be charged faster, another vehicle can transfer the power from its panel to the other vehicle which needs to be charged. This is done by connecting two vehicles through a power cord. This mode is applicable during emergency scenarios.

B. The power system for the solar powered grid connected hub

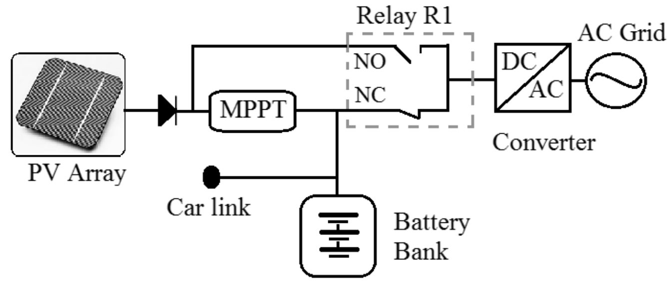


Figure 2.6: General block diagram for Hub

Figure 2,6 represents the general block diagram of the hub. It consists of a similar setup of the buck boost converter, MPPT controller, current sensors and the microcontroller and is powered by a large PV panel. The panel need not be a single panel in the same area but may also be a group of panels spread out in different areas. It has rectifier circuit for charging the battery bank through the grid when required. It also consists of a PWM inverter circuit to pump any excess energy back to the grid. The switching is done using the microcontroller. The synchronizing takes place with the use of a zero crossing detector circuit for generating reference voltage. The PWM pulses are filtered into sinusoidal wave using a filter and the output AC voltage is synchronized with the grid reference voltage using the microcontroller.

Modes of hub: the hub also has mianly three distinct modes of operation. They are classified as:

1. *M1(Standalone)-*

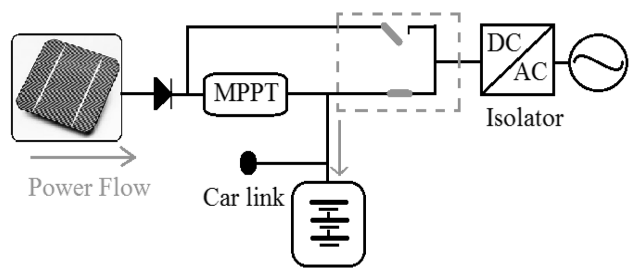


Figure 2.7: Block diagram for Hub M1

Figure 2.7 shows the block diagram of the working of the hub during mode 1 operation. When the battery charge percentage is between 25% to 75%, the battery bank charges or discharges according to the condition of vehicles connected to it. It charges any vehicles connected to it .When the battery charge percentage is between 25% to 75%, the battery bank charges or discharges according to the condition of vehicles connected to it. It charges any vehicles connected to it. This mode is called as standalone mode.

2. *M2(Inversion)-*

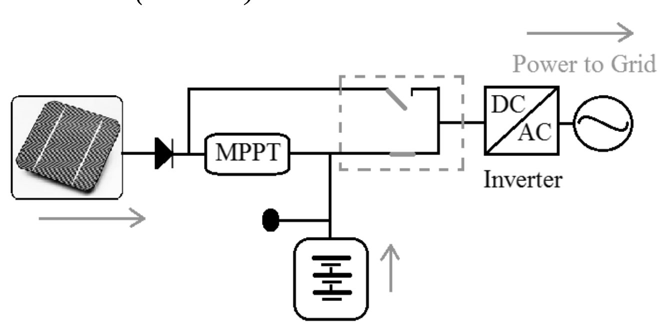
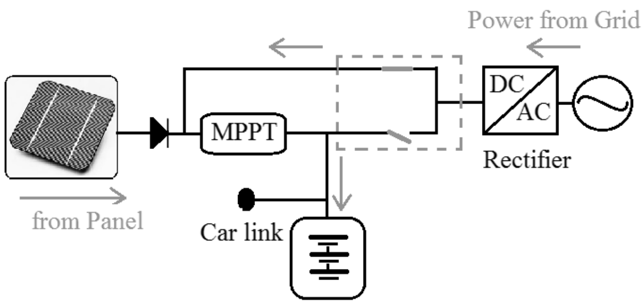


Figure 2.5: Block diagram for Hub M2

Figure 2.5 shows the block diagram of the hub during its second mode of operation, which is inversion. This mode occurs when the charge of the battery bank crosses the preset value of 75%. Then the inverter circuit comes into play and pumps the power back to the grid.

