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Battery Charge Controller for Electric Bike using Renewable Energy Source

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Abstract: This paper presents a solar power assisted battery charger for electric bike. One of the renewable energy sources – solar energy is taken into consideration as an input to the battery of the Electric bike for charging. Also the availability of the AC mains supply in the absence of adequate solar energy i.e. in cloudy conditions and at night time is considered and accordingly the suited controller is designed and same is presented in this paper. Both the solar energy and the AC mains supply are controlled by a microcontroller and results and discussed here. This paper represents the energy saving by the use of available renewable source.

Keywords: DC-DC Boost Converter, Rectifier, DC-DC Buck Converter, PIC Microcontroller.

I. INTRODUCTION

Renewable energy
A natural resource is a renewable resource if it is replaced by natural processes at a rate comparable or faster than its rate of consumption by humans. Solar radiation, tides, winds and hydroelectricity are perpetual resources that are in no danger of a lack of long-term availability. The renewable energy sources are 1.Biofuel 2.Biomass 3.Geothermal 4.Hydro electricity 5.Solar energy 6.tidal power 7.Wave power 8.Wind power. Solar energy is the energy derived directly from the Sun. Along with nuclear energy, it is the most abundant source of energy on Earth. The fastest growing type of alternative energy, increasing at 50 percent a year, is the photovoltaic cell, which converts sunlight directly into electricity. The Sun yearly delivers more than 10,000 times the energy that humans currently use.
Solar energy can be harnessed through two routes, namely solar photovoltaic and solar thermal. In photovoltaic route, it is directly converted to electricity while in the thermal route it is first converted into heat and then to electricity [1]. A total of 33 grid interactive solar photovoltaic power plants have been installed in country with financial assistance from the Ministry. These plants, with aggregate capacity2.125 Megawatt peak (MWp), are estimated to generate about 2.5 million units of electricity per a year. In addition, the solar energy systems are being used for stand-alone application such alighting, telecommunication, small power requirements, battery charging, water heating, cooking etc. Solar Cells supply electric energy
Renewable from primary resources. Solar cells are rarely used; individually the solar cell transforms the light energy into continuous electric energy. It represents a source with a good energy density. From an electric point of view, the solar cell is considered as a voltage source. And also solar Energy can be used in many Applications. In this solar roadways are one type. Road solar panels can do more than generate clean electricity. They may also be able to:1)Sense animals on the roadway, potentially alerting drivers, 2)Heat themselves when covered in snow and ice, and 3)Act as a power source for electric cars, providing recharging stations at points along its length. Solar road panels are complex and extraordinarily expensive.

There are a lot of potential applications of photovoltaic energy, but there are two main branches; the ones that are connected to the electrical network (rural electrification, agricultural applications, telecommunications, etc.); and the ones that are connected to the electrical network such as energy production plants, buildings, etc. By 2015, if General Electric has their way, all our homes will be running on smart grids with mini-turbines and solar panels to produce electricity, consuming zero net energy in the process. Tata BP Solar has received the prestigious Golden Peacock Innovation Award for the year 2009. Solar power plants can face high installation costs and developing countries have started to build solar power plants, replacing other sources of energy generation.
In this paper, Input is varying from (0-18)V DC Voltage and Output Voltage is (58.8±0.4) V, 3A. That is Electric bike Battery Charging Voltage is 58.8±0.4Volts.For this requirement we are using a Boost converter in between them. And also we Charge the Electric bike from AC supply. This can be connected to battery, when the solar input is not available. That is, when the cloudy conditions and at night time. These two operations can be controlled by a microcontroller. The microcontroller used here is PIC 16 Family type.

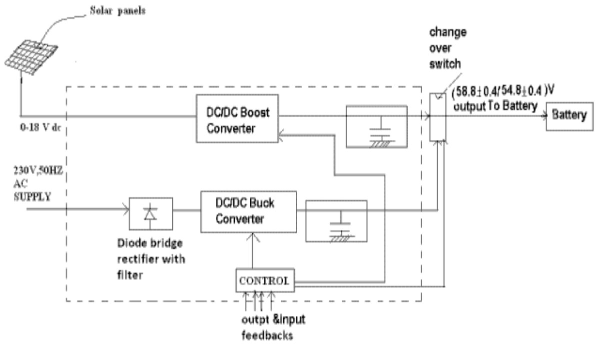

Fig. 1: Block Diagram of total scheme

1.1 SOLAR PANEL DETAILS:

Panel specifications:

Module type 1275

- Ratings of each solar module
- 16.4 V, 100 mW/cm^2 at 25^{o}c, 4.5121A, 74 W.
- Peak power voltage=17V

Module type 1240

- Ratings of each solar module
- 37W,16.4 V,100mW/cm^2 at 25^{o}c

1.2 OUTPUT CURVES (V-I CURVE)

The single most important technical aspect of PV cells and modules is the current and Voltage (V-I) curve. The curve allows the designer to understand how module will be influenced by the environment and how load will interact with module. The standard representation of output of PV device s called V-I curve.

Experiment for VI characteristics of one module:

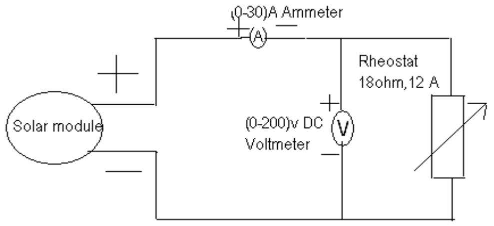

Fig.2: Circuit diagram for VI curve experiment

Observation at peak time: At 2.00 pm

TABLE I: OBSERVATION TABLE

Sr. No	Voltage (Volts)	Current (Amps)	Power (Watts)
1	18.7	0	0
2	17.6	2.5	44
3	16.05	5	80.25
4	14.32	6	85.92
5	12.45	7	87.15
6	10.00	8	80.00
7	8.89	9	80.01
8	6.21	10	62.1
9	3.6	11	41.8
10	2.5	11.5	28.75

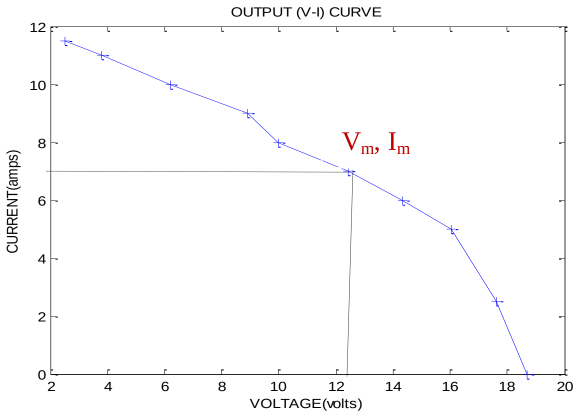

Fig.3. Output VI curve

1.3 OBSERVATIONS:

Voltage at maximum power= 12.45V for each module
Current at maximum power =7A for each module
Open circuit voltage = 18.7V for each module
Maximum power from each module = 87.15 W
For 16 modules, Maximum power = 87.15*16 = 1394.4 W
Assuming average sun hours/day = 4hr, then maximum energy = 1384.4*4=5577.6 Watt-Hr

1.4 INPUT AND OUTPUT DETAILS:

Input:
Domestic Supply : 230 V,50hz AC
Solar Supply;(0-18V) DC
Output :
48V Battery Charger
Output : Boost Voltage=58.8±0.4V
Float Volatge=54.4±0.4V
Battery:12V,20Amp*4(48V,20A)
Battery life:20000km
BatteryCharge time=6hrs
ElectricityConsumption=1 unit per charge

II. CONVERTER TOPOLOGY

The two converter topologies are discussed below [6]:

2.1 Boost Converter:

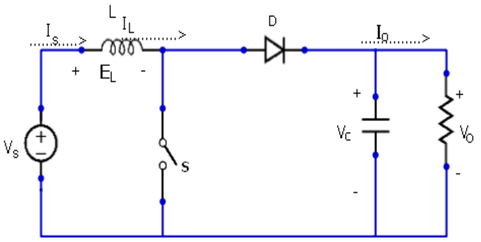

Fig 4(a): circuit diagram of DC/DC boost converter

Mode 1 operation:

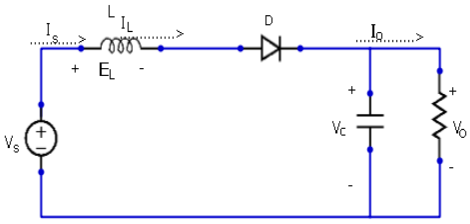

Fig 4(b): Mode 1 operation of DC/DC boost Converter

Assuming that inductor current rises linearly from $I_1$to I_1

$$V_s = L\Delta I / t_1 \text{ .... (1)}$$

Mode 2 operation:

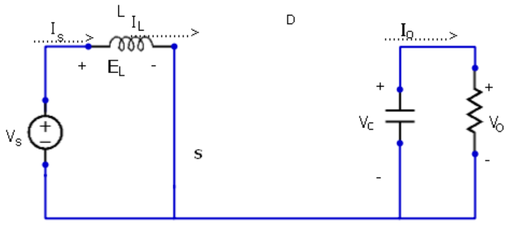

Fig 4(c): mode 2 operation of DC/DC boost Converter

During this mode inductor current falls linearly I_2 to I_1 is

$$V_s - V_o = -L\Delta I / t_2 \ldots\ldots\ldots\ldots\ldots (2)$$

Where $\Delta I = i_2 - i_1$ is the peak to peak ripple current in the inductor L.

From 1 & 2, Substitute $t_1 = kT$ and $t_2 = (1-k)T$

Average output voltage is given as

$$V_o = V_s T / t_2 = V_s /(1-k) \quad \ldots\ldots\ldots (3)$$

The switching period T can be expressed as

$$T = t_1 + t_2 = \Delta IL / V_s + \Delta IL / V_s (V_o - V_s)$$
$$\Delta I = V_s (V_o - V_s) / fLV_o \qquad \ldots\ldots\ldots\ldots (4)$$

When transistor on, the capacitor supplies the load current for t = t1. The average capacitor current during time t1 is $i_C = i_O$ and the peak to peak ripple voltage of capacitor is

$$\Delta V_c = V_c - V_c(att = 0) = 1/c \int_0^{t_1} i_c dt = 1/c \int_0^{t_1} i_o dt$$
$$\Delta V_c = i_o (V_o - V_s) / V_o fc$$

2.2 Buck Converter

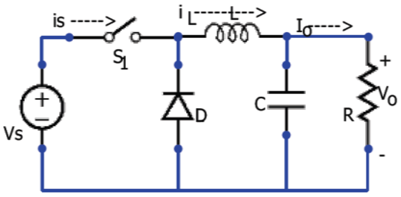

Fig: 5(a) circuit diagram of step down DC/DC converter

Mode 1: when switch is on

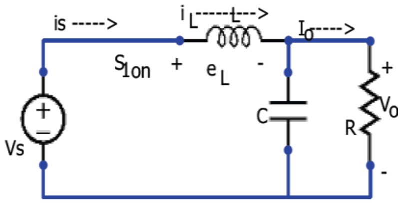

Fig 5(b): mode 1 operation

The voltage across the inductor L is given as

$$E_L = Ldi / dt$$

Assuming that inductor current rises linearly from $I_1$to I_2

$$V_s - V_o = L(i_2 - i_1)/t_1 = \Delta I / t_1$$
$$t_1 = \Delta IL / (V_s - V_o) \ldots\ldots (1)$$

Mode 2: when switch is off

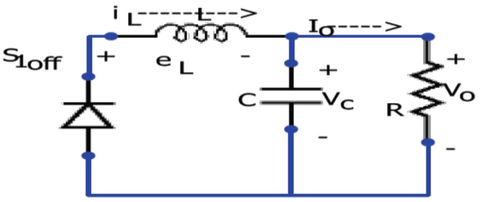

Fig 5(c): mode 2 operation

During this mode inductor current falls linearly I_2 to I_1

$$-V_o = -L\Delta I / t_1 \qquad \ldots\ldots\ldots (2)$$

Where $\Delta I = i_2 - i_1$ is the peak to peak ripple current in the inductor L, From 1 & 2, $\Delta I = (V_s - V_o) t_1 / L = V_o t_2 / L$ Substitute $t_1 = kT$ and $t_2 = (1-k)T$ Average output voltage is given as $V_o = V_s t_1 / T = kV_s \ldots\ldots\ldots (3)$

The switching period T can be expressed as

$$T = t_1 + t_2 = \Delta IL / (V_s - V_o) + \Delta ILV_s / V_o$$
$$\Delta I = V_s (V_s - V_o) / fLV_s \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The capacitor output voltage is given as

$$V_c = 1/c \int i_c dt + V_c \text{ (at t=0)}$$

And the average ripple voltage of the capacitor is

$$\Delta V_c = V_c - V_c(att = 0) = 1/c \int_0^{T/2} \Delta I / 4dt = \Delta I / 8fc$$

