Making a Case for Quadrant Battery Monitoring

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Abstract
Over the past 20 years VRLA batteries have grown to become the staple of data center critical power backup systems around the world. Over the course of that time monitoring technologies have developed and become ever more sophisticated in order to allow users of critical VRLA systems some insight in to their state of health. While it is generally accepted that continuous monitoring of lead acid batteries is prudent, unfortunately the cost of such technology, to this day, remains at a point where it can be cost prohibitive.

This paper explores an alternative technique of permanent battery monitoring which gives users all of the insight they need at a much-reduced cost.

Introduction
Even before, but particularly since the advent of the general use of valve regulated lead acid (VRLA) battery 20 years ago, battery monitoring has struggled to come of age within the data center industry. For years, discussions on whether ohmic value was a fair or even relevant indicator of battery health began and continued to be debated.

About 10 years ago, after the lifespan of approximately two generations of VRLA batteries, those debates have now largely subsided in to general acceptance that, although ohmic value may not tell you everything you need to know under every circumstance, it does indeed make a large contribution to putting together a more complete picture of a battery's health and condition.

Despite this initial struggle, the battery monitoring industry has grown slowly but steadily and there are now a plethora of hardware systems for the data center operator to choose from. Battery monitoring technologies vary from single unit systems with wires to each multi-cell unit to multi-unit systems which have a dedicated monitoring module for each multi-cell unit. Some technologies use fiber optics to communicate while others have moved in to the world of wireless technology to communicate.

Regardless of the diversification in these technologies, the common denominator in every case is twofold:

Firstly, all of these solutions strive to get as much data as possible from each individual multi-cell unit in a system. This data is then compared once to a simple limit level. In most cases these individual alarm limits are required to be set by the user and it is then up to the user to respond to those alarms when triggered. This can be quite a daunting task. For example, if you compare the purchase of a battery monitoring system to the purchase of an automobile then this equates to buying a vehicle which you then need to painstakingly set your own alarm limits for water temperature, oil pressure, transmission temperature, alternator voltage, tire pressure, fuel warning levels, oil change etc.

The other problem with this is that much of the value of any of these systems is not being fully realized. The data is being gathered, compared to a limit and then (although most probably stored) it is rarely used again.

The second common denominator with these technologies is cost. Despite advances, it appears that whatever the technique used, permanent battery monitoring hardware manufacturers have hit a glass ceiling which makes the ROI on a battery system very difficult to justify. In order to get payback for the typical outlay for such systems, usually requires the use of the hardware over several battery lifetimes. This means that most clients that purchase fixed monitoring systems are usually the larger of data center operators in the marketplace and this appears to have remained fairly consistent since the introduction of VRLA batteries due to the cost of the initial outlay very often being too prohibitive for the small to medium size data center operator.

This price hurdle has meant that the growth of fixed monitoring systems within the data center industry has effectively been riding on the wave of new data center build outs rather than increasing in use across the industry as it should be.

The practical use of data

The user is typically not benefitting adequately from the data, if it is even looked at. Additionally, few data center users have enough data to form a big enough picture and even fewer have the resources to devote the time to collating large amounts of battery data to create a bigger picture, even if they do have many batteries. This historical data is a hugely valuable resource which can help, not only the user, but the entire industry see new disruptive patterns which help make new strides for everyone.