3. *M3(Rectification)-*



4. **Figure 2.5: Block diagram for Hub M3**

Figure 2.5 shows the diagrammatic representation of the hub in the third mode- Rectification. When the charge of then battery bank falls below the preset value of 25%, the rectifier circuit converts AC/ DC to charge the battery bank.

III IMPLEMENTATION

A. Hardware Implementation

The experimental verification of the proposed system was carried out using a Texas Instruments Piccolo C2000 microcontroller based hardware prototype. It consists of two identical car prototypes interfaced with a hub.

The sub systems, cars and the hub are powered by a 5W and 10W PV panels respectively. The energy is stored in 12V 4.5 Ah battery banks through a MPPT controller. The MPPT controller is implemented on a PCB (refer to Appendix A), to maximize the power output from their respective PV panels. Apart from these, each of the systems has its power circuit and indication circuit made on dot-boards. Individual parts of the system are explained hereafter in this section.

1. The MPPT Controller

Figure 3.1: The MPPT Module

The Maximum Power Point Tracking Controller (identical for both the hub and the cars) is operated by the SM72442 - TI Programmable Maximum Power Point Tracking Controller. The controller was programmed to provide a constant charging voltage of 13.4V (optimal charging voltage for the 12V battery). It provides pulses to control the switches (4 N-Channel MOSFETS TI CSD16342Q5A) in a buck/boost converter through a driver (SM72295 TI Photovoltaic Full Bridge Driver). The SM72442 controller was chosen for its versatile nature and its ability to maintain optimum performance under fast-changing irradiance conditions, a prerequisite for MPPT of moving photovoltaic panels.

The input current from the PV Panel and the output current from the converter are measured by the INA193A - Current Shunt Monitor and fed to the controller. The controller and the driver are powered by 5V and 3.3V linear regulators respectively.