III. DESIGN OF DC-DC BOOST CONVERTER AND BUCK CONVERTER

1. Design of Dc-Dc Boost Converter[6]:
   - i. Input voltage is variable dc voltage obtained from solar panels.
   - ii. I.e. variable dc voltage varying from 2V to 18V.
   - iii. Charger output is 58.8V is boost voltage
   - i. Charger current is 2.7-3 A
   - ii. Assuming Switching frequency 20 kHz
   - iii. Switching period T =.05ms
   - iv. Assuming percent change in output voltage ΔV_c =58.8*0.01=.588V
   - v. Assuming lossless circuit

$$P_o = P_{in}$$

$$P_o = V_o I_o \text{ =58.3*3=176.4 W} \approx 200W = P_{in}$$

   - vi. Taking input at

$$V_{in} \text{ = 2V} \quad I_{in} = P_o / V_{in} \text{ =200/2=100 A}$$

   - vii. Assuming ripple current ΔI =5A
   - viii. Duty cycle
   - ix. $k = (V_o - V_{in}) / V_o$

=58.8-2/58.8=0.966 at 2V
=58.8-18/58.8=0.694 at 18V

   - x. Finding inductor value capacitor values

L at 2V = $V_{in} k / f\Delta I$ =2*0.966/20*10^3*5
=19.32 μH
L at 18 V=13.88 μH

Capacitor **C=** $V_{in} k / f\Delta I$
=3*.966/20*10^3*0.588
=246 μF at 2V
=177 μF at 18 V

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2. Design of Buck Converter [6]

i. Input voltage from AC mains

$$V_{in} = V_m = 230 * \sqrt{2} \text{ Volts}$$

ii. Output voltage V_o =58.8 Volts

iii. Output Current i_o =3 A

iv. Resistive load $R_o = V_o / i_o$ =19.6 Ω

v. Assuming Switching frequency f=25 kHz

vi. Percentage change in output voltage ΔV_c =.588 V

vii. Percentage change in ripple current ΔI = 5 A

viii. Duty cycle $k = V_o / V_{in}$ =58.8/230* $\sqrt{2}$

1. =0.1807

ix. Finding Inductor and Capacitor values

$$\text{L} = V_o(V_{in} - V_o) / \Delta I f V_{in}$$

$$=58.8(230*\sqrt{2} - 58.8)/5*25*10^3*230*\sqrt{2}$$

$$=.38\text{mH}$$

$$=380\ \mu H$$

$$\text{C} = \Delta I / 8 f \Delta V_c$$

$$=5/8*.588*25*10^3$$

$$=0.0425 \text{ mF}$$

$$\cong 50\ \mu F$$

IV. CONTROLLER

In this we are using 16f877A type microcontroller. The new PIC16F877 Controller is the ideal solution for use as a standard controller in many applications. The small compact size combined with easy program updates and modifications make it ideal for use in machinery and control systems, such as alarms, card readers, real-time monitoring applications and much more. This board is ideal as the brains of your robot or at the center of your home-monitoring system. Save time and money, by simply building your ancillary boards and monitoring circuits around this inexpensive and easy to use controller.

a) Features:

i. Includes Powerful Microchip PIC16F877 Microcontroller with 8kb Internal Flash Program Memory.
ii. Operating Speed at 10MHz Direct In-Circuit Programming for Easy Program Update.
iii. Up to 28 I/O points with easy to connect standard headers.
iv. RS232 Connection with MAX23 Internal EEPROM.
v. 8 Channel 10-bit A/D Convertor.
vi. One 16-bit Timer with Two 8-bit Timers.
vii. Power and Programming LED
viii. Reset Button
ix. Ideal as an Interchangeable Controller for Real-Time Systems

b) Controlling Aspects:

1. Controls the on/off time of Boost Converter
2. Controls the on/off time of Buck Converter
3. In case of worst conditions of Voltage variations of Solar Power, Switch is connected to AC mains by using Controller.
4. Controls the Change Over Switch

V. MATLAB SIMULATION

The proposed model is implemented in MATLAB-Simulink environment as shown below.

