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Design and Control of Power Converter for LED Lighting Driven from the PV Module

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ABSTRACT: Utilization and extraction of solar energy for residential lighting applications from PV modules plays a beneficial role in off-grid areas. This power converter should be highly reliable and cost effective and also require an effective control strategy to drive the LED lamp. Under different conditions this power converter is suitable to supply the lighting load to drive the LED lamp. This paper proposes a power converter which is able to operate under different conditions such as during availability of bright sunlight, during the condition with insufficient sunlight, during night time or absence of sunlight & when battery gets fully charged. Integration of MPPT with a suitable control algorithm and charge controller is used in a closed loop power converter. The analysis of power converters during different states of operation has been done based on simulation results on Matlab/Simulink to prove how this power converter is effective to improve the reliability and economic implications of the existing system.

KEYWORDS: Solar PV module, LED lamp, power converter, control strategy, battery, capacitor, inductor.

I.INTRODUCTION

In present life it is very important to utilize non-conventional sources of energy due to increase in consumption of energy it can be converted into various forms to fulfil the various energy demands. In off-grid areas it has great influence of electrification from the solar power through PV module because of its availability & free to harness. The solar PV system has many advantages such as pollution free, noise free & so on. In rural areas where there is lack of grid connection in those areas it is very beneficial to extract the electric power from solar PV modules for the household lighting with the sufficient luminous intensity. As compared to other forms of lighting systems, LED bulbs have many advantages such as high efficiency, longer life etc., and it is suitable for solar lighting application. To drive LED modules there are various power converters. However, there are many issues associated with the previously existing control methods & circuits. There is a necessity of a high reliable & cost effective power converter due to the factors like variation of solar radiation, varying load conditions, battery back-up etc. To increase the longer life time period of the battery requires a proper charge controller due to the axillary power supply used in the battery.

To drive the LED lighting from solar power the Buck-Boost converter is used. This Buck-Boost converter does not have the capability to drive the load directly from the sunlight available during day time. To drive the load and battery simultaneously sepic converter is used, which reduces the reliability & the lifetime of the battery. Another disadvantage of sepic converter is, when the battery is used as an auxiliary power supply is to regulate the flow of current to very small value when it SOC value has reached around 95%.

This paper proposes a suitable power conversion circuit to drive the LED lightingFrom the PV module. The proposed power converter is able to operate under different conditions such as during availability of bright sunlight, during the condition with insufficient sunlight & when battery gets fully charged. The analysis of power converters during different states of operation has been done based on simulation results on Matlab/Simulink to prove how this power converter is effective to improve the reliability and economic implication of the existing system.

II.CIRCUIT CONFIGURATION AND OPERATION STATES

The power converter is the main source and the battery as its providing supplementary power supply. It is carried out by operating in different modes or states of operation based upon many conditions like the load requirement, battery

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charge level and the intensity of solar radiation. As shown in fig.1 there are two MOSFET (switches) S1 and S2 (10kHz) complementary to each other. These switches' actions help to achieve the function of MPPT control and power balance between PV module, the battery and the LED light level. There are input capacitors Cpv and Cb connected across the PV module and the battery. This converter charges the battery from PV power through common inductor L as well as from the actions of switches S1 and S2 along with the output capacitor Co. When there is not availability of sunlight or when PV module is not sufficient to fulfil the load demand then the battery discharges the current form a boost converter that supplies the load when required.

