International Journal of Engineering Research
Volume No.5, Issue No.1, pp : 6-10

ISSN:2319-6890)(online),2347-5013(print)
01 Jan. 2016

Testing, Performance and Reliability Evaluation of Charge Controllers for Solar Photovoltaic Home Lighting System in India

Adarsh Kumar[1],ChandraShekhar Sharma[2], Dr. Rajesh Kumar[3], Avinashkumar haldkar[4]
[1,2]Department of Electrical Engineering, Samrat Ashok Technological Institute, Vidisha, Madhya Pradesh, India
[3,4]National Institute of Solar Energy, Gurgaon, India
singhadarshkr@gmail.com

Abstract:Charge controller is the most important part of a Solar Photovoltaic Home LightingSystem (SPVHLS) which controls the charging ofbattery from photovoltaic (PV) module and discharging of battery through load. This paper analyzes testresults of fourteen charge controllers (CC) available in Indiaaccording to the Ministry of New and RenewableEnergy (MNRE) specification. The different parameters of charge controllers to be tested arebattery high voltage disconnect (HVD), low voltage disconnect(LVD), load reconnect voltage (LRV), short circuit protection etc. It is found thatseven charge controllers meet the technical specifications ofMNRE. There is also a study of different features and properties of the chargecontrollers. Finally a brief discussion on selection appropriate charge controller for Solar Photovoltaic Home LightingSystem (SPVHLS) and further improvement ofcharge controller is presented.

***Index Terms*— Solar Photovoltaic, Solar photovoltaic home lighting system,Charge controllers, Testing, MNRE, NISE.**

I. INTRODUCTION

A solar charge controller is required in almost all solar PVsystems that having batteries backup. The work of the solar charge controller is to regulate the power going from the solar module to the batteries and then to load. The most basic function of a PV charge controlleris to prevent battery overcharging and deep discharge. If battery is allowed toroutinely overcharge, or deep discharge, their life time and performance will bedramatically reduced [1]. A charge controller will sense thebattery voltage, and decrease or cut the charging current whenthe voltage gets high enough. This is particularly important withsealed lead acid battery where we unable to replace the waterthat is lost during overcharging [2]. A careful margin exists between maintaining a battery’s full charge and overcharging. The overcharging is curse for flooded lead-acid batteries. It not only reduces battery life, but it can also lead to a potentially dangerous situation [3]. There are some otherfunctions that a charge controller does such as reverse polarity protection, reverse leakage current protection,preventing battery over-discharge, protecting from electricaloverload, maximum power point tracking, and short circuit protection etc.

MNRE, Government of India has been promoting solar electricity and the use of solar photovoltaic lighting system in rural and remote area since 1980s. And for that MNRE has introduced solar program. Nowadays MNRE not only promoting to rural area but also to urban areas.National Institute of Solar Energy (NISE)is the apex National R&D institution in the field Solar Energy. It assist the MNRE in implementing the National Solar Mission and to coordinate research, technology and other related works.MNRE provides grants to lower costs of solar PV home lightingsystem (SPVHLS) and also offers soft loans throughthe Indian Renewable Energy Development Agency (IREDA). NISE test the technical standards for the equipment’ssuch as solar module, charge controller, battery etc. of solarPV home lighting system for MNRE approval certification. The equipment that is not approved by MNRE isineligible for MNRE grants and refinance. In local market allavailable charge controller are not approved by MNRE.Collected charge controllers are tested according to the MNRE Specification.

II. CHARGE CONTROLLER TESTS AND ANALYSIS

For a solar PV home lighting system, the controller must comply with thetechnical standards as written in MNRE specification provided by MNRE in India.The sample charge controllers are taken from various companies which came for certification of MNRE approval. Some foreign manufacturedcharge controllers are also collected for testing purpose.Performances of these sample charge controllers are measuredto check the conformity to the specifications provided by theMNRE [4]. Low voltage disconnect (LVD), Loadreconnectvoltage (LRV), Batteryhigh voltage disconnect, reverse polarity protection, self-current consumption, short circuit protection, over currentprotection etc. were measured.

A. *Low Voltage Disconnect (LVD)*

One of the hazard of battery is deep discharge, it will cause some battery damage. The capacity and the life of the battery will be reduced by small amount every time the deep discharge occurs. If the deep discharge repeatedly done or if the battery sits in this over discharge state for days or weeks at a time, battery can be ruined quickly. So, LVD is compulsory to protect the battery.

