BATTERY MAINTENANCE AND MONITORING – WHAT'S REAL AND WHAT'S NOT? (MORE RELIABILITY FOR THE DOLLAR?)

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ABSTRACT

A more direct title for this paper might be: Lead Acid Battery System Reliability - What can benefit the user most and why? Is it Maintenance? Monitoring? Both? Or Neither?

Battery System Reliability is our discussion topic. A reliable battery system is tantamount to a reliable power plant, which is tantamount to a reliable communications network. This paper presents opinions and perspective from a *telecommunications battery user* on the feasibility of achieving reliable lead acid battery systems for Telecom applications – by using maintenance and monitoring techniques. The discussion includes some of the promised benefits of maintenance and monitoring, some basic difficulties, some farther-reaching less tangible issues, and some possible solutions. Attention is also given to the practicality to implement each method and approach. The paper concludes by addressing the original precept.

FOREWORD

Battery System Reliability:

- Can we *guarantee* at all times, the rated performance of the battery system, throughout its full design life?
- More specifically, can we guarantee the rated performance of the battery system throughout its field service life?

No, we cannot! There simply isn't any known or perfected means to *guarantee* your battery system's performance and reliability. But isn't guaranteed performance of the battery system exactly what the user needs? Yes – Absolutely! What then? How do we live with the reality of battery performance uncertainties and pending battery system failures?

To begin, let's recall and restate the fundamental precept*: Even with the highest quality manufactured lead acid battery products, there is no single operation or combination of operations including both maintenance and monitoring (separately or together) that will absolutely guarantee battery system performance.* Moreover, the idea of purchasing the lowest $ cost, low quality battery products, will ultimately serve to decrease power system reliability and network reliability. With that said, what then can the *telecommunications battery user* expect to gain and accomplish from:

- Applied manual maintenance of the Lead Acid Battery plant.
- Automatic remote monitoring of the Lead Acid Battery plant.

What viable choices does the user have, given time constraints, insufficient manpower and reduced budget resources, which altogether serve to impede or prevent the full implementation of maintenance and monitoring programs? Even by looking past these resource constraints, is there a practical and achievable means, for user directed battery maintenance and battery monitoring to achieve the desired levels of battery performance? If yes, then how do we get there? If no, then why not?

BACKGROUND: TELECOM BATTERY SYSTEMS

How is the lead acid battery provisioned and applied in the Telecom environment? The Telecom environment relies on standby energy storage systems in the form of lead acid batteries, to make 24 & 48 Volt backup DC power. These systems are connected in parallel with the telecom equipment load(s) making them "always online". But when are they actually used? They are used 100% of the time while connected. Under normal conditions, the battery plant is in standby (secondary), while the prime power source (commercial AC) provides electrical energy to the Telecom DC Power plant. The DC power plant in combination with the battery provides and distributes conditioned DC power to operate the telecom equipment. In this standby operation, the battery plant does not discharge its DC energy, but filters the rectifier output, and maintains itself at a fully charged condition by consuming a very small amount of DC current (trickle charge).

What about abnormal operating conditions? The battery may discharge (provide power) during momentary interruptions to normal power, or for extended periods of time during either planned or unplanned AC power failures. When the prime power source is severed or when interruptions to the flow of rectified DC power occur, the lead acid battery plant instantaneously becomes the prime power source for the communications equipment load. The battery allows no interruption of power to the load. How long will the battery run the office? The user's battery reserve (backup time) usually ranges between 2 – 8 hours and is user specified in accordance with the specific needs of the communications facility.

Lead Acid Battery Types & Classifications:

1. VLA or Vented Lead Acid (commonly called wet or flooded batteries)
2. VRLA or Valve Regulated Lead Acid (commonly called AGM, Gel, or Sealed)

VLA Battery:

The vented lead acid battery has a proven 20-year service life. In a typical telecom office standby battery plant, by operating the VLA battery in a 65 – 80 Degree Fahrenheit ventilated environment, application of proper float charging, occasional cycling (with equalize charging used only when poor battery charge state conditions dictate), and proper routine maintenance care, basically insures the VLA battery will deliver its rated capacity throughout its service life (20 years +). Note: The VLA telecom battery is usually rectangular, is full of electrolyte (water and sulfuric acid), and must stand upright with terminal posts on top of the battery. Each 2V Battery Cell can range in capacity from 100 Amp Hours to 6000 Amp Hours.

How does this battery respond to maintenance? Without question the trained user / maintainer of the VLA battery will get useful feedback through routine inspections and maintenance. And because the VLA battery has a long service life, good stability (with low cycling), and because signs of decay are relatively easy to spot during routine inspections and maintenance, the author does not see many advantages gained by *monitoring* these battery systems (with the possible exception of obtaining and recording data on the number, frequency and duration of battery discharges, which can be used for capacity calculations).