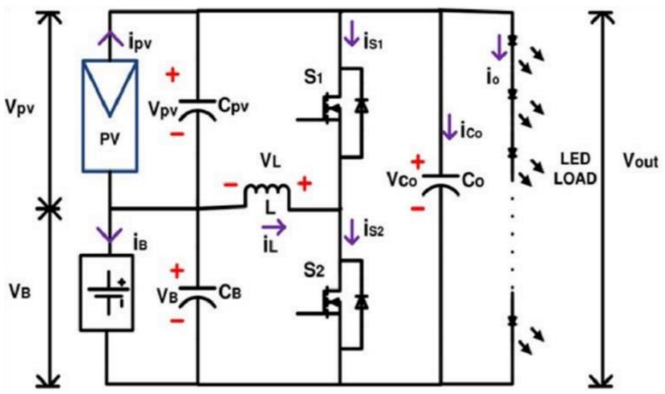
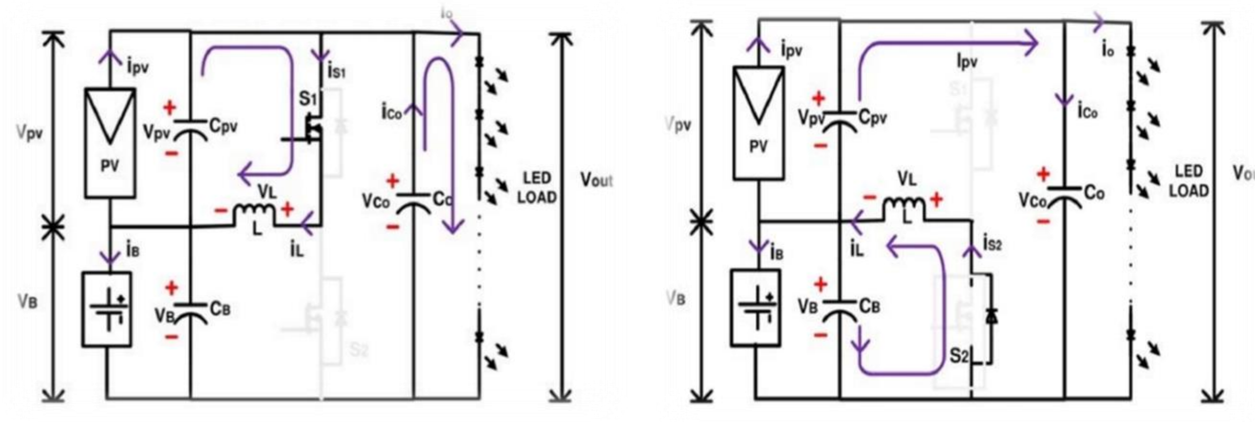


Fig.1 the Proposed Power Converter

III.OPERATION

Based upon the switching action and the availability of the sunlight and the SOC (state of charge) of the battery thecircuit operation is held. There are 4 states based upon these conditions.
STATE I: **-** When there is availability of sunlight (bright sunlight).



(a) Mode I operation under state I and state IV (b) Mode II operation under state I and state IV
Fig.2. Operation modes of state I and state IV

During daytime this operation is performed when there is bright sunlight which is observed by the PV module and the energy gets absorbed by the battery. PV modules can be worked as the main component in this state. Hence the MPPT condition to extract the maximum power from the intensity of the bright sunlight. S1and S2 are turned ON and OFF in phase 180° complementary to each other to get the power balance between the PV module and the battery and the LED light level. In Mode 1. The switch S1 ON and switch S2 is OFF and the inductor L charges current i_L and in Mode 2. S1 is OFF and S2 is ON, inductor L discharges current i_L.

STATE II: -*During conditions with insufficient sunlight.*
The availability of sunlight is only at daytime but intensity of radiation is low. Therefore, it results in the low power supply by solar panel to LED lamp. In Mode 3. The load receives the power from the PV source and the output

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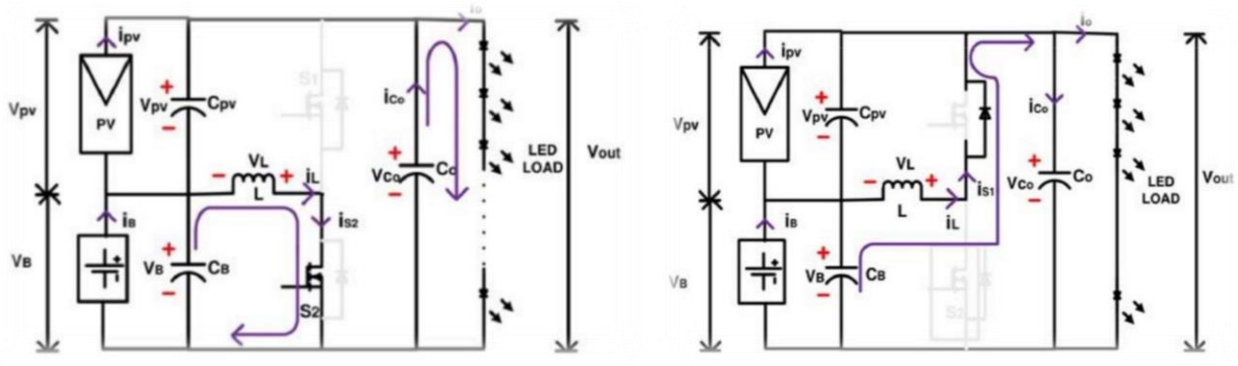
capacitor Co and the output capacitor Co discharge into load, i.e. S1 is OFF condition and S2 is ON. In Mode 4. S1 is ON and switch S2 is OFF hence the load receives power from the solar panel