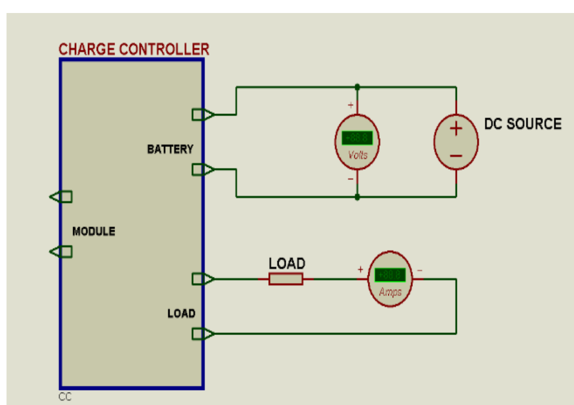

Figure 1.Circuit connection for LVD / LRVtest

For measurement of LVD, circuit was connected as Figure

International Journal of Engineering Research
Volume No.5, Issue No.1, pp : 6-10
ISSN:2319-6890)(online),2347-5013(print)
01 Jan. 2016

1.When the state of charge of batteryis reduced below the specified level (i.e., LVD) then charge controllerdisconnects load from battery. Test result of different samples Charge controller is shown graphically in Figure 2.

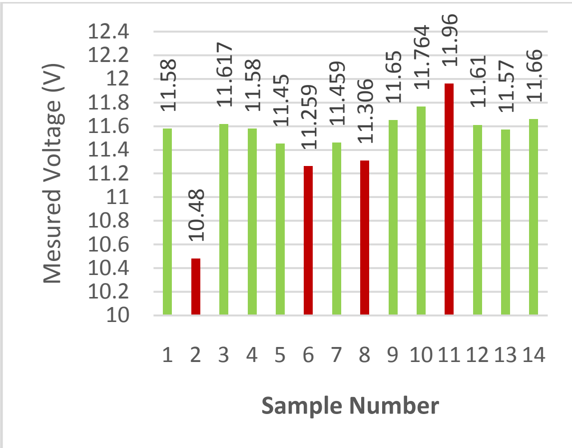

Figure 2. Low voltage disconnect voltage

According to the MNRE standard, LVD disconnect Voltage is 11.6±0.2 V. So the sample no.02, sample no.06, sample no. 08 andsample no.11 did not comply with the specification.

B. Load Reconnect Voltage (LRV)

Low voltage disconnect hysteresis (LVDH) is the voltage span between the LVD and the voltage point (i.e., LRV) where the charge controller automatic reconnects the load to the battery. If the LVDH is too small, the load may switch on and off rapidly at low battery state of charge, possibly damaging the load, battery or controller, and increasing the time it required to charge the battery fully. If the LVDH is too large the load may remain off for extended periods until the module array fully recharges the battery. The LVD added to the LVDH will give the LRV.

For measurement of LRV, circuit was connected as Figure 1. Test result of different samples Charge controller is shown graphically in Figure 3.

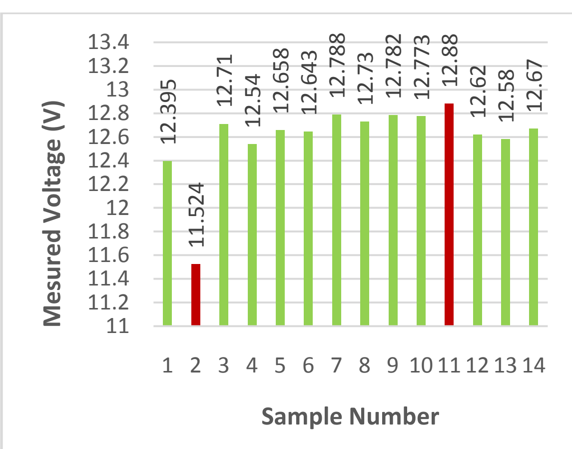

Figure 3. Load reconnect voltage

According to MNRE standard, LRV is12.6±0.2 V. So the sample no.02, and sampleno.11 did not comply the specification.

C.High Voltage Disconnect (HVD)

At the point when a battery attains full charge, it can no more store incoming energy. If energy source keeps on being connected and supplying energy at the full rate, the battery voltage gets too high.This will lead to excessive loss of electrolyte, acute gassing, faster grid corrosion, overheating and degradation of battery life. Overcharging prevent battery from fully serving system loads. It also weakens the bonds between the grids and the electrolyte. Preventing overcharge is simply amatter of stopping the flow of energy to the battery bank. That iswhy at a specified battery voltage (i.e., HVD), the battery is detachedfrom solar module to stop current flow for charging.

