International Journal of Advanced Science and Research
ISSN: 2455-4227
Impact Factor: RJIF 5.12
www.allsciencejournal.com
Volume 3; Issue 1; January 2018; Page No. 27-29

Effect of temperature on flooded lead-acid battery performance

[*1] Gauri, [2] Manish Singh Bisht, [3] PC Pant, [4] RC Gairola
[1] Department of Physics, H. N.B. Garhwal University, Srinagar Garhwal, Uttarakhand, India
[2-4] National Institute of Solar Energy, Ministry of New and Renewable Energy (Govt. of India) Gurgaon, Haryana, India

Abstract
In a SPV system batteries are subjected to varying environmental and loading conditions. The health and performance of a solar battery is affected not only by the depth of discharge but also by the operating temperature of the battery. The operating temperature comprises of ambient as well as internal temperature/electrolyte temperature of the battery. In a country like India, where the ambient temperature has wide variations, it becomes essential to consider the effect of temperature on battery while designing a SPV system. This paper presents the study of effect of both internal and external temperature on capacity of flooded lead acid battery samples with respect to charging voltage and capacity of the battery. A charging profile for usual operating temperature conditions is also suggested.

Keywords: lead-acid battery, ambient temperature, internal temperature, capacity, charging voltage

1. Introduction

Batteries are an integral part of solar photovoltaic (SPV) systems, especially for standalone applications. Though various secondary storage battery technologies are available, the storage option in SPV is still dominated by lead-acid technology due to maturity of technology, recyclability and lower cost [1]. The life of a battery is usually expressed in number of cycles which it can deliver before its end of life. These life cycles vary from quality manufacturing process to the operating conditions of a battery. The battery is often considered as the weakest link in a system and is a major reason for SPV power plant malfunctions [2]. The field failure of batteries is a big concern for power engineers. Battery malfunction not only adds to the high recurring cost but also causes system failure resulting in loss of both generated power and money. The main reason known for battery degradation is depth of discharge but temperature is also a vital factor to be considered for battery efficiency. High operating temperature results in short service life of a battery [3]. Like all chemical reactions, also electrochemical reactions are much influenced by temperature. The most important law describing the influence of temperature on a chemical reaction is the Arrhenius Law:

$$\mathbf{K = A\, e^{Ea/RT}}$$

Where,
K - Reaction rate;
A - Rate constant;
Ea - Activation Energy;
R - Molar gas constant, and
T - Temperature.

High temperature results in enhanced reaction rate and thus increasing instantaneous capacity but reduces the life cycle of a battery. Every 10°C rise in temperature reduces the life of a battery to half of its rated value [4]. In a power plant or other SPV applications; battery has to operate under open climatic conditions which include ambient temperature and humidity. But the real operating temperature of a battery is its internal temperature which is affected by ambient temperature as well as loading and charging conditions. This internal temperature plays an important role in performance and life of a battery. The knowledge regarding performance of a battery at different ambient temperature is crucial in order to design an efficient system and prolong the life of batteries.

The aim of the study was to investigate the effect of ambient temperature on the performance of a flooded lead-acid battery in terms of charging voltage and current, capacity, internal temperature and efficiency.

2. Experiment Methodology

The experiment was conducted on new samples of 12V 100Ah flooded lead-acid batteries. Initially 15 random sample were selected for capacity test. Out of 15 only 10 samples, which showed relatively close capacity values, were shortlisted for further study (Fig. 1).

2.1 Test Procedure

The individual cells were subjected to capacity and charge efficiency analysis at different ambient temperature in the temperature range of 0 ^{0}C – 50^{0}C as per BIS[#] standards and average values were recorded. Each sample was exposed to 5 cycles each for capacity analysis followed by efficiency test. The data was recorded at temperature interval of 10^{0}C. The parameters monitored were current, voltage, capacity, efficiency and internal temperature.

2.2 Testing Equipment

Bitrode LCN machine was used to perform capacity and efficiency tests. This machine is a combination of power supply, load and data logger and is interfaced to a computer for control. The ambient temperature was simulated by using Kaleidoscope make climatic chamber.