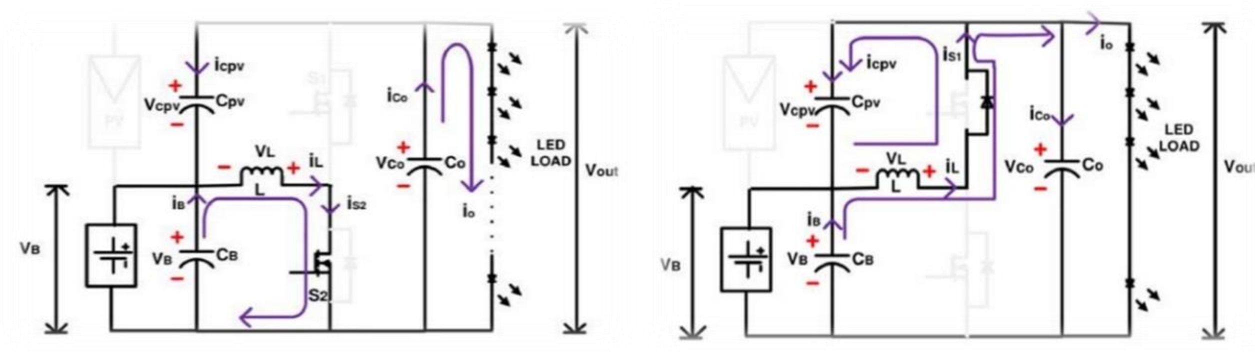


(a) Mode III operation of state II (b) Mode IV operation state II

Fig.3. Operation modes of state II

STATE III: During night time or absence of sunlight.

When there is absence of sunlight, the battery is the only source available to satisfy the power required by the LED lamp. Battery discharges into the load by the switches S11 and S2 therefore switch S1 is OFF and switch S2 is ON and the inductor charges the current i_L. In Mode 6. The battery along inductor L, two switches S1 and S2, and output capacitor C_0 forms Boost Converter.



(a) Mode VI operation of state III (b) Mode VI operation of state III

Fig.4. Operation modes of state III

STATE IV: When the battery gets fully charged.

The working is the same as that of State 1. SOC value of around 95% small amount of current flows through the battery. Here non MPPT condition done by the PV module. Hence the cycle continues.

IV. SIMULATION RESULT

The Specification Gives In the table no1.the proposed power converter is simulated in matlab and Simulink and various state has been Analysed Table No1.With The specification a 60W solar exMSX60 PV panel in table2 is implemented in matlab file using Perturb the MPPT is achieved and observe method. The MPPT achieved using Perturb Observe method, the PVpanel delivers 60W of maximum power at Sun intensity of radiation and simulation is taken at the same radiation level. A 10Ah, 13V lead-acid battery is used as auxiliary power supply. A LED lamp of 15W (30V, 0.5A) which is capable of emitting 900lm of intensity light utilised. The various states of operation and different load conditions are achieved by using the simulation results of the closed loop control of the power converter.

STATE I: State I condition is achieved by 30W driven two LEDs with battery SOC of 50%. The PVpanel is working at MPPT (17V, 3.5A) feeding the load and the battery gets charged with the current value of 2.2A, the negative value signifies that battery is charging The Simulation.