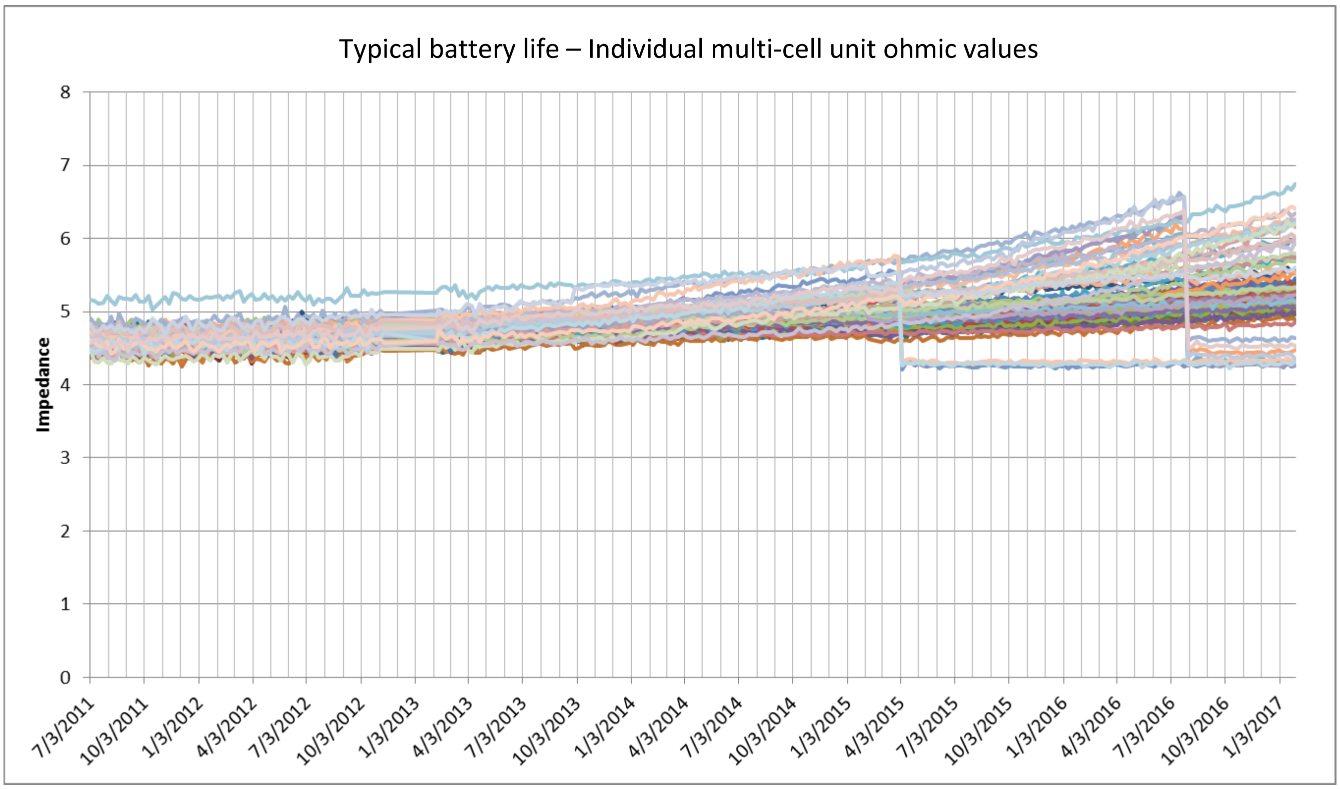

Figure 1. The typical quantity of data of individual multi-cell unit's ohmic values within a string over its life.

The author is in the unique position of being able to examine battery data from all manner of monitoring hardware manufacturers, over all manner of battery types over multiple years of battery lives. This has allowed the author to make some new and interesting observations.

Most UPS charging systems constantly float charge their batteries once they have established their charged capacity. With constant voltage charging, while the voltage of individual multi-cell units may fluctuate within a string, the overall total string voltage will remain exactly the same.

One such observation that has been made is that with all the various technologies used for permanently monitoring batteries seen so far, the same is true of the total ohmic measurement of the string. While individual ohmic values may fluctuate, the overall ohmic value will remain constant. The notable exception to this fact is that, over time, the total ohmic value will gradually increase over the lifetime of the battery string.

Through working with real battery data and determining that, although initially non-intuitive, adding together multiple ohmic readings across a string resulted in more repeatable and consistent readings, the author next moved to see whether this phenomena could be used to accurately determine one suspect multi-cell unit in a string using a much reduced hardware platform.

