International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 2, Issue 4, April-2013, pp: (6-10), Available online at: www.erpublications.com

LabVIEW-based Battery Monitoring System with Effects of Temperature on Lead-Acid Battery

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Abstract: **Lead acid batteries are one of the most commonly used batteries. Monitoring the performance parameters of the battery provides essential data useful for managing the batteries efficiently. This paper proposes a highly accurate and efficient battery monitoring system based on NI LabVIEW. As the calculations are done on computer, this system is faster than micro-controller based systems and provides highly reliable real-time data. Experiments studying the effect of temperature on battery performance have also been performed and discussed in this paper.**

Keywords: Battery monitoring, Lead-Acid battery, LabVIEW

I. Introduction

Electrical energy plays an important role in our lives. Generation, transmission and distribution of electrical energy are major tasks. Batteries are used to store this energy. The energy of chemical compounds in the batteries acts as a medium of storage. Batteries are used for varied applications like power supply for portable devices, power back-up and so on. Batteries used for uninterrupted power supply require constant monitoring to ensure efficient operation. The battery management system ensures continuous operation, optimum use of battery energy and controls the charging and discharging of the battery. The three main objectives of common battery management systems are: protect the cells or the battery from damage, prolong the life of the battery and maintain the battery in a state in which it can fulfill the functional requirements of the application for which it is specified.

The function of a battery management system can be split into the following tasks: data acquisition, battery state determination, electrical management, thermal management, safety management and communication [1]. The measured and calculated data of the system is the input. The state of the battery can be estimated by two parameters: state-of-charge (SOC) and state-of-life (SOL). Both parameters influence the available capacity of the battery.

A simple battery monitoring system keeps a check on the key operational parameters during charging and discharging such as voltages and currents and the battery internal and ambient temperature [2]. The monitoring circuit would normally provide inputs to protection devices which would generate alarms or disconnect the battery from the load or charger should any of the parameters become out of limits.

The most common way of estimating the State of charge is to rely on the open circuit voltage of the battery. [3] This estimation is not accurate since it does not take into account the parameter variation in electrochemical batteries. Further, the open circuit voltage is not available when the batteries are in use. Hence, it is not a very effective way of estimating the battery state of charge. The State of health (SOH) which is an indicator of the ageing and any manufacturing imperfections is not indicated by the open circuit voltage. The system proposed in [4] contains an embedded microcontroller to track the energy content of cell battery, optimize the output current and to provide extensive feedback of all the measurements taken. Two unique advance features of the BMS are its ability to optimize the battery pack energy and also to provide cell equalization.

II. Battery monitoring system

Battery monitoring system is an integral part of the battery management system. Estimating the battery parameters for efficient functioning of the system is required. The three indicators of a battery monitoring system are:

i. State of charge (SOC)
ii. State of Health (SOH)
iii. Remaining running time

State-of-charge (SOC) is the percentage of maximum possible charge that is present inside a rechargeable battery.
State-of-Health (SOH) is a ‘measure’ that reflects the general condition of a battery and its ability to deliver the specified performance in comparison with a fresh battery.
The remaining running time (t_r) is the estimated time that the battery can supply current to a portable device under valid discharge conditions before it will stop functioning.

The discharging/charging behavior of a battery depends on a number of parameters such as:

a. Voltage
b. Current
c. Temperature
d. Capacity

a. Voltage
In the case of reversible systems the cell voltage may be derived from the thermodynamic data of the cell reactions. But often this equilibrium voltage cannot exactly be measured (even not in open circuit). But when working with an online battery monitor, closed circuit voltage is the closest and most reliable approximation.

b. Current
For a system to function properly; the battery should discharge at an optimum rate and this is taken care of by the battery monitoring system. If the battery discharges at a rate higher than specified, the battery run time is reduced. In extreme cases, it could even heat up and melt the wire insulations leading to fire outbreak.

c. Temperature
The internal and ambient temperature of the battery plays an important role for determining the battery performance as it can change dramatically with temperature. At the lower extreme, in batteries with aqueous electrolytes, the electrolyte itself may freeze setting a lower limit on the operating temperature. At low temperatures Lithium batteries suffer from Lithium plating of the anode causing a permanent reduction in capacity. At the upper extreme the active chemicals may break down destroying the battery. In between these limits the cell performance generally improves with temperature. Hence, the internal temperature of the battery should be monitored to account for any anomaly if the temperature is the reason for it.

d. Capacity
The capacity of a battery is defined by international convention as the electrical charge in units of Ah that can be drawn from the battery. When the battery is discharged with a constant current, its capacity is given by the relation:

$$C_{Ah} = I.\Delta t / Ah$$
$$C_{Ah} = \int_0^t I(t).\,dt \ / Ah$$

The discharge parameters that beside the design of a battery mainly influence the capacity are:

- Discharge current.
- Voltage limit, i.e. the final, the end point, the cut-off, or end-of-discharge voltage (EOD) that has to be specified.
- Temperature.