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TABLE I

Parameter	PV module	Load	Battery
Voltage	16.8V	30V	12.95V
Current	3.6A	0.99A	2.22A
Power	60W	29.7W	28.74W

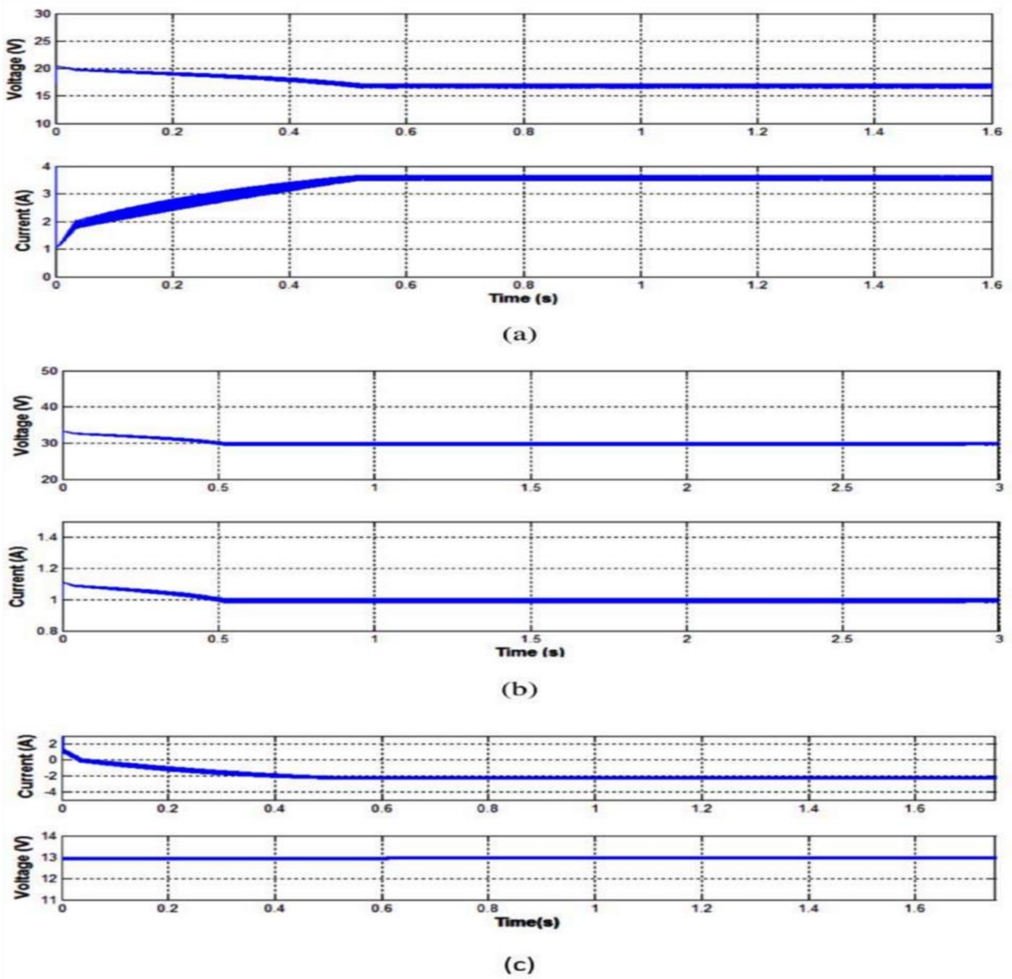

Fig.5. Simulation results for state I operation. (a) PV panel voltage and current. (b) Load voltage and current. (c) Battery charging current and voltage.

STATE II: **-** In state II operation to fulfil the load requirements the battery discharge hence load gets power from both PV module and battery. The below table II and fig.6 shows the simulation results for 75W load with 5 LED lamps. The battery is discharge the current into the battery current.