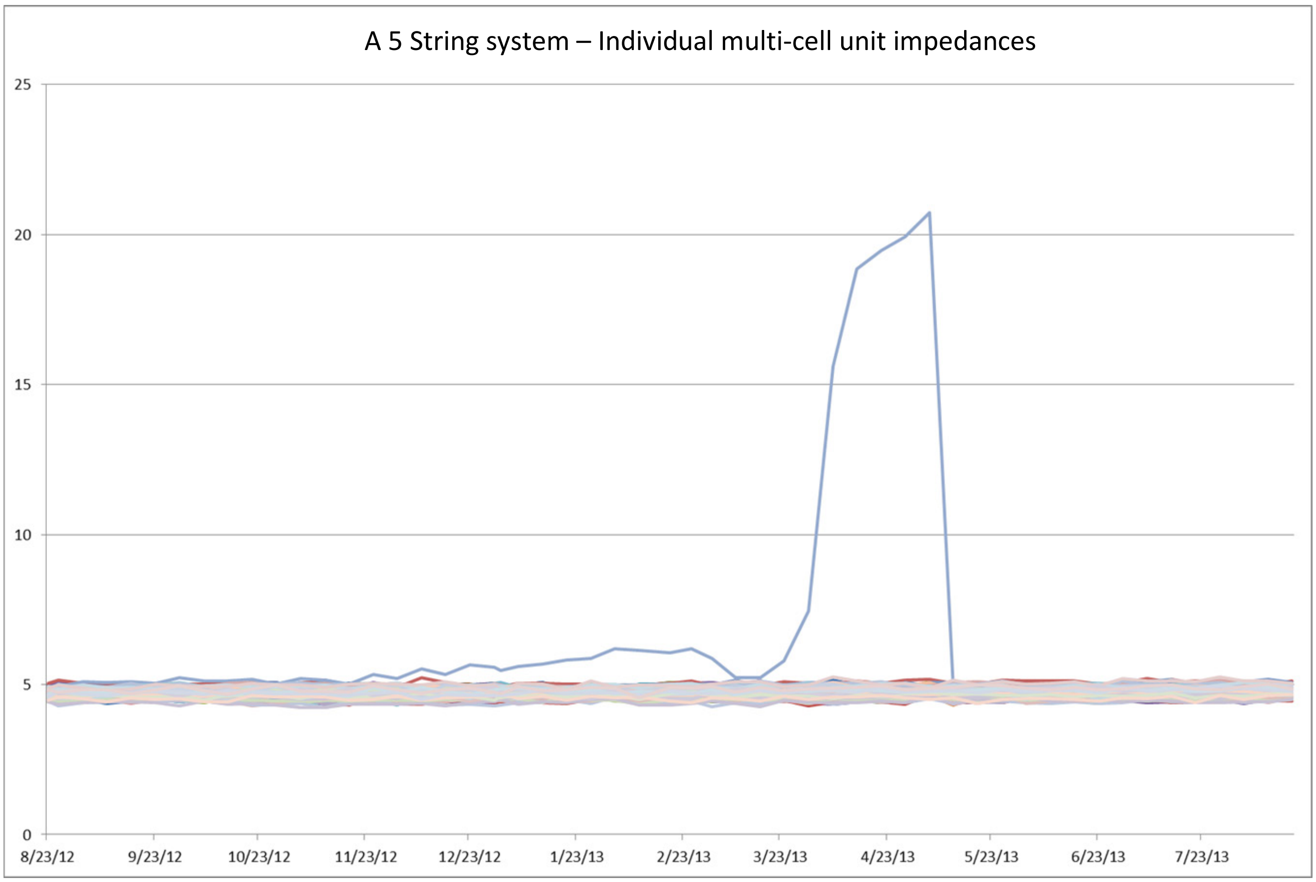

Figure 2. One multi-cell unit failing within an entire battery system.

Dividing this data up in to individual string we wanted to see if we could determine which string the failing multi-cell unit was in.