Further parameters that also influence the capacity are the state of charge and the history of the battery, e.g. the preceding storage period or number completed discharge cycles. Any comparison of capacity data must always consider these parameters.

The depth of discharge (DOD) is an important parameter in regard to the number of cycles that can be reached with rechargeable batteries. For lead-acid batteries, deep discharges that are continued beyond the recommended maximum DOD can reduce the service life drastically.

III. Data Acquisition

The battery used for the experiment is EXIDE™ 12EB5L-B. In the developed battery monitoring system, data acquisition for desired parameters is done using National Instruments (NI) analog input modules along with LabVIEW. The data obtained by the input modules is communicated to the NI DAQ (Data Acquisition system) through the serial port. The NI DAQ further uses USB communication protocol to transmit the data to the PC. When the whole system is connected, the NI modules should be self-tested to ensure that everything is well connected and communicating properly. The sensing and measurement components designed in LabVIEW are known as Virtual Instruments (VIs). Each VI has a front panel, a back panel and a connector panel. The back panel contains the actual program in G language while the front panel is available for the user to give inputs and view the outputs. A sub VI is a standalone VI that can be called by another VI just like subroutines in a conventional structured programming language.

Firstly, the physical channel being used for acquisition should be specified at the front panel. Before running the VI for a particular parameter sensing, the user should set the upper and lower limiting values expected for each parameter. This is done to protect the monitor from out of range values and also to increase the accuracy of measurement. While the VI's are running, the instantaneous values of each parameter are displayed on the front panels. In addition to this, a graphical profile is sketched continuously at the front panel until the user stops the monitor externally. This shows the trend in change of parameter values over time.

In the VI for current sensing, shunt resistor location should be specified (internal or external). If an external shunt is used then its value should be mentioned. The type of thermocouple used and the cold junction parameters should be specified explicitly on the front panel prior to starting the VI for temperature sensing.

Also, there is a provision to handle the idle periods of the monitor. If it does not sense any value for 10 seconds, the VI shuts down automatically. This function helps in saving power and the exiting of VI without recording any value also alerts the user about the incomplete sensing circuit connections. Along with this the error generation sub VI helps to notify the user about any error which occurs during the working of monitor. In the event of an error a message is generated.

IV. Battery performance at different temperatures

This test is conducted to know the battery performance at different temperatures. The battery is heated in an oven to different temperatures ranging from 30°C to 70°C while discharging through a load. The discharge profiles are generated and then compared. Slopes of voltage discharge profiles at various temperatures are given below in Table 1.

Table 1

Temperature	Slope of Voltage Discharge Profile (mV/min)
30° C	6.849
50° C	12.525
70° C	40.163

V. Results

1) As seen in the Fig. 2 and Fig. 3, the monitor very precisely plots the real time voltage and current discharge profiles of the battery on the front panel of respective VI's.
2) The battery performance deteriorates substantially at higher temperatures. The discharge rate becomes very high at elevated temperatures as shown in Fig.4.
3) After discharging at higher temperatures (>50° C), the battery starts self-discharging and becomes unfit for future use.

VI. Future Scope of Work

Impedance measurement system of the battery is also being included in the monitor. Then by the analysis of all the recorded parameters the monitor will predict the State of Health and the State of Life of the battery and generate warning signals to identify the faulty cells in the battery bank.

