MONITORING OF BATTERY DISCHARGE TEST: A DIFFERENT APPROACH

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Introduction

Since the development of VLRA batteries, it has become clear that there is a need to monitor battery performance and its individual cells for the purpose of detecting pending failures by conducting regularly scheduled battery discharge tests.

Three sensing leads are required to test each cell (two for the cell and one for the intercell) to perform a battery discharge test. This is manageable when only a few cells need to be monitored. It becomes an installer's nightmare, however, when several strings of 240 cells need to be monitored. Distributed intelligence and/or fiber optic monitoring systems help a lot but the installer (or user) still has to deal with many wires which are connected to the batteries of different voltage levels.

Attempts were made to transmit data wirelessly using High Frequency, fiber-optics or IR links. The first solution was costly and disliked by users because it added another transmitter on line; the second is just not an improvement because it simply replaces wire with fiber, the third one is not designed for distance communication and is very slow.

In this paper the author will show how to maintain a high data collection rate with such slow communication as a human may be. The experience with such an approach may open the door for future work utilizing the other communication means including IR. The concept would be of special interest for users or technicians performing battery discharge/charge tests.

Design History Review

Battery monitoring equipment is a relatively new technology. At first, the task appeared to be an easy one for any electronic engineer.

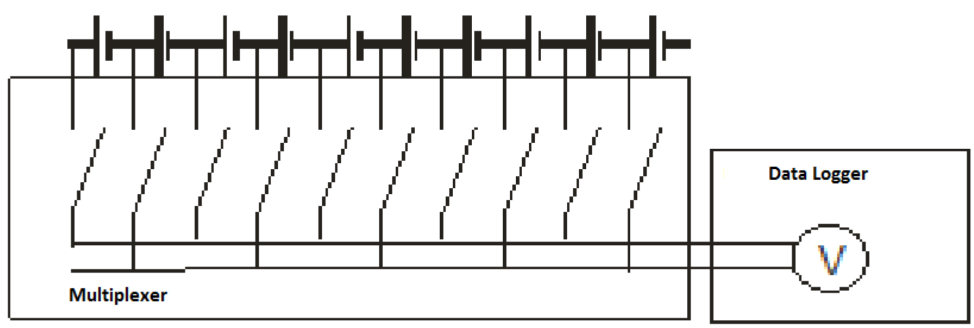

Figure 1. Classic design principle

It appeared that all that was required was a high voltage multiplexer to measure the individual cells in the battery string and a communication system to collect the data. Unfortunately, the attempt to use commercially available data loggers resulted in multiplex failures when the common mode voltage range of the multiplexers inside of the equipment was exceeded.

"Lesson 1" learned – multiplex failure due to burnout.

The solution to this problem was to use relays in such combinations that only one relay at a time would be connected to the battery. Mechanical characteristics of the relay made the data scanning process very slow. In addition, the moving parts of the multiplexer made the whole installation inherently unreliable (egg with Mean Cycle between Failures   1/10^9 20 sec. in a 240 cell string battery - one relay needs to be replaced every month).

"Lesson 2" learned - mechanical devices are slow and unreliable.

Replacement of relays by electronics was a natural progression to improve battery monitoring equipment reliability and performance however the semiconductors which are capable of handling several hundred volts are large and expensive. The solution was to divide the battery into segments thus reducing the voltage. Each segment would be monitored separately with individual cells in each segment temporarily storing the data. The control computer would communicate sequentially with each segment device capturing the individual cells data, Finally then the residing software would "glue" the data collected to provide an integrated failure risk profile for all cells in the battery.

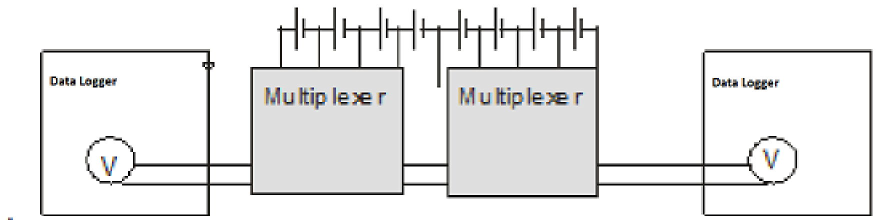

Figure 2. Distributed architecture

Progress

Such distributed architecture shown schematically in Figure 2 solved the HV DC common mode and allowed the user to tailor the configuration in accordance with his/her needs. The only problems seemed to be powering the device and insulation of the communication link to the monitoring device.