For HVD measurement, the circuit was connected as Figure 4. The DC sourcevoltage was higher than the battery and supplying adequatecurrent. When the current value of Ammeter was 0Amp,reading of the Voltmeter was taken.

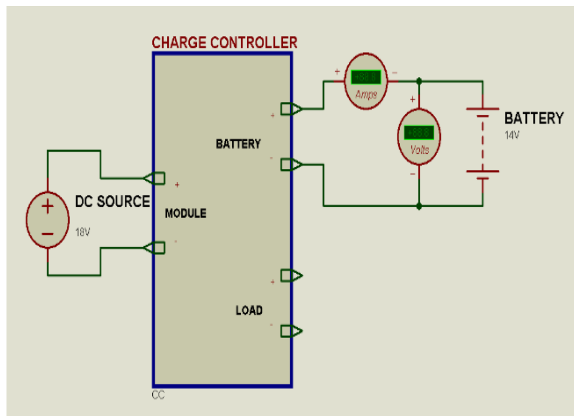

Figure 4. Circuit connection for HVD test

Measured battery HVD voltages areshown in Figure 5.According to the MNRE specification, HVD is 14.3±0.2 V.From graphical depiction it is seen that sample no.01,sample no.05, and sample no.07didn't comply this. Although sample no.03, andsample no.07 did not comply with the specification they haveHVD. But sample no.05did not have HVD feature.

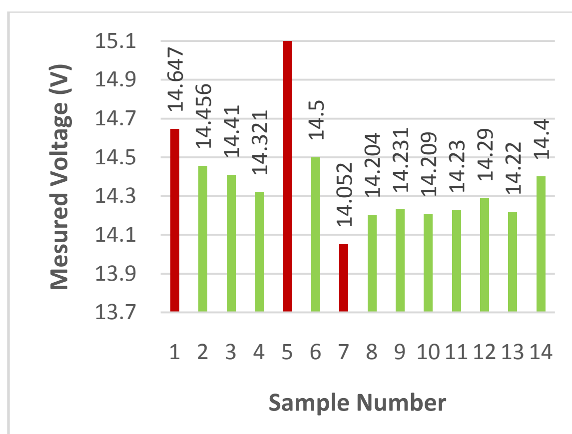

Figure 5. High voltage disconnect voltage (HVD)

D. Idle Current

 ISSN:2319-6890)(online),2347-5013(print)
01 Jan. 2016

Every electronic device having components like BJT, MOSFET, SCR, etc. requires some current for internal circuitry. The idle current is current flowing out of the battery when the lamp is off and no charging is under process (i.e., self-current consumption of electronic component of charge controller). According to the MNRE technical specification, the magnitude of the measure current under this condition should be less than 10 Mafor home lighting system.

For measurement of Idle current, circuit was connected as Figure 6. The reading of ammeter is noted when the switch of the lamp is open and no charging in process.Testing results all samples are shown in Figure 7.

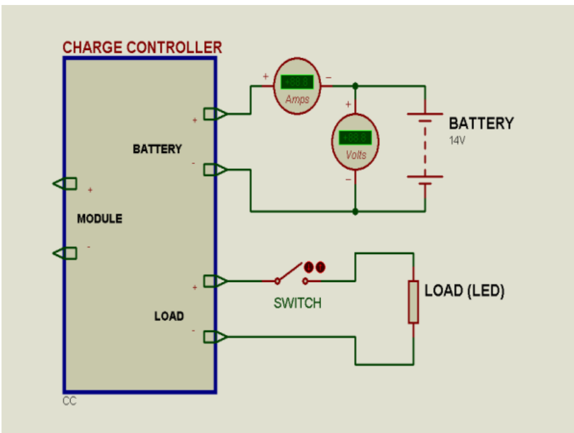

Figure 6. Circuit connection for Idle current

From graphical depiction it is seen that sample no.07, and sample no.11 didn't comply with this specification of MNRE.