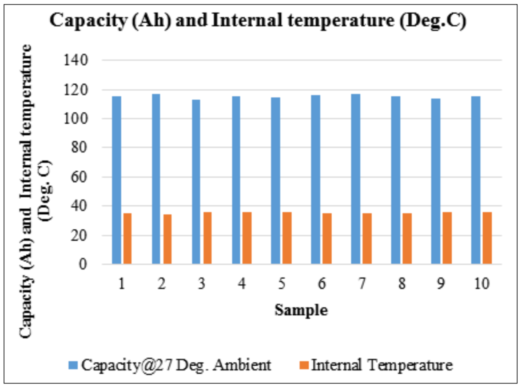

Fig 1(a)

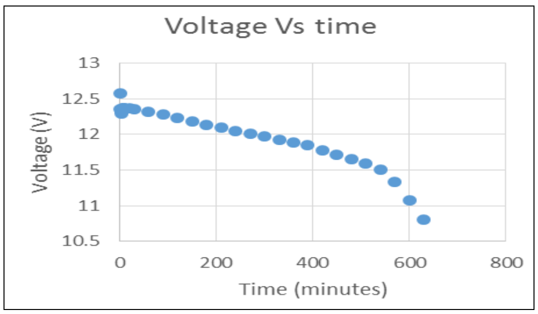

Fig 1(b)

Fig 1(a): Capacity and internal temperature of samples at 27^{0}C ambient. **(b)** Voltage vs time plot at 27^{0}C ambient.

3. Results and Discussions

3.1 Effect of Ambient temperature on internal temperature

The internal temperature of a battery is a vital phenomenon affecting the performance and life of a battery. It is affected by the rate of charge/discharge as well as by ambient temperature. High internal temperature results in lower service life of the battery. Analyzing the pattern of internal temperature with respect to ambient temperature at C_{10} discharge rate, a linear relationship between the two is established (Fig.2). It denotes that higher the ambient, higher is the internal temperature of a battery at same rate of charge/discharge.

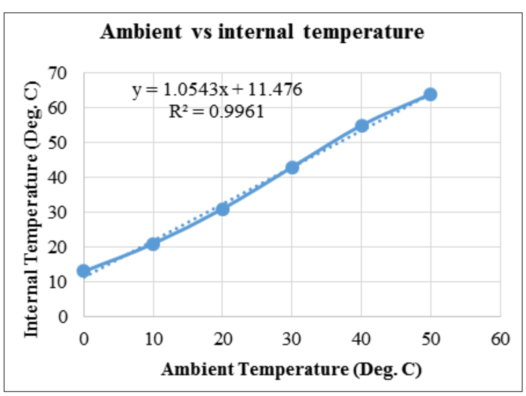

Fig 2: Plot of ambient temperature internal temperature

3.2 Effect of Temperature on Voltage and Current

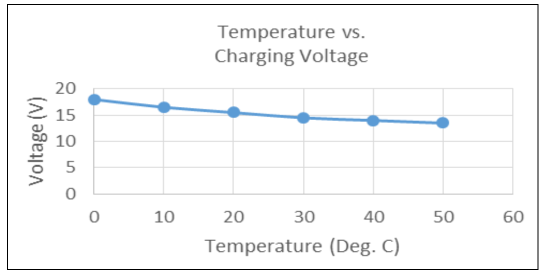

Fig 3(a)

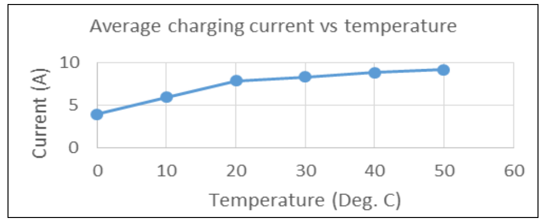

Fig 3(b)

Fig 3(a): Charging voltages for different temperature. **(b):** Average charging current at different temperatures

The study revealed that the same value of upper-cutoff voltage for charging a battery is not viable at different temperature. Full state-of-charge of the battery was not achieved at low temperatures when using 14.5V as reference voltage for charging. Similarly the batteries were overcharged at high temperatures when 14.5V was used. The data reflected that separate upper charging cutoff has to be applied at different temperatures to ensure full state of charge of the batteries (Fig. 3 (a)). Temperature played an important role in charge acceptance of the battery. The average charging current accepted by the samples at same C-rate was different for different temperature values (Fig 3 (b)). The average charging current is directly proportional to the temperature.

3.3 Effect of temperature on Capacity and Efficiency

Battery capacity is the ampere-hours delivered by a battery when discharged through a load. The analysis of test data reflected that capacity of a battery is directly proportional to the operating temperature. Higher the operating temperature, higher is the capacity observed at same rate of charge and discharge Fig. 4 (a).The charge efficiency is expressed as the ratio of the ampere-hours input of the battery to ampere-hours output from the battery. The efficiencies showed a decline at the temperature ranges below and above 30^{0}C which revealed that the charging efficiency of the batteries is maximum at 30^{0}C Fig. 4(b).