2. Power and Indication circuits of the Car

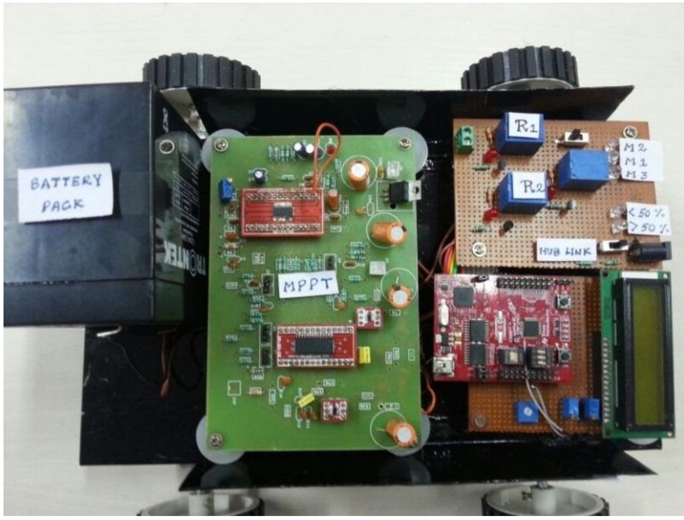


Figure 3.2: hardware implementation of the vehicle

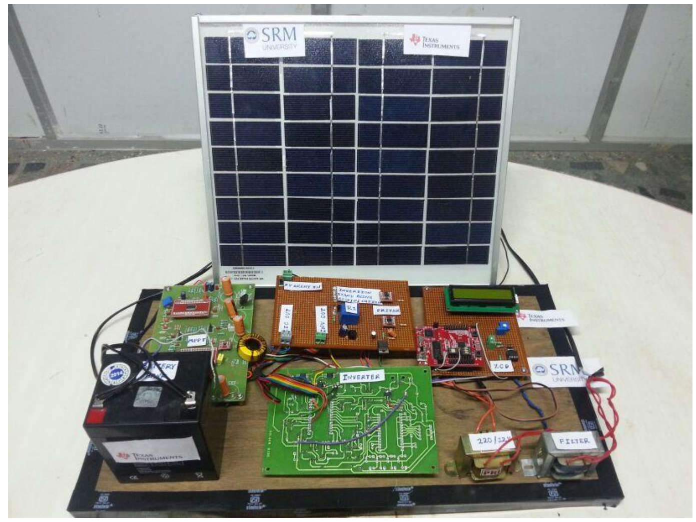


Figure 3.3: Hardware implementation of the HUB

Each of the identical cars consists of a 5W PV panel connected to the power circuit through the MPPT PCB. The power circuit comprises of two relays operated by the microcontroller. The first relay R1 controls the point at which the hub is connected to the car. When unexcited, R1 connects the hub in parallel with the PV panel of the car, the battery is charged from both the hub and the car's PV panel. Under fully charged condition, R1 is excited and feeds the power from the car's PV panel to the hub. Relay R2 is used to isolate the battery when fully charged, thus protecting it from being overcharged. There is also a switch S1 which is manually operated by the user to connect and detach the car from the hub.

The indication circuit informs the user about the charge level of the battery and the mode of the power flow between the car and the hub. The charge level is calculated and displayed by the microcontroller by measuring the voltage across the battery's terminals. The present mode of power flow is also indicated through LEDs.

3. Power and Indication circuits of the Hub

The hub consists of a 10W PV panel connected to the power circuit through the MPPT PCB. The power circuit comprises of a relay operated by the microcontroller, an AC/DC converter, a ZCD (Zero Crossing Detector) and two transformers.
Based on the mode of power flow, the AC/DC converter either works in rectification or inversion mode.

In inversion mode, R1 is unexcited. During inversion mode, the AC/DC converter is switched to a full bridge inverter circuit consisting of four mosfets driven through high-frequency mosfet driver TPS28226DR. It produces a sine pulse width modulated output with peak voltage of 12V. A 220/12V transformer is used to step down the grid ac voltage, with which the filtered output of the inverter is synchronized. This synchronization is carried out by comparing the output of the inverter with the output from the ZCD.

During rectification mode, the AC/DC converter is switched to a bridge rectifier that produces a dc voltage of 12 V. The dc voltage is then connected parallel to PV panel and charges the battery.

B. Software Implementation

The microcontroller TI Piccolo C2000 is used to control the prototype. The software Code Composer Studio V5 was used to compile the program to the microcontroller. The main function of the software is to measure the conditions such as battery voltage and system current and switch the relays to change the operating mode for optimal operation. Figures 3.4 and 3.5 show the logical operation of the programs in the mircrocontrollers.