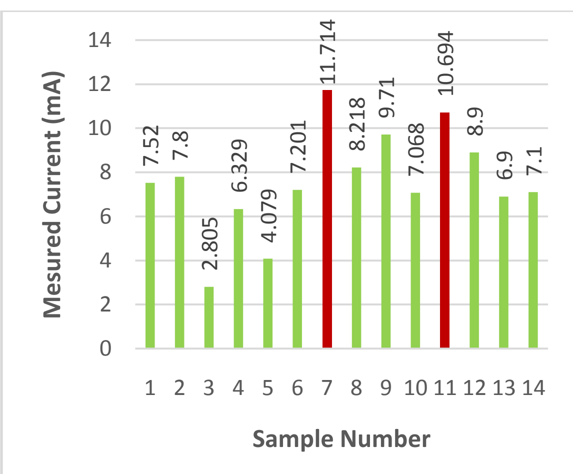

Figure 7.Idle Current

E. No load protection

No load condition show the ruggedness and endurance capacity of electronic circuit.
Circuit was connected for No load protection as shown in figure no. 8. To check the No load protection the charge controller is kept on for five minutes while the load is removed
All samples complied with this standard of MNRE.

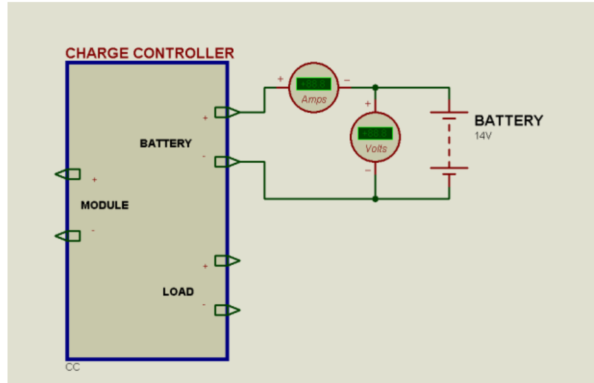

Figure 8. Circuit connection for No load protection

F. No Load Current

There should be a little loss in No load condition, because loss in charge controller circuit directly proportional to battery discharge. This test was done to ensure that the battery should not get discharged excessively when load is cut-off.
For No load current test, circuit was connected as figure no. 8. The reading of ammeter is noted when the system is switched on, load is removed and no charging in process.
According to the MNRE standard the magnitude of this current flowing out of the battery should be less than 10 % of the total current under full load condition.
All samples complied with this standard of MNRE.

G. Voltage Drop from Module to Battery Terminals

There should be a good voltage difference between the module terminals to the battery terminals for proper charging of battery. For maintaining that the voltage drop from module terminals to the battery terminals should be as less as possible.

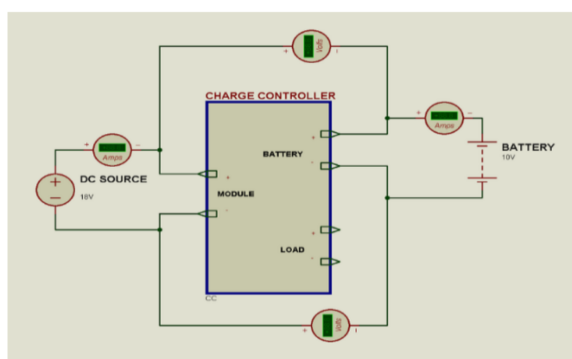

Figure 9.Circuit connection for voltage drop from module to battery terminals

For voltage drop from module terminals to the battery terminals, circuit was connected as Figure 9.
The reading of both voltmeter was noted when current of ammeters was maximum. Test result of different samples Charge controller is shown graphically in Figure 10.

International Journal of Engineering Research
Volume No.5, Issue No.1, pp : 6-10
ISSN:2319-6890)(online),2347-5013(print)
01 Jan. 2016

According to MNRE specification, the voltage drop from module terminals to the battery terminals should not exceed 0.6 volts including the drop across the diode and the cable when measured at maximum charging current. . So the sample no.07, and sample no.11 did not comply the specification.

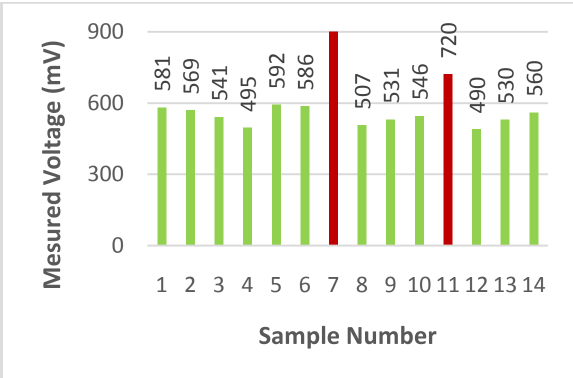

Figure 10.Voltage drop from the module terminals to the battery terminals

H. Load short circuit protection

Short circuit can cause excessive heat and possibly ignition if near combustible material, and possibly component damage, if protection is not provided. Load short circuit protection is mandatory at the loadterminal according to the MNRE standard Circuit was connected for Load short circuit protection as Figure 11. To check the Load short circuit protection the load terminal of charge controller short circuited by a thick wire having low resistance for a period of five minutes.