Table II

Parameter	PV module	Battery	Load
Voltage	17V	13V	30V
Current	3.58A	1.3A	2.5A
Power	60.86W	16.9W	75W

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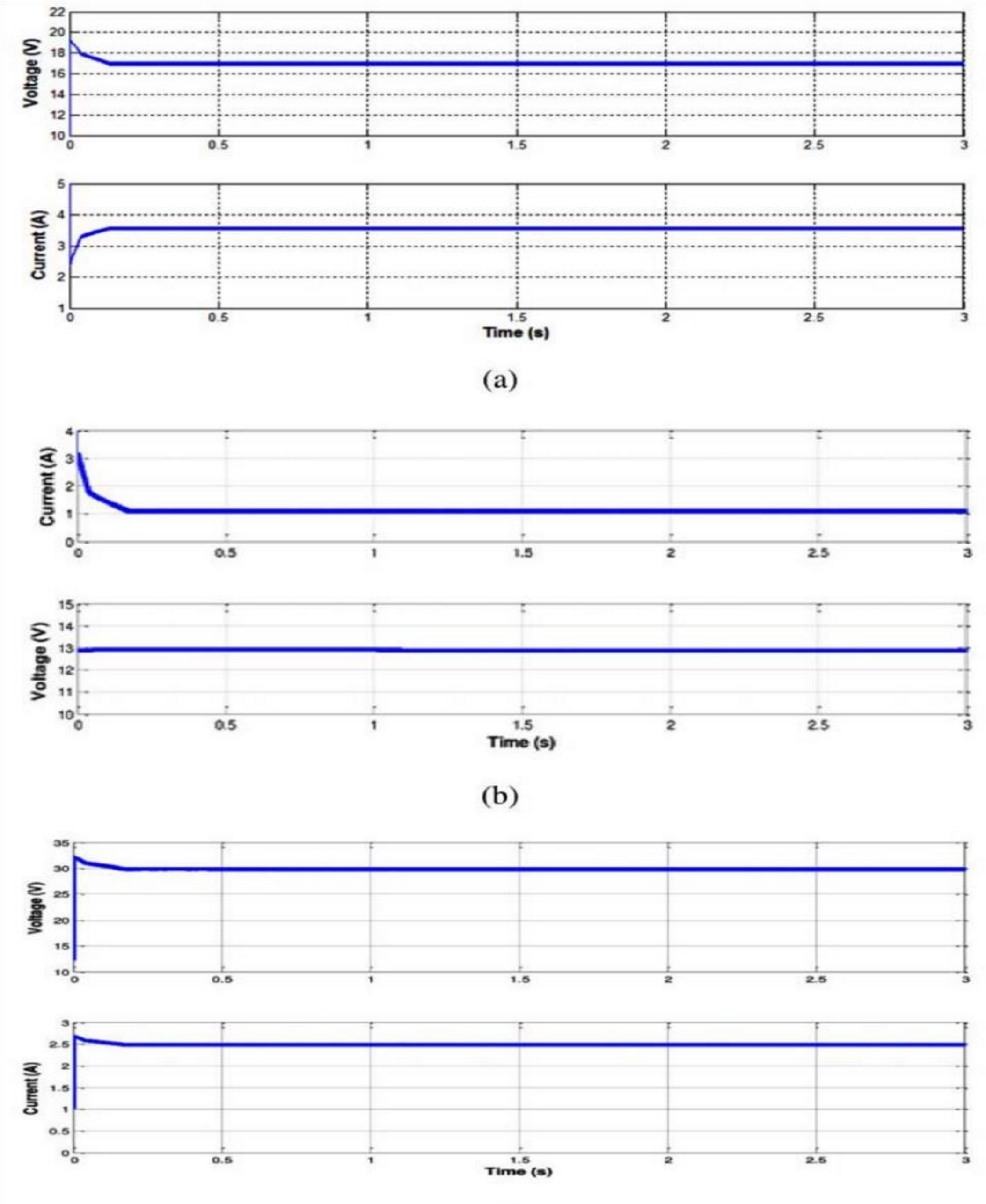

(c)

Fig. 6. Simulation results for state II operation. (a) PV panel voltage and current. (b) Battery discharging current and voltage. (c) Load voltage and current

STATE III: **-** In state III the battery charged at 70%SOC gives supply to the load during night time. The table III and fig.7 shows the simulation results for 30W load condition with 2 LED lamps. The battery is discharging the current into the load is indicated by the positive value of the battery current.