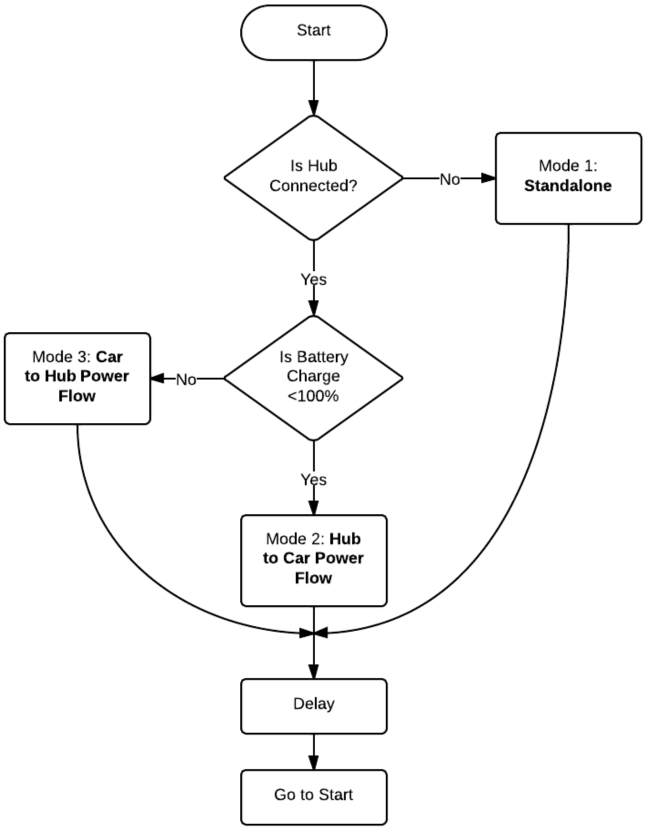


Figure 3.4: flow chart of car

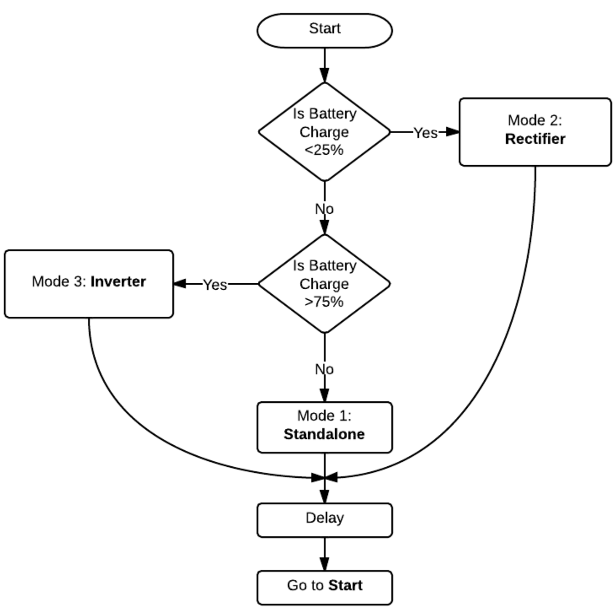


Figure 3.5: flowchart of hub

IV. RESULTS

The testing of the hardware prototype gave the following results which have been measured using a DSO:

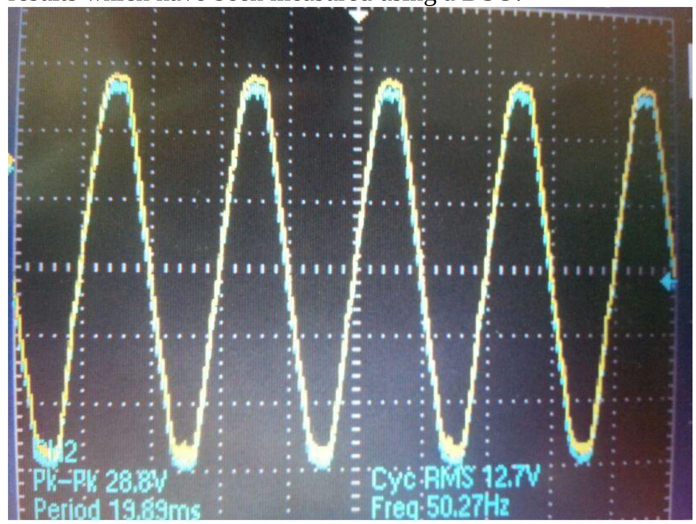


Figure 4.1: synchronization of inverter output with the grid voltage

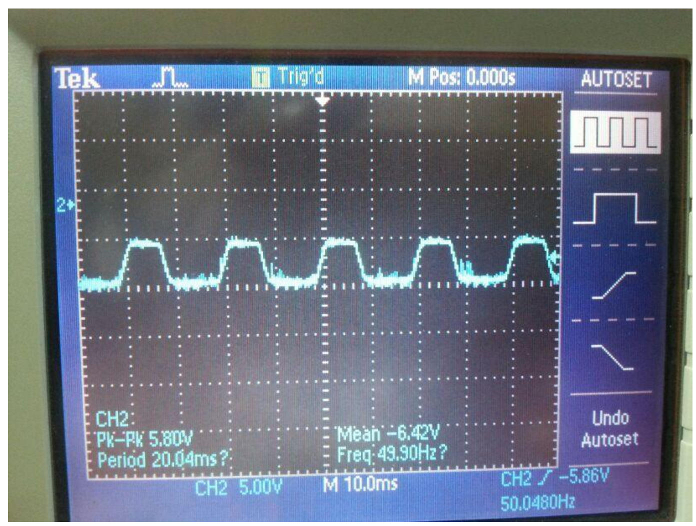


Figure 4.2: switching pulses from the ZCD

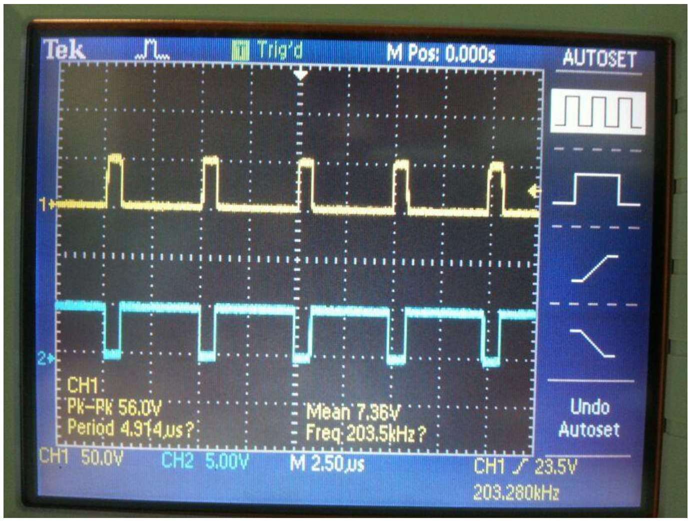


Figure 4.3: switching pulses for the buck boost converter(Mosfets 1 and 3)

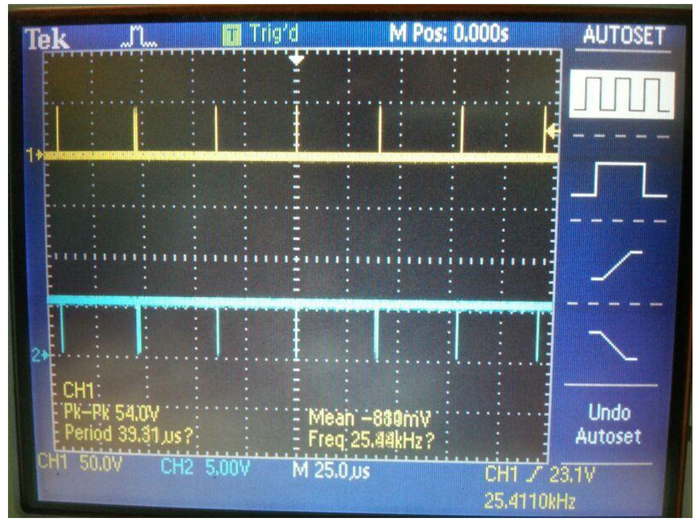


Figure 4.3.1: Switching pulses for the buck boost converter (Mosfets 2 and 4)