VII. Illustrations

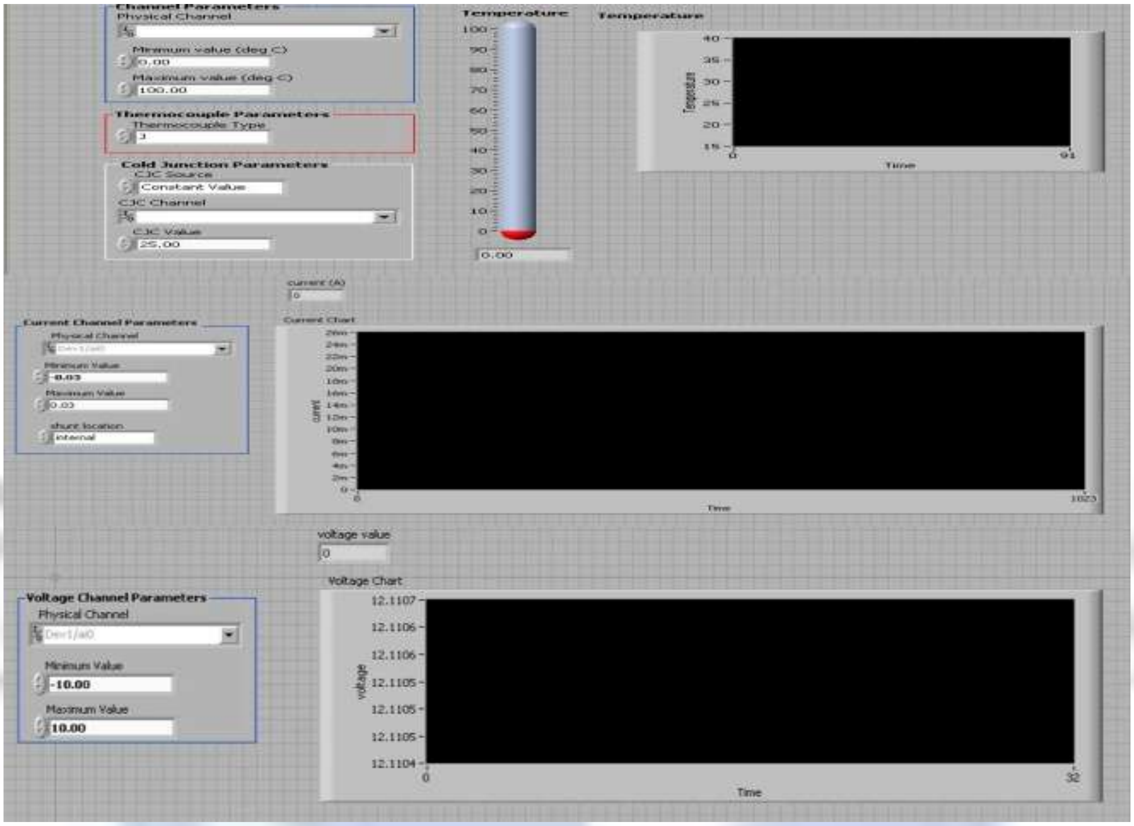

Fig. 1 Front panels of Temperature, Current and Voltage sensing VI's respectively

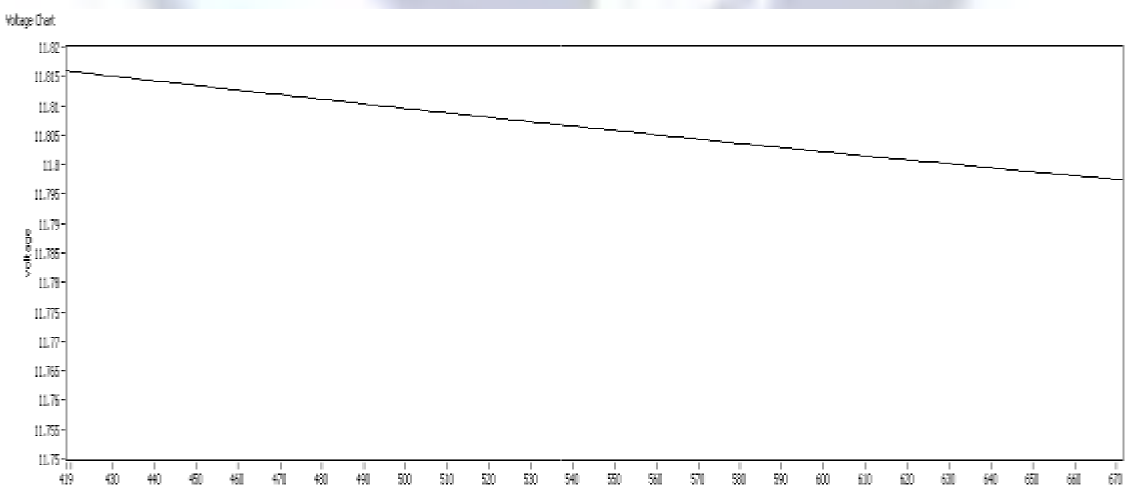

Fig. 2 Voltage Discharge Profile in volts (V)