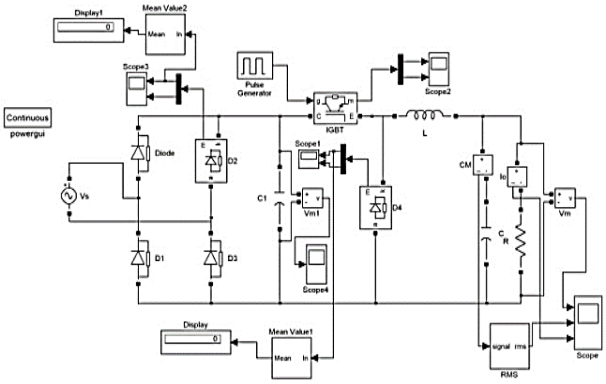

Fig 6: Simulation circuit diagram Simulation Results:

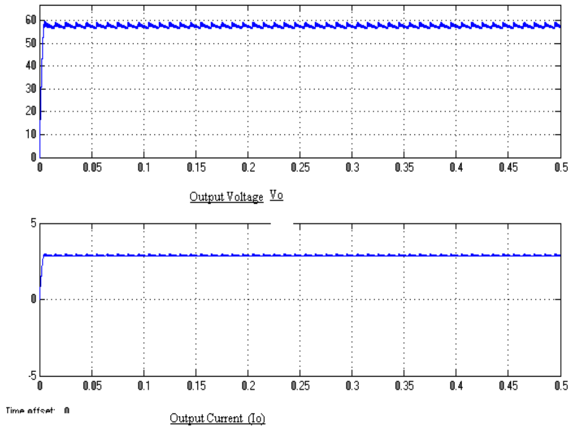

Fig 7: simulation results of output voltage and current

The boost converter simulation in MATLAB is as shown in fig.8.

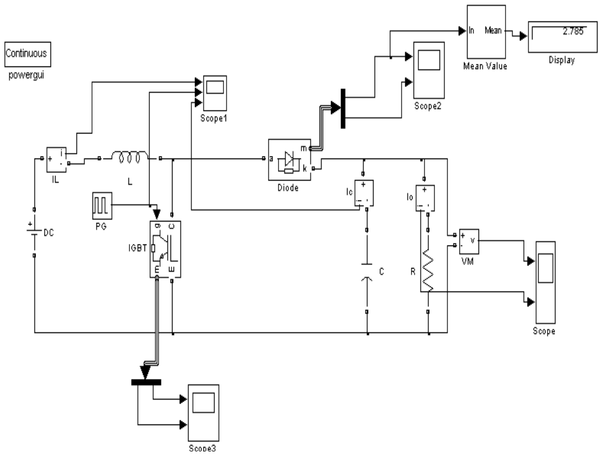

Fig 8: Simulation circuit diagram of boost converter

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Simulation results:

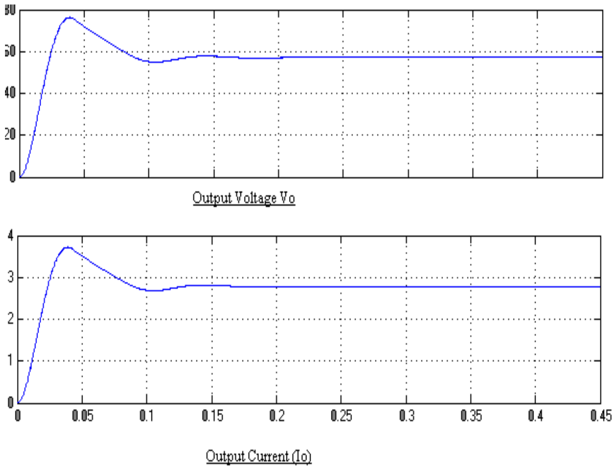

Fig 9: simulation results of output voltage and current

VI. CONCLUSION

In this paper we see that charging the battery of electric bike by using solar energy and ac mains supply, and battery charging is controlled by charge controller using PIC Microcontroller for generating PWM signal. These generated PWM signal given to the DC/DC converters for battery charging. So per one liter of petrol for a bike, its average travelling speed is 50km and one liter petrol costs 56 rupees for travelling 50 kms, so we are saving up to 65 rupees by charging with solar energy. But, by charging with AC mains supply, it consumes 1 unit of energy with the cost is 7 rupees. Total cost is 65-7=58 rupees is we are saving by charging with solar energy.

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