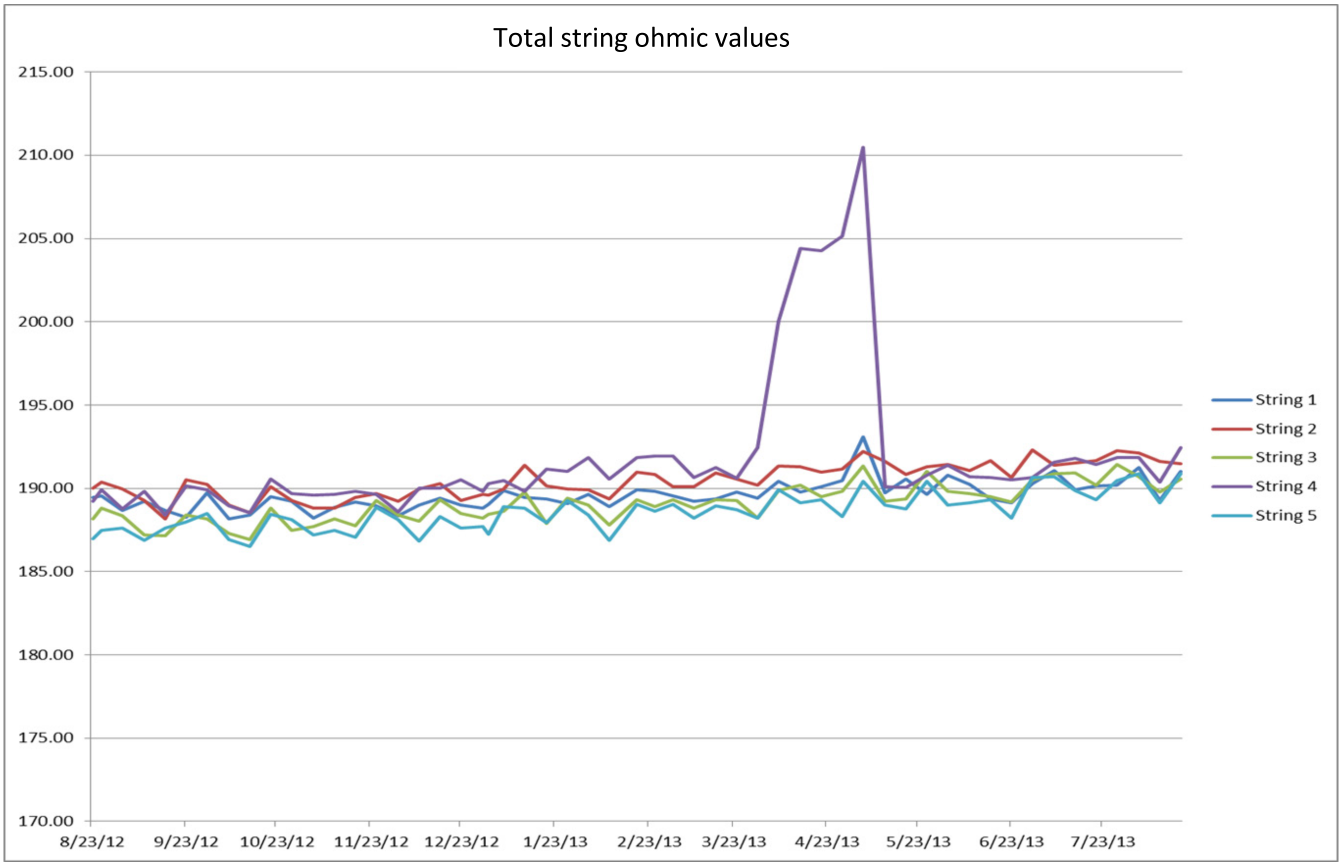

Figure 3. The failing unit is in string 4.