Powering the device from the segment (or the cell) removed the high voltage stress which exists between the device and the ground. The communication link insulation was accomplished by an opto-couple placed between the device common and the communication wires. The problem appeared to have been solved. With the opto-couple rated at 1000 V DC an electronic designer could be satisfied with HV insulation requirements.

An opto-couple, however, is sensitive to HF noises. The amplitude and frequency of noises depend on many factors, such as type and size of equipment connected to the battery, frequency of the carrier used to control Pulse Modulation Chargers or SCR conversion and so on. Battery monitoring equipment can be built and tested successfully in the lab but unfortunately it fails miserably when installed and left on line because the noise levels in the field are frequently different than predicted or tested in the lab.

"Lesson 3" - Use a device with unlimited CMR (Common Mode Rejection) such as a fiber optic cable.

Since the beginning of history of battery monitoring equipment many more lessons have been learned. There were many trials and errors in the battery monitoring field. Today it seems that all battery monitoring manufacturers have learned how to deal with the problems discussed above. However, despite all improvements made over the years to battery monitoring / testing equipment implementation in the field still remains complicated, difficult and time-consuming to install, operate, and maintain monitoring equipment.

Most battery monitoring manufacturer's equipment is designed not only to collect data but also controls communication, sets up limits and so on. Operation, maintenance and using testing manuals for battery monitoring systems have become complex task requiring trained personnel.

Status	NA	OPN	FLT	FLch	CHG	EQL	DISCH	Units
Jar V Per Status	2.1	2.15	2.22	2.2	2.2	2.3	2.02	V
Jar Low V Limits	1.4	2.03	2.15	1.8	1.7	1.8	1.71	V
Jar High V Limits	2.5	2.3	2.35	2.4	2.5	2.93	2.4	V
Significant Jar delta V	0.03	0.02	0.04	0.05	0.05	0.04	0.02	V
Significant Average V Delta	0.02	0.01	0.02	0.03	0.03	0.03	0.01	V
Significant Current delta	10	10	10	10	10	10	10	1/10A
Time Based Recording	0	3600	3600	3600	3600	600	60	Sec
Times to Record	0	0	1	1	1	1	7	Times

Figure 3. Multiple Level Settings Sample

Consider the sample of alarm setting for battery (see Figure 3). For each status of the battery the alarm set points of the high/low voltage (for example) would be different. The user must enter the proper alarm value on each slot but this may vary depending on noise level. In addition, the user must set communication parameters, assign disk space and many, other limits. It is almost a certainty that one or more errors would be discovered later. Even when everything is set properly, there would likely be personnel changes without proper training and as observed by many battery monitoring employers, the monitors are often forgotten, not used, not on line or with all alarms silenced.

Thus following the development history, the simple circuit seen in Figure 1 has evolved into the complex system as seen in Figure 4.

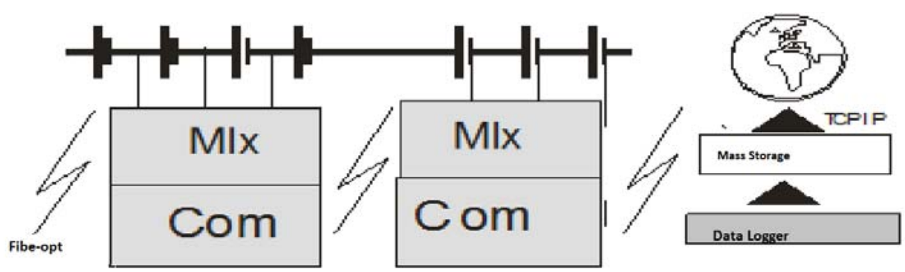

Figure 4. Fundamental blocs of today's monitoring systems

Battery analog parameters from cell are converted to digital form and are temporarily stored in local memory. The computer requests the data, stores it in memory, calculates the limits, sets up the alarms, displays the voltages, etc. Once this is done, the computer repeats the sequence for the next cell segment data collecting device. Since this is done in real time there must be a communication link between the data collection device and the computer. The speed of such communication determines the time required to scan and record all data from each cell being monitored. Assuming 10 bytes per record per cell and 2 strings of 240 cells each with 9.2 kb speed we have the scanning time of the system approaching 20 sec. which is unacceptable for many installations.