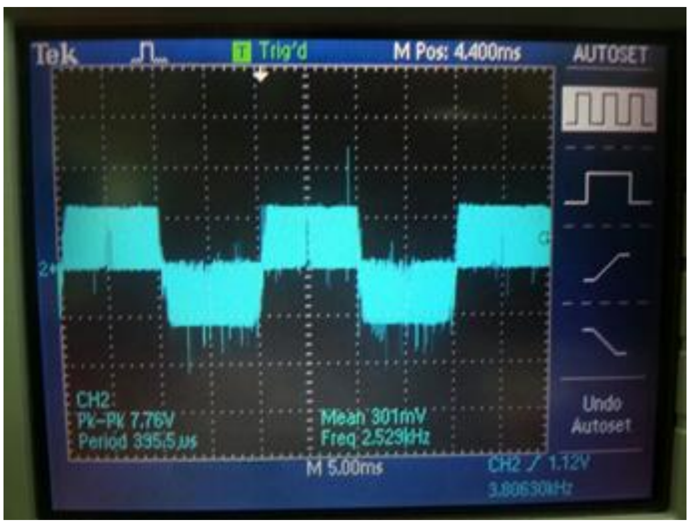


Figure 4.4: Sin PWM modulated inverter output

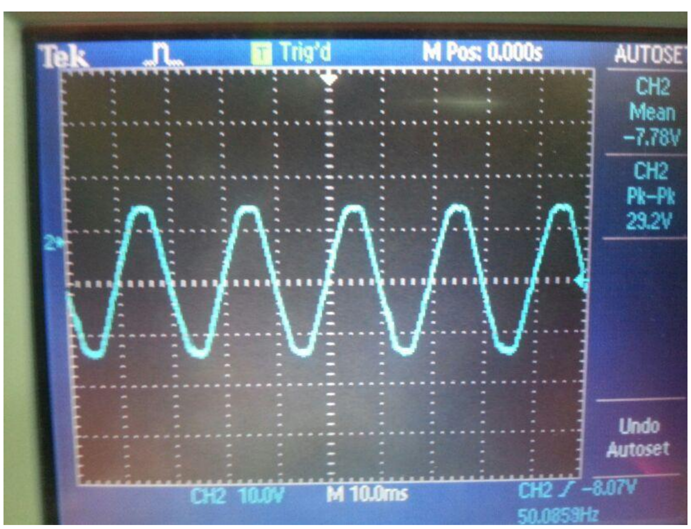


Figure 4.5 : Filtered output sin wave of the inverter

V. CONCLUSIONS

Although there is a long way to implement solar powered vehicles and charging stations in India, the process can be expedited with the formulation of innovative methods to maximize the utilization of energy. With peaking fuel prices, shrinking supplies and global warming issues, solar energy has become a focus area for policy makers and governments globally. Our project is a step towards developing a cleaner and greener transportation system for the future. In this paper we have proposed a new system architecture for the charging of solar power electric vehicles. The proposed strategy will efficiently charge the batteries and also allow the excess energy to be pumped back to the grid hence utilizing energy that would have otherwise been wasted. It is also reliable for the users since it has a provision to charge from the grid if there is a deficit in power from the panels. The prototype validates the working principle of the system. Such a system will be highly useful for shuttle services in a confined area. The benefits of this approach are that it utilizes the full potential of the PV panels at all times and the vehicles almost purely run on green energy. The major limitation of the system is the high initial cost. Charging time of the batteries is also high and it is not The system is independent at most times. Further improvements in the battery charge measurement technique, fast charging technique and charge controlling will make it more efficient and feasible. Solar power and electric vehicles are the way forward to a greener tomorrow.

ACKNOWLEDGMENTS

We the authors of the report entitled '<u>A Solar Power System for Electric Vehicles with Maximum Power Point Tracking for Novel Energy Sharing</u>', would like to thank Texas Instruments for giving us the platform to exhibit our talent and providing us with the necessary help and components for the completion of *our project. We would like to give a special acknowledgement to our institution SRM University and our mentor Mr. C. Bharatiraja whose faith and guidance helped us leaps and bounds in our journey in this competition. Finally we would like to thank Parthipan,Promit Choudhary and Tiagarajan for their help.*

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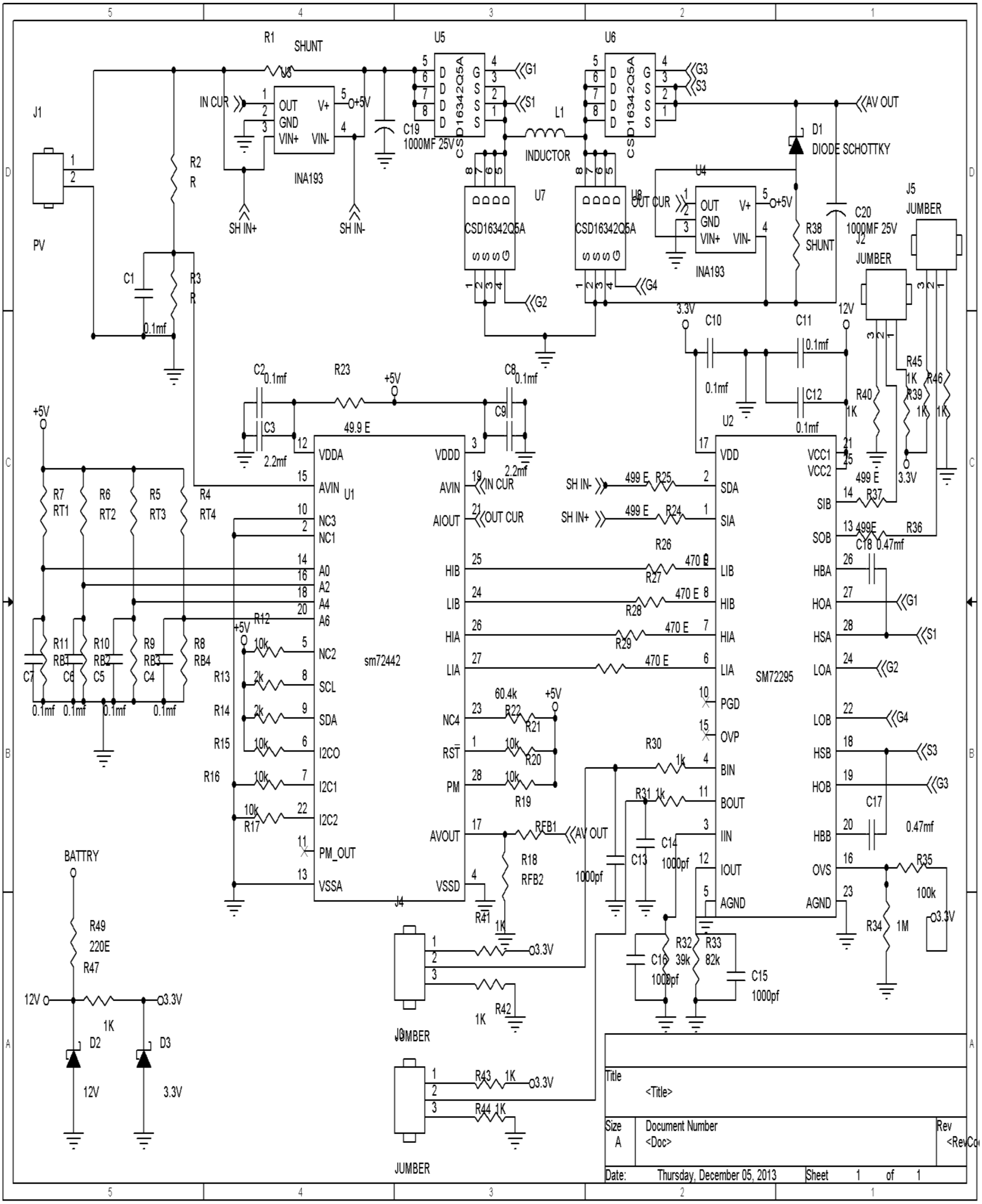
APPENDIX A