Once it was determined that we could detect one failing multi-cell unit in a string, we had to ask whether this would be sufficient for the data center operator. Constantly in touch with end users on a daily basis, we already knew how procedures are typically handled in the real world, namely:

How a site procedure typically works with a remote monitoring service and an individual multi-cell unit monitoring system:

1. A specific multi-cell unit flagged as a failing
2. A service company called out
3. String is taken off line
4. The service company checks all cells/multi-cell units in the string
5. The service company replaces bad cells/multi-cell units found

It was determined that string or string segment monitoring would work in a very similar way.

How a site procedure works with string or string segment monitoring:

1. Problem with a string or segment is flagged
2. A service company called out
3. String is taken off line
4. The service company checks all cells/multi-cell units in the string
5. The service company replaces bad cells/multi-cell units found

Practical considerations

Once it was established that the platform would give the user the information needed and it would fit within the normal operating parameters of a data center, there were then a number of practical considerations in attempting to do this.

- Battery disconnect formats – Many, if not most strings are broken up by breakers in to smaller safer sections. The device must not "span" these breaks.
- Safe working limits of any hardware fixed to the battery string – The higher the voltage the more safety considerations and the more power to be dissipated.
- Cost – The resultant hardware platform had to be significantly lower than what was currently available.

Several hardware formats were considered and eventually dividing a string in to four parts was considered to be the most practical. We knew full string monitoring could detect a failing multi-cell unit but having considered the practical aspects we had to then go back to the data and run further simulations to determine if the four section format would also work satisfactorily.