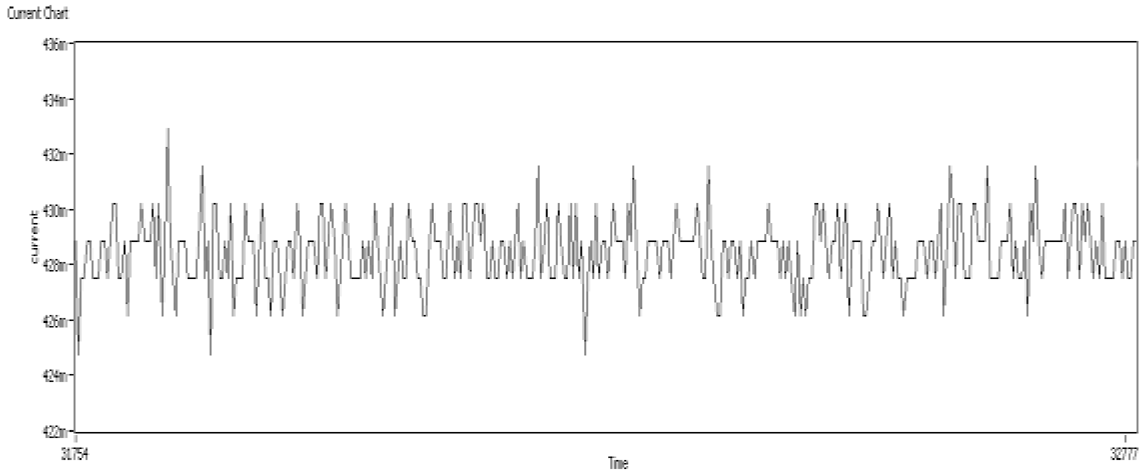

Fig. 3 Current Discharge Profile in Amps (A)

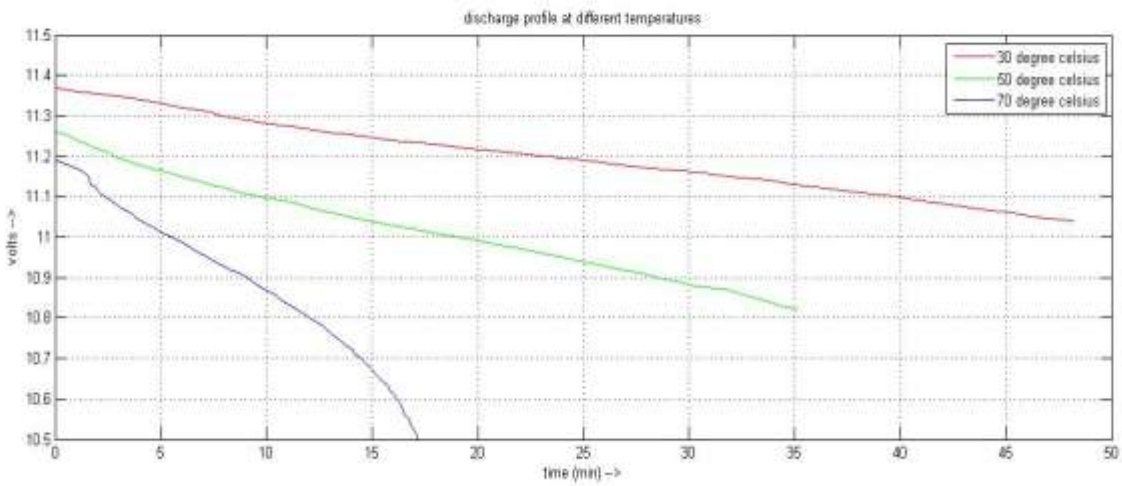

Fig. 4 Voltage Discharge Profiles at varying temperatures

References

[1]. Yuang-Shung Lee, Wei-Yen Wang, Tsung-Yuan Kuo, "Soft Computing for Battery State-of-Charge (BSOC) Estimation in Battery String Systems", IEEE Transactions On Industrial Electronics, Vol. 55, No. 1, January 2008.

[2]. A. Lohner, **S.** Buller, E. Karden, R.W. De Doncker, "Development of a Highly Accurate, Universal and Inexpensive Measuring System for Battery Management Systems", 15th Electric Vehicle Symposium (EVS), 1998, Brussels (Belgium).

[3]. B. Tsenter, "Battery Management for Hybrid Electric Vehicle and Telecommunication Applications", Battery Conference on Application and Advances, IEEE The 17th Annual, pp. 233-237, 2002.

[4]. Xiangling Shi, Zhenjiang Cai, Qingjian Zhai, Dening Zhang, Hongjuan Kou,"The Design of Battery On-line Monitoring Device Based on Wireless Communication", 2008 ISECS Int. Colloquium on Computing, Communication, Control, and Management.

[5]. A. Szumanowski, Y. Chang, "Battery Management System Based on Battery Nonlinear Dynamics Modeling", Vehicular Technology, IEEE Transactions on, Volume 57, Issue 3, pp. 1425-1432, 2008.

[6]. K. Onda, M. Nakayama, K. Fukuda, K. Wakahara and T. Araki, "Cell Impedance Measurement by Laplace Transformation of Charge or Discharge Current–Voltage", Journal of The Electrochemichal Society, 153 (6), A1012-A1018, 2006.