R1
SHUNT
U5
U6
J1
PV
IN CUR
OUT
GND
VIN+
V+
VIN-
+5V
INA193
SH IN+
SH IN-
C19
1000MF 25V
CSD16342Q5A
L1
INDUCTOR
G1
S1
G3
S3
AV OUT
D1
DIODE SCHOTTKY
U4
U7
U8
OUT CUR
R38
SHUNT
C20
1000MF 25V
J5
JUMBER
J2
JUMBER
G2
G4
R2
R
R3
R
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12V
C10
C11
0.1mf
C12
R40
R39
R45
R46
1K
C2
C3
2.2mf
R23
49.9 E
C8
C9
2.2mf
U1
sm72442
VDDA
AVIN
NC3
NC1
A0
A2
A4
A6
NC2
SCL
SDA
I2CO
I2C1
I2C2
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VSSA
VDDD
AIOUT
HIB
LIB
HIA
LIA
NC4
RST
PM
AVOUT
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VDD
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VCC1
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SIB
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HOA
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499 E
R24
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R28
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470 E
R30
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R32
39k
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APPENDIX B – Bill of Materials

Sl no	Component	Cost per component	Quantity	Net cost	TI Supplied/ Purchased
1	SM72442MT/NOPB	560	3	1680	Supplied
2	SM72295MA/NOPB	310	3	930	Supplied
3	INA193AIDBVT	170	6	1020	Supplied
4	TPS28226DR	90	2	180	Supplied
5	CSD16342Q5A	30	16	480	Supplied
6	LM317	15	1	15	Yes
7	MCU (C2000) LAUNCHXL-F28027	1065	3	3195	Supplied
8	5W Solar panel	550	2	1100	NA
9	10W Solar panel	850	1	850	NA
10	12V 4.5Ah Lead Acid Battery	650	3	1950	NA
11	LCD Display	150	3	450	NA
12	SMD to DIP adapters	100	10	1000	NA
13	Motors	150	8	1200	NA
14	Resistors	0.3	80	24	NA
15	Capacitors	**1**	**40**	40	NA
16	Inductors			0	NA
17	10K potentiometers	9	45	405	NA
18	5V relays	8	25	200	NA
19	wires	8	10	80	NA
20	LEDs	20	2	40	NA
		Total Cost		**14839**	