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TABLE III

Parameter	Battery	Load
Voltage	13.11V	30V
Current	2.52A	1A
Power	33.03W	30W

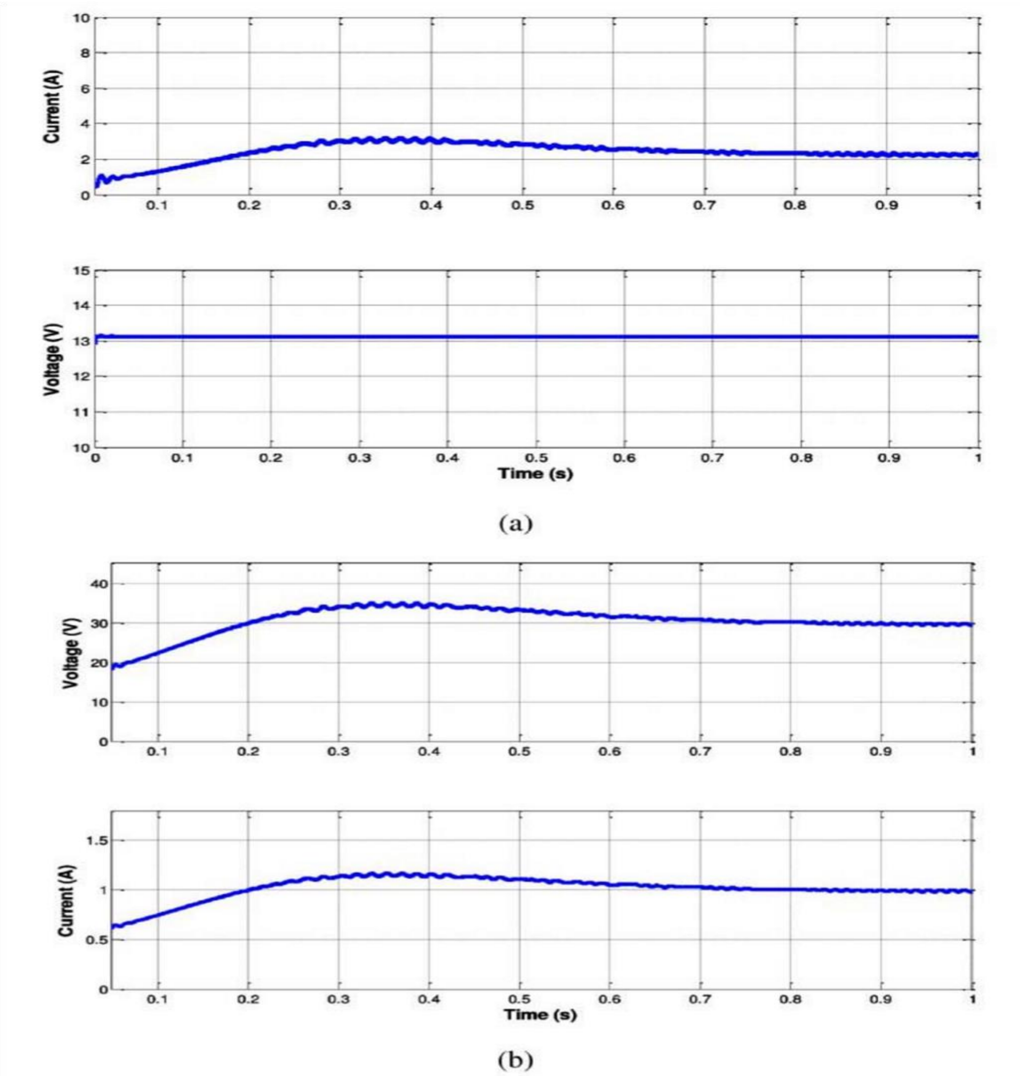

Fig.7. Simulation results at state III operation. (a) Battery Discharging current and Voltage. (b) Load voltage and current.