> *Perspective: Prior to the introduction of Telecom VLRA battery systems approximately seventeen years ago, there was little or no thought given to automatic lead acid battery monitoring.*

VRLA Battery:

The second battery type is the Valve Regulated Lead Acid battery. The principal advantages that this battery offers are greater energy density (smaller physical footprint) and flexibility in placement of the battery. It can be made to fit almost anywhere and will mount in several different physical orientations. This battery is routinely deployed into large central offices, remote central offices, closets, relay racks, vaults, cabinets, etc.

> *Example - Comparison of Energy Density: The classic configuration of a two row, two tier high, two string lineup of 48V VLA battery systems totaling to 8,000 Ampere-Hours, can be replaced with eight strings of 1500 Ampere-Hour VRLA battery systems, virtually occupying the same footprint and totaling to 14,000 Ampere-Hours.*

Rather than expelling and venting gases freely during the electrochemical reaction process like the VLA, this battery normally recombines gases internally (without venting) back into electrolyte. The battery is either an AGM (absorbed glass mat) or Gel Cell (gelled electrolyte), which describe two different means for capturing / holding the electrolyte within the cell. Most of telecom VRLA batteries in use today in the U.S. use the AGM technology. Unlike the VLA battery, which contains plenty of water and electrolyte, the AGM cells have been aptly characterized as a *starved electrolyte lead acid cell.* The battery is completely without excess liquid, and has just enough electrolytes to provide the full rated plate capacity – at the time that the plates are fully formed and charged (which for some batteries may not be realized until 6 –12 months after being placed into service). The battery is labeled and often thought of as a sealed battery, although the battery does expel gases through a pressure relief valve – that opens allowing pressurized gases to escape when necessary. The main problem for this VRLA battery is the imperfect internal gas recombination. This results in hydrogen gas emissions out of the battery, which slowly decreases the level of electrolyte inside the battery. This loss of gas (and water) known as "dry out", contributes to early cell capacity failures and is considered the primary determinant for its shortened service life.

The VRLA battery is typically deployed into two environments – controlled and non-controlled. The controlled environment is a normalized temperature and ventilated environment (i.e. like a central office), while the non-controlled environment has little or no environmental controls (i.e. temperature, humidity & ventilation). A typical non-controlled environment application is the remote terminal outdoor telecommunications cabinet, which houses the telecommunications service equipment and also the VRLA battery systems.

What type of performance can be expected from the VRLA battery in each environment? According to industry statistics, which have often been presented at forums like this one, the "20 year design" VRLA *battery system* operating in a controlled temperature environment has not yet demonstrated that it can hold capacity and provide reliable performance - after 4-7 years of field service. In the non-controlled environment, things are much worse. The battery may see ambient temperatures ranging from 20 F – 140 F. The battery "lives" in these volatile temperature environments (typically in a cabinet) and is typically subjected to extreme high temperatures for extended periods of time (very common in southern regions of the U.S. - like this area for example). And not surprisingly, these conditions will dramatically reduce the battery life and performance. The battery cannot provide long-term reliable performance and often fails suddenly and/or very early during its projected service life. Worse yet, the battery system may become thermally unstable, and fail catastrophically in thermal runaway. The life expectancy of VRLA batteries deployed into the non-controlled - outside plant cabinet environment, averages (all regions of the U.S.) 1.5 - 3 years according to my own experience and findings.

How well does this battery respond to maintenance? This battery is often marketed and sold as a Maintenance Free product, but is more accurately described as "Maintenance Resistant". I say this because the battery does not consistently indicate useable information during non-intrusive maintenance and testing procedures. Maintaining this battery generally amounts to taking measurements. There is really no means of correcting deficiencies through normal maintenance and testing (with a possible exception for retrofitting a cell with catalyst and water additions – which is intrusive, specialized, and beyond "maintenance procedures"). Non-intrusive measurements and maintenance testing can certainly provide some indicators that may point to rapidly declining battery health or indicate emergency conditions (i.e. thermal instability). However, it is generally quite challenging to ascertain the battery system's current state of health and predict it's remaining life using common maintenance techniques. Quite simply, the measured indicators do not always accurately correlate to the battery's internal cell conditions and state of health. The measurements can often misleads the user to make erroneous conclusions – and may soon result in unexpected "early" battery failures. Moreover, the available tools and test equipment require skilled and very experienced personnel to test and interpret each piece of measured data, understand and account for errors involved in testing, and then make informed judgments on the battery's state of health.

Note: Ranging in capacity from 5 AH to 2000 AH per cell, the VRLA battery cell capacity is more limited than it's VLA cousin, but greater flexibility in deployment configurations more than compensates. The VRLA battery is often designed to house multiple cells in one container, making typical battery unit /module voltages of 2V, 6V, 12V or 16VDC.