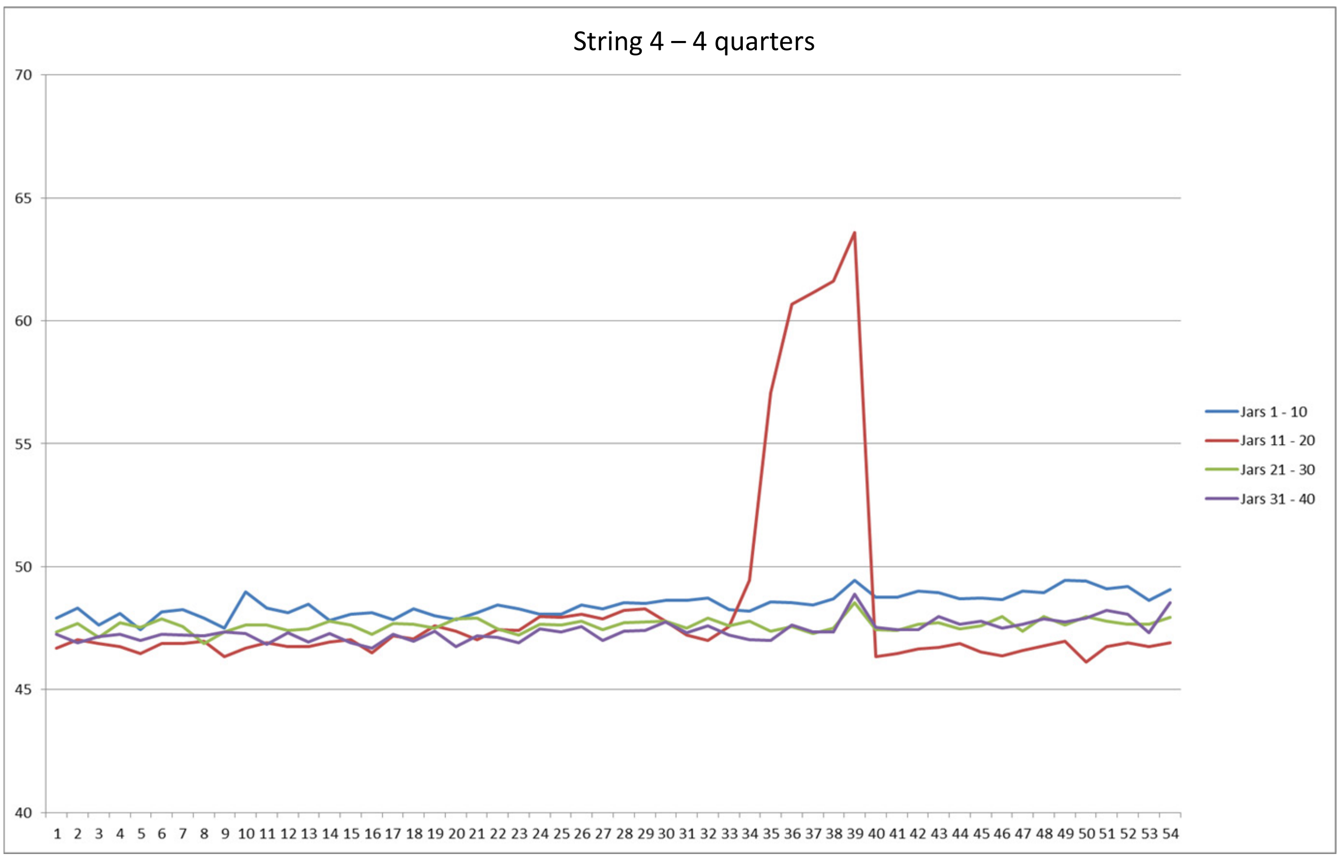

Figure 4. The same failing multi-cell unit is between unit 11 and unit 20.