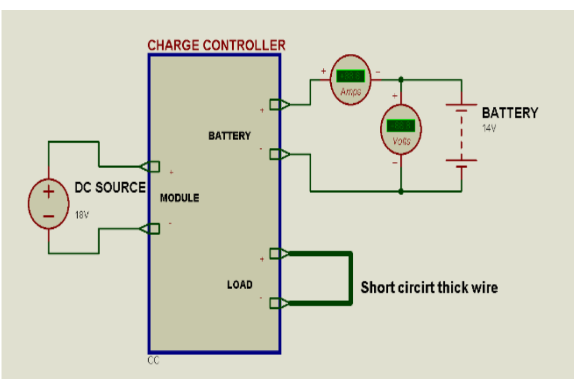

Figure 11. Circuit connection for Load short circuit protection

To protect load as well as charge controller each sample should haveload short circuit protection. Sample no.05 and sample no.06 didn't comply with thisspecification.

H. Reverse Current Flow Protection

Panel current should flow in one direction (i.e., panel to battery) for better utilization of PV system. In night and cloudy days panel side voltage goes lower than battery voltage, then panel may pass a bit of current in reverse direction, causing a slight discharge from the battery.

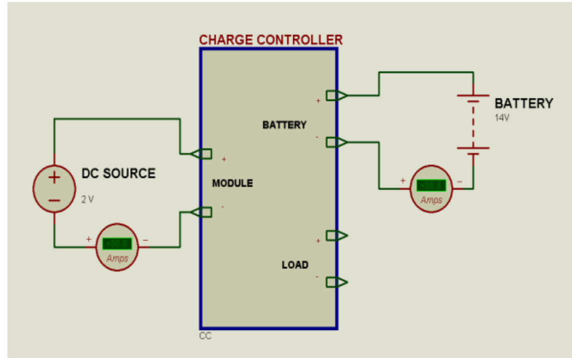

Figure 12. Circuit connection for reverse current flow protection

This test is to ensure that a blocking diode is installed on the PCB of charge controller to protect the discharging of battery through module. The circuit connection for the test as shown in figure 12.Reading of both ammeters were taken. Zero or very low reading of ammeters insure the protection is OK.According to MNRE this reverse current flow should be very low or zero Amp. All samples complied with this standard of MNRE.

I. Reverse Polarity Protection

There may be opposite polarity connection at the solar module sideand at the battery side. MNRE specifies it as a compulsory tohave protection against reverse polarity so that no currentflows from reverse direction.

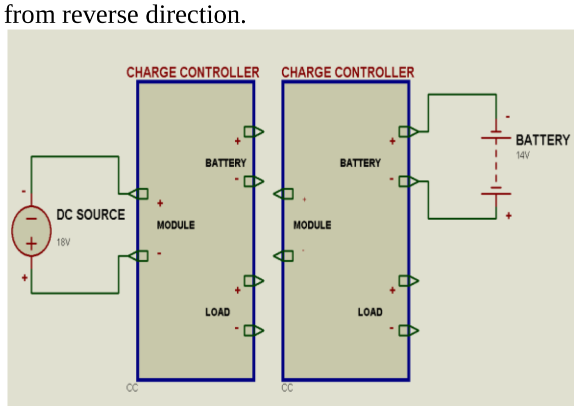

Figure 13. Circuit connection for reverse polarity protection

The system was kept as connected in Figure 13 for five minutes and the Chargecontroller was observed whether there was any damage. All samples satisfied with this specification.

III. FEATURES AND PROPERTIES OF TESTED CHARGE CONTROLLERS

There are two type of charge controller on the basis of basic connection with array, they are series controller and shunt controller. Shunt controller is connected in parallel to the solar module, battery and the load. When battery is fully charged, the charge controller stop current supply to the battery by making the solar module short-circuited [1]. But the series charge controller is connected in series between the solar module and battery. The controller disconnects the battery from the solar module by opening the switch.All the sample we tested are shunt controller except sample no. 13 and sample no. 14 are series controller.