STATE IV: - When the battery has reached 96% and the solar power is sufficient to satisfy the load say about 15W, then PV module goes out of MPPPT and battery charges with the low value of current, the corresponding results is shown in table IV and fig.8.

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TABLE IV

Parameter	PV module	Load	Battery
Voltage	20.35V	33.6V	13.28V
Current	1.2A	0.56A	0.21A
Power	24.42W	18.81W	2.78W

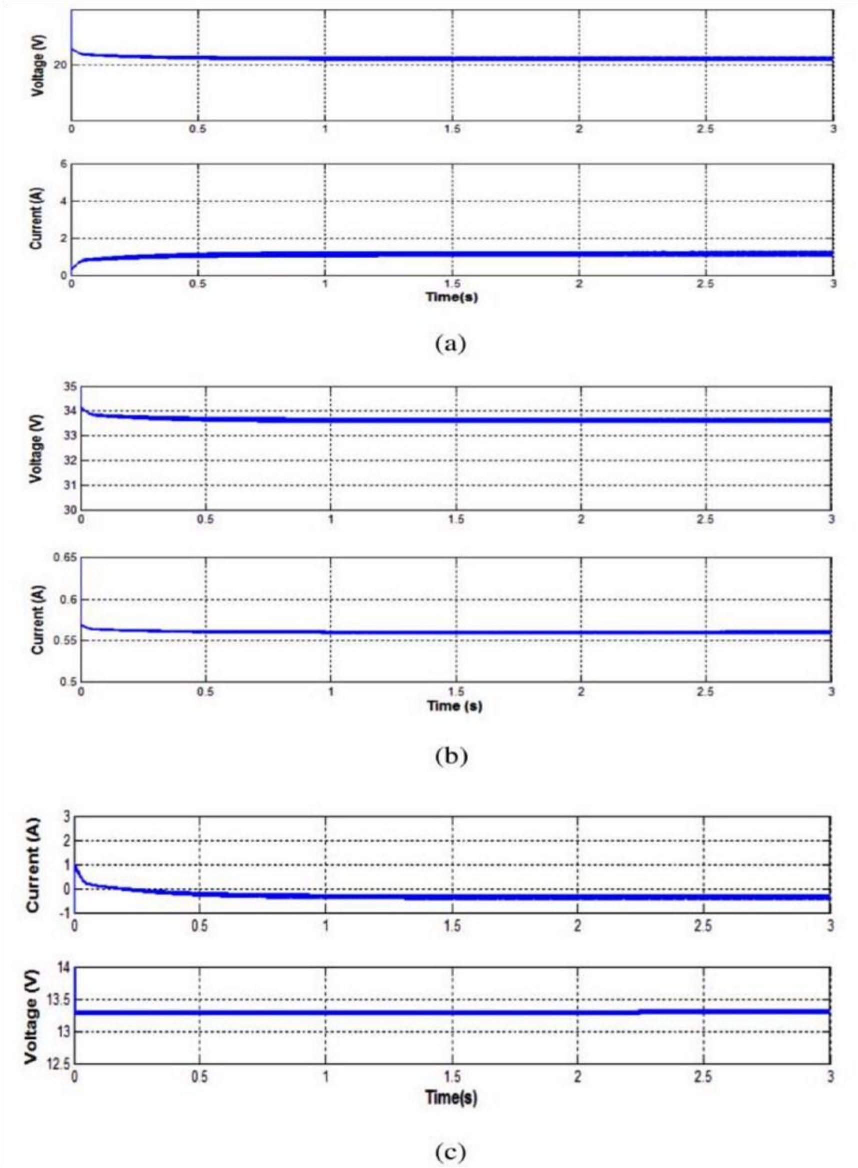

Fig.8. Simulation results for state IV operation. (a) PV panel voltage and current. (b) Load voltage and current. (c) Battery charging current and voltage.

V. CONCLUSION

Highly reliable and the cost effective system with combination of solar power and battery power of lightning application, acceptable power converter has been proposed and under different state of operation has been done. It is implemented in close loop control with integration of MPPT controller and with the help of power converter charge

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controller is adopted and simulation results are carried out using Matlab and Simulink platform. The results are various modes of operation and load conditions are embellish.As well as the analysis can be made to use the proposed DC to DC converter to drive the motor or supply grade in the area where there is a huge availability of solar power.