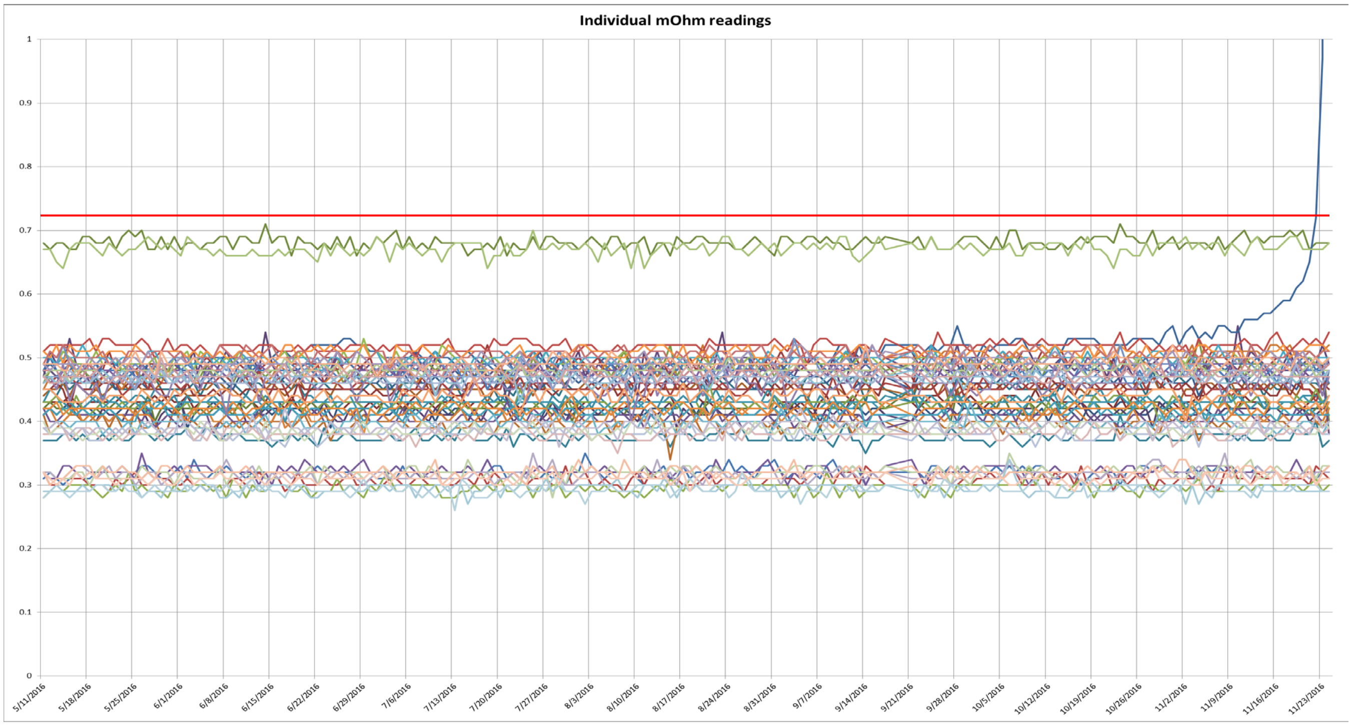

Figure 5. Individual unit ohmic readings, typical overall alarm limit and a typical failing cell (in blue)

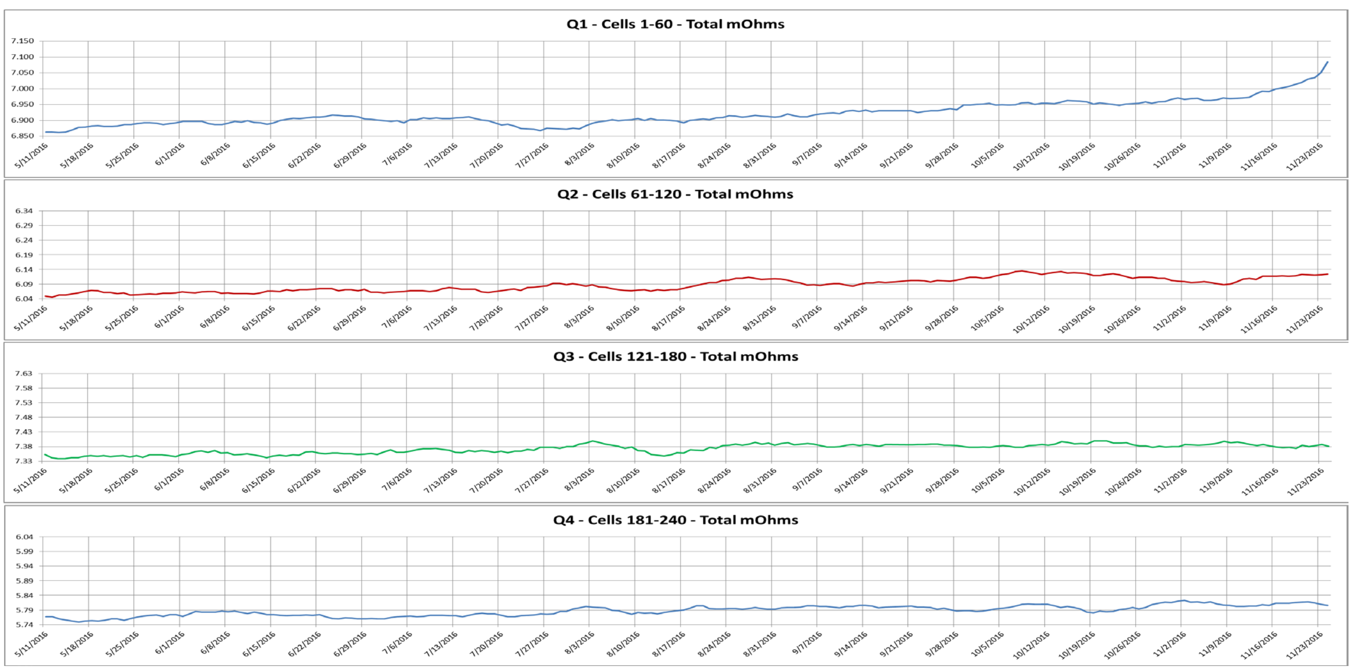

Figure 6. Identical data as previous graph but with ohmic values summated in to quadrants.

A number of things can be noted from the summated data:

- The ohmic readings are more repeatable than with individual cells/multi-cell unit ohmic readings.
- Although very difficult to see with individual monitoring, a very gradual increase in each of the four quadrants can be seen over time. This common increase is the actual aging of the cells within the battery string over time.