ISSN:2319-6890)(online),2347-5013(print)
01 Jan. 2016

There are three type of charge controller on the basis of design and technology such as ON-OFF, PWM and MPPT charge controller.Among the charge controller we tested, itis found that, sample no. 3 and 8 arePWM charge controllers. Others are On-off charge controllers.

During the testing process we observed some extra features which is presented below. All sample have two indicators, green and red except sample no. 02. The green indicator indicated the charging under progress and glowed only when the charging is taking place. It stopped glowing when the battery is fully charged. Red indicator indicated the battery "Load Cut Off" condition. Sample no. 02 had function of beep sound on the battery "Load Cut Off" condition. Sample no. 3 and 4 had mobile phone charger USB port.

IV. APPROPRIATE CHARGE CONTROLLER FOR SOLAR PHOTOVOLTAIC HOME LIGHTING SYSTEM

If maximizing charging capacity were the only subject considered when specifying a solar charge controller, everyone would use a MPPT controller. But here we was searching for appropriate charge controller for solar PV home lighting system which is mainly used in rural India where battery life,system cost, performance and reliability is main factor.

After testing the charge controllers, we get only two were PWM charge controllers, where others are ON/OFF charge controller. But ON-OFF Charge controller degrade the battery quickly which add extra cost in system. Literature [5], [6] shows that PWM charging increases the charging efficiency and battery life. So for small solar system like Solar Photovoltaic Home Lighting System, where system cost is mainly depend on battery cost, PWM charge controller should be preferred because of better battery care handling and lower cost than MPPT charge controller.

It was also found that no sample charge controllers had maximum power point tracking (MPPT) system. This can increase the output of the solar module from 10 to 30 percent. Though it needs an efficient DC-DC converter and capable microcontroller or, microprocessor with algorithm which are costly, it may be cost effective for larger solar PV systems.

V. FURTHER IMPROVEMENT

We got only two sample charge controller have PWM technique among all samples. SoPWM technique should be implemented in all the charge controllers for long performance and reliability of charge controller as well whole system.

VI. CONCLUSIONS

Solar Photovoltaic Home Lighting System (SPVHLS) has turned into an effective and feasible answer for the present energy crisis in India. As a major component of solar PVhome lighting system, the performance of charge controller plays a vital role in the growth and popularity of solar PV home lighting system. In this paper, we arbitrarilytaken fourteen charge controllerscame for certification of MNRE approval, which alsopresent in the local market of Indiaproduced by both local and foreign manufacturer. We thoroughly tested these charge controllers and compared againstthespecificationsety MNRE for performance and reliability analysis.Among 14 samples only seven charge controllers came in categories of high performance and good reliability by meeting the technical specifications of MNRE. The testing data are presented in this paper. A few deviations were found from the standard values which can cause underperformance of solar PV home lighting system. It was found that PWM charge controller is better in India in respect of efficiency, performance and cost. Future work ought to join large scale testing and performance evaluation of the locally available charge controllers in India.

REFERENCES

i. *Dr. Md. Sai fur Rahman, Dr. Shahnawaz Ahmed, Dr. S.I. Khan et al, Solar Home System, 1st ed., Dhaka, Bangladesh, German technical Cooperation (GIZ), March 2013.*

ii. *S.A. Khan, R. Rahman and A. Azad, "Solar Home System Components Qualification Testing Procedure and Its Effect in Bangladesh Perspective," IEEE Global Humanitarian Technology Conference (GHTC), pp. 381 – 386, October 2012, Seattle, WA.*

iii. *M. Thele, J. Schiffer, E. Karden, E. Surewaard, D.U. Sauer, "Modeling of the charge acceptance of lead–acid batteries", Elsevier 10th european lead battery conference, Athens, Greece, January 2007.*

iv. *MNRE (2013), Technical specifications for White-LED based Solar Photovoltaic Lighting Systems including Solar Lanterns, Home Lighting and Street Lights, Available at: http://mnre.gov.in/information/systems-specifications/, India, (Posted on 06.05.2013).*

v. *Lam, L.T., et al, "Pulsed-current charging of lead/acid batteries-a possible means for overcoming premature capacity loss" CSIRO, Australia, Journal of Power Sources 53, 1995.*

vi. *Hund, Tom, "Battery Testing for Photovoltaic Applications," Sandia National Laboratories, Albuquerque, NM, presented at 14th NREL Program Review, Nov. 1996.*