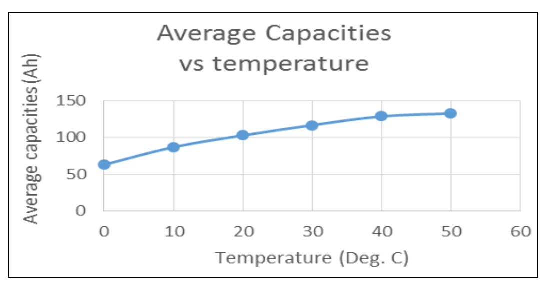

Fig 4(a)

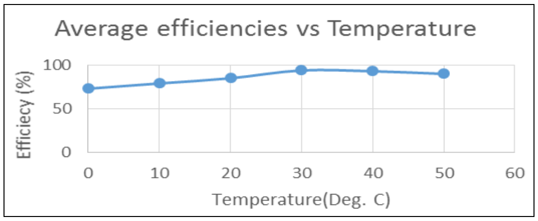

Fig 4(b)

Fig 4(a): Average capacities at different temperatures. **(b):** Average efficiencies at different temperatures.

4. Conclusion

Based on the above study it can be concluded that the best operating ambient condition of a battery is 30^0C. The ambient temperature above and below this range affect the battery in a negative way. In order to compensate for the ambient it can be recommended that the batteries should be charged at a higher voltage and C-10 current at low temperatures, and at high temperatures the charging current should be reduced to 75% of the rated C-10 current.

5. Acknowledgements

Sincere thanks to NISE administration for providing the required facilities and the staff for immense support and valuable efforts to bring out this work.

6. References

1. Yilmaz M, Krein PT. Review of Battery Charger Topologies, Charging power levels and infrastructure for plug-in electric and hybrid vehicles, IEEE transactions on Power Electronics. 2012; 28(5):2151.
2. Jorge M Huacuz, Roberto Flores, Jaime Agredano, Gonzalo Munguia. Field Performance of Lead-Acid Batteries in Photovoltaic Rural Electrification Kits, Solar Energy, 1995; 55(4):287-299
3. MD Li. Failure of a battery causing the 110KV substation breaking down, rural electrification, 2003; 9:28.
4. Gustavsson M, Mtonga D. Lead-Acid Battery Capacity in Solar Home Systems—Field Tests and Experiences in Lundazi, Zambia, Solar Energy, 2004-2005; 79:551-558.
5. Pavlov D, Monahov B. Temperature dependence of the oxygen evolution reaction On Pb/PbO2 electrode, Labat, 1996.
6. Abavana CG. Renewable Energy for Rural Electrification: The Ghana Initiative. Seminar on Rural Energy Provision in Africa. International Solar Energy Society, Nairobi, Kenya, 2000.
7. Petrovic V. Rapid battery charging method and Apparatus, US patent no. US 6388425 B1, 2001.
8. Armenta-Deu C. Prediction of Battery Behaviour in SAPV Application. Renewable Energy, 2003; 28:1671-1684.
9. Diaz's, Egido MA. Experimental Analysis of Battery Charge Regulation in Photovoltaic Systems. Progress in Photovoltaic Research and Application, 2003; 11:481-493.
10. Diaz's, Lorenzo E. Solar Home System Battery and Charge Regulator Testing. Progress in Photovoltaic Research and Application, 2001; 9:363-377.
11. Huacuz JM, Flores R, Agredano J, Munguia G. Field Performance of Lead-Acid Batteries in Photovoltaic Rural Electrification Kits. Solar Energy, 1995; 55(4):287-299.
12. Lorenzo E. In the Field: Realities of Some PV Rural Electrification Projects. Renewable Energy World, 2000; 38-51.
13. Nieuwenhout FDJ, Van Dijk A, Van Roekel G, Van Dijk D, Hirsch D, Arriaza H, *et al*. Experience With Solar Home Systems In Developing Countries: A Review. Progress in Photovoltaic Research and Application, 2001; 9:455-474.
14. PVPS. Lead-Acid Battery Guide for Stand-Alone Photovoltaic Systems, IEA Photovoltaic Power Systems Programme (PVPS), 1999; P. 33.
15. PVPS. Testing of Batteries Used In Stand Alone PV Power Supply Systems, Test Procedures and Examples Of Results, IEA Photovoltaic Power Systems Programme (PVPS), 2002; P. 43.