This can be improved in two ways only:
1. Increase the speed of operation or
2. Reduce the data volume.

The former offers only limited improvement and presents considerable challenges for an engineer especially when slow IR communication is considered.

Improvements
The author proposes to use the second approach.

Since battery monitoring systems are idle 99% (or more) of the time, it is possible to move some intelligence from the computer down to the cell level and utilize this time to perform some useful tasks like downloading of meaningful data. There would be a delay time between data sensing and data presentation but for some applications this is not important. The described concept would be best suited for a controlled battery discharge test. The principle of operation in such an application is described below.

Operational concept

Imagine a small individual monitoring device capable of operating at the full range of individual cell voltages (1.5 to 15V). The device collects the data from single cells and intercell connectors at preset intervals (e.g. 15 sec.). At this rate a single integrated circuit (IC) can collect and store data of a full discharge/charge cycle for 16 hours each with a resolution of 5mV / 20 uV for each cell/ intercell.

Each monitoring device would have a unique ID number visible to the naked eye and that number would also be stored in its memory. The operator installs the device on each cell to be monitored. The ID number of the device must correspond to the cell number. Three short sensing wires would be connected from the device to each cell. They would be used to measure the cell voltage and intercell connector resistance.

Once installed, the device would be powered and would start to collect data immediately. All of the devices would run at the same speed (quartz controlled) but each one would collect data at different times. This does not matter in a battery discharge test application since all devices would recognize the voltage dip when a load is applied to the battery. At that instant all devices would clear their memory and commence logging data from the beginning. They would run until they are disconnected and physically removed. Internal memory is sufficient size to capture the data for up to 16 Hours or more depends of sample rate. Since all devices are running “free” on internal clock there could be some speed difference between them. However this difference would be in he order of seconds.
After the battery discharge test, the operator collects all the devices and plugs them in one by one to the rs232 port of his/her laptop. The resident software downloads the data from the monitoring devices and converts the data automatically into an Excel spreadsheet. Discharge may be interrupted for whatever reason but data would be still collected until device is removed from the battery. Below is illustration of capability of the device which was used during endurance test of 12V, 7AH battery.

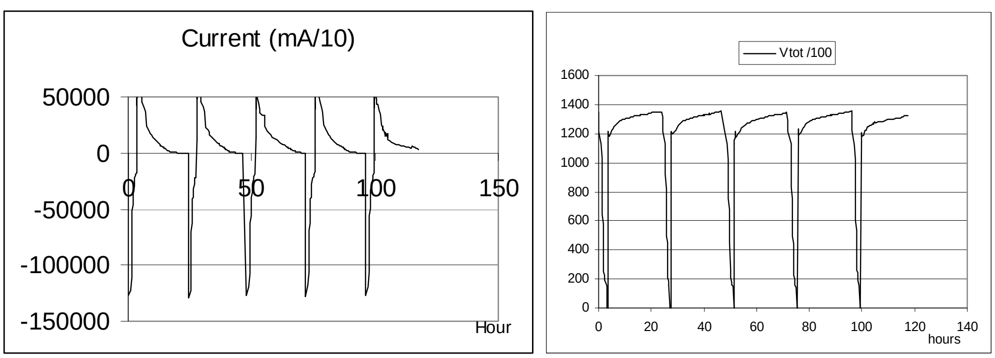

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Figure 5. Sample of data

The concept of this monitoring system is simple:

- There is no limitation on the number of cells to be monitored during the test.
- There is no time scanning limitation due to the speed of transferring data.
- There is no other hardware required.
- There are no long wires running from each cell to the monitoring equipment

Summary

This short review presents a brief history of the incremental improvements in battery monitoring systems for battery discharge tests along with a discussion on the advantages of the means of locally monitoring individual cells. The proposed approach allows for the elimination of long wires normally used during scheduled battery discharge tests. The device discussed in this paper is not to be interpreted as a replacement for permanently installed battery monitoring systems nor offers observation of the data in the real time.

Acknowledgement

The author thanks Jose Marrero for the inspiration to undertake this work which ultimately led to a new approach to battery monitoring equipment devices for battery discharge tests.