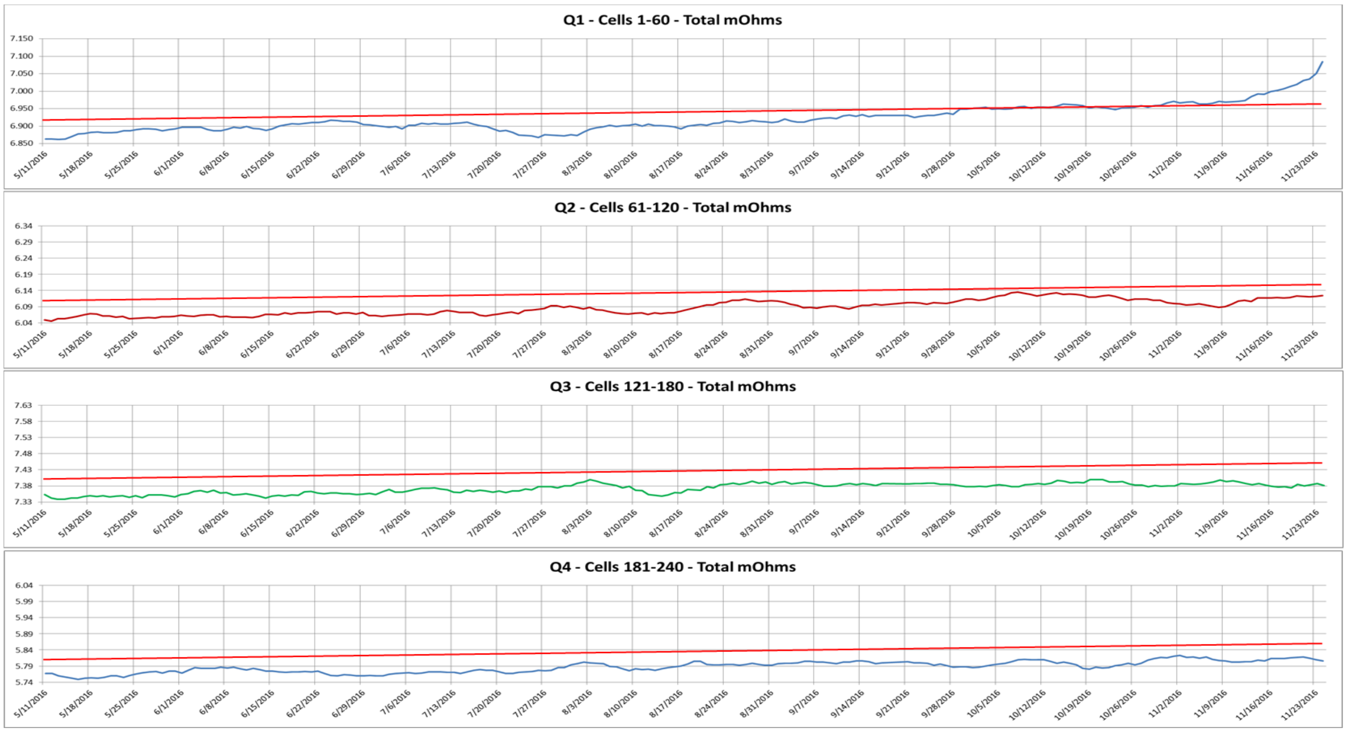

Figure 7. The dynamic alarm settings breached on Oct 1st in quadrant 1 (Q1 - where failing cell is situated).

Conclusion

String segment monitoring offers what users need with a much reduced hardware platform and much reduced cost, however, there are some important points to be considered:

- Despite the hardware being simpler, alarm limit setting is complex.
- Alarms limits must be set for each quadrant and some limits must be dynamic.
- All alarm limits must be reset after each spot replacement.
- The condition of the battery system must be clarified before string segment monitoring is deployed on it.
- This technology is currently limited to battery systems which are float charged in a constant voltage environment.