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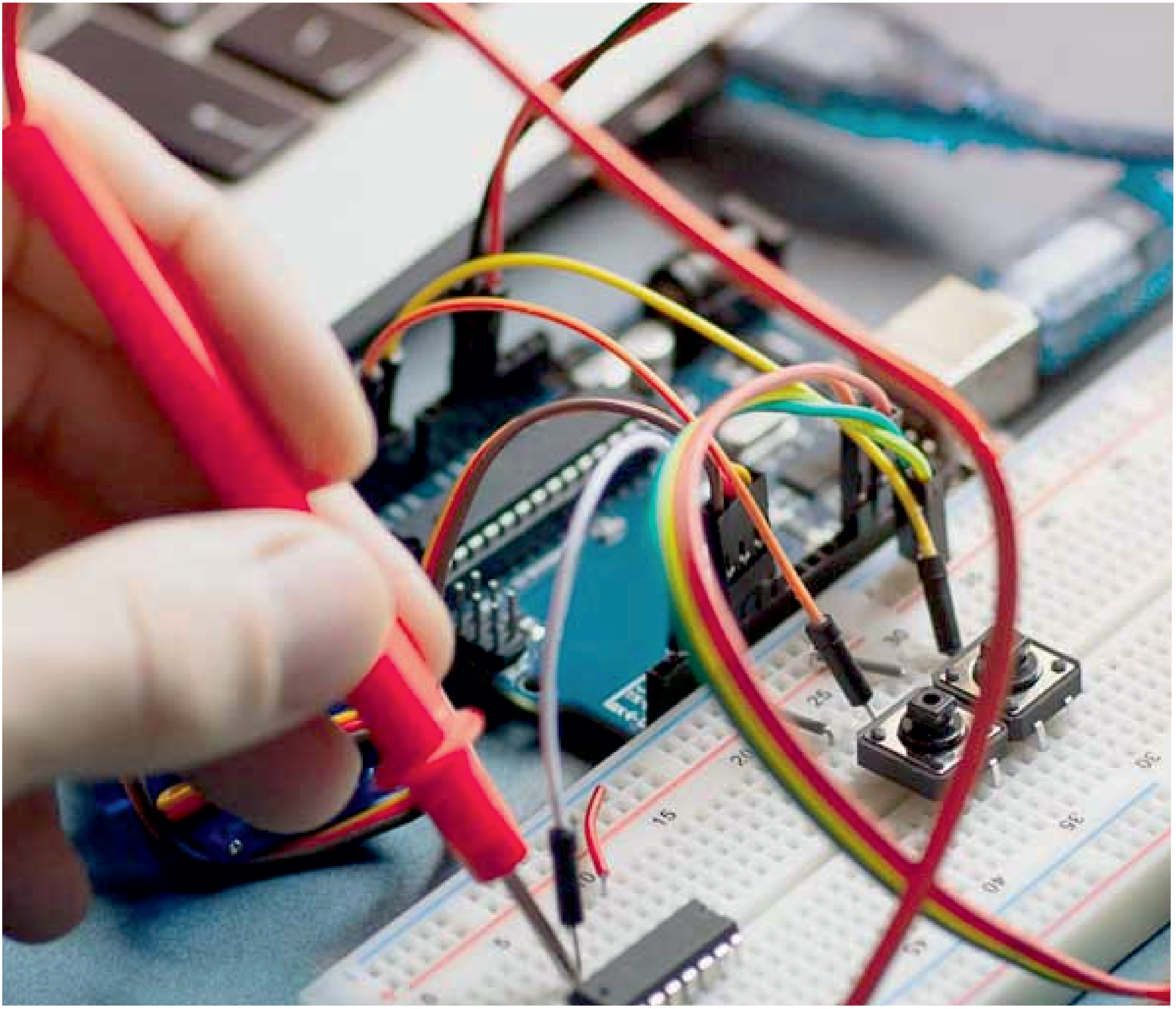

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