Telecom Battery Summary:

The vented lead acid (VLA) battery is a large capacity, wet (water and acid) battery, mounted upright on a battery stand. It typically provides a long reliable service life (20 years) if deployed, operated, and looked after appropriately. This amounts to not much other than housing the battery in a temperate and properly ventilated environment, operating the battery at the manufacturer specified charge voltage, and performing routine maintenance. By comparison, the VRLA battery offers greater energy in a smaller footprint, and will mount in a variety of rack and stack configurations making deployment into very smaller spaces practical. The flexibility and increased energy density is of great value to the user. But unfortunately the VRLA battery does not respond consistently to maintenance, and exhibits a very short service life (typically under 7 years), which sometimes ends abruptly and without warning in a catastrophic failure. If these characterizations of short service life and unreliable VRLA performance are representative of what the Telecom users has repeatedly experienced, then it should be plain to all (users and suppliers) that this battery is not yet providing the basic reliability the telecom industry must have.

BATTERY MAINTENANCE:

Whenever we discuss battery maintenance the first items of concern for the user are typically the time requirements and skill elements needed to perform battery maintenance. With Telecom resource reductions, today's company field technicians are over burdened keeping revenue producing network systems operating and subscribers in service. The technicians don't seem to have the time or take the time to perform preventive battery maintenance and test routines, much less analyze, trend, interpret and make decisions on what to do with the resulting measured data. Even with proactive battery maintenance programs in place and time to carry them out, the field technicians are not battery experts. They need training, tooling, test equipment and work experience to become knowledgeable and effective in the safe handling, operating and maintaining of lead acid battery systems. Consequently, if the Telecom (in-house) technical forces cannot adequately maintain its network battery systems, one alternative for Telecomm is to outsource their battery maintenance to organizations that specialize. But outsourcing to specialists means high $ costs to hire skilled (qualified and certified) contractors for maintenance and testing the battery plants. These $ costs may lead the Telecom to back away from this level of $ expenditure – especially when the return on investment is not easily visible to managers and decision makers who are managing insufficient budget allocations.

An opposite approach is for some users that believe the investment into maintenance is fruitless since no matter how much labor is expended; the VRLA battery tends to fail even with predictive data that is suggesting otherwise. These users perform minimal maintenance and feel that this approach is no less effective or leaves them no more exposed than with more intensive and costly maintenance programs.

Why Maintenance?

After reading the discussion above on VRLA, why consider battery maintenance? The primary goal for repetitive maintenance is to ensure that battery system operating levels and conditions remain optimal. Frequent visual checks, online & offline measurements, tests, component adjustments, cleanings, should all be completed periodically to ensure that operating levels stay within the prescribed normal range and that a safe operating environment is maintained. Performance measurement and test results should be recorded and tabulated for reference, data trending and analysis. This trended data provides history, reference, and assists the user in the prediction of the remaining service life of the battery system.

What are the benefits of frequent maintenance? Battery plant maintenance is used to help ensure that normal system operation continues without interruption. When maintenance is performed correctly and consistently, the data gathered during quarterly and annual routines will provide the user with the information required to make informed judgments on the battery plant condition, and predict remaining service life. Note: Using a quarterly maintenance interval should allow engineering and surveillance personnel to stay up to date on operating levels and conditions of the plant.

What is the impact of performing maintenance infrequently? If maintenance is performed less frequently and inconsistently, the user will have much less information available with which to assess the current plant conditions and remaining service life. Moreover, with long intervals between maintenance visits, the battery system may become unstable and / or fail without warning.

What is the impact if maintenance on the Battery plant is not performed at all? The short-term result might be the user believes he has avoided expense and saved dollars. In the longer term, the battery system or one or more of its subsystem(s) will ultimately fail unexpectedly, and the user will likely suffer an outage. Depending on the mechanism and severity of the battery system failure, several consequences may result:

(a) Hazardous power room conditions which can often result in personnel injury
(b) Fire or explosion
(c) Communication network outage
(d) Noxious gases may coat and damage or destroy network electronics
(e) Loss of subscribers and/or business

> *Perspective: Following any network outage or near outage brought about by power system failure, the affected organization will typically have an immediate change of heart, and determine that intensive maintenance is justified and needed after all.*

Maintenance Costs:

The resources needed and dollar costs associated with performing frequent maintenance routines can be substantial. The figures below pertain to quarterly and annual maintenance routines at two types of communication offices – small-unmanned sites (i.e. 600 Amp power plant) and large manned sites (i.e. 10,000 Amp power plant).

The labor cost expenditures per year per power plant are summarized in the table below:

Maintenance Requirement	Small Sites	Large Sites
Man Hour’s Per Year	25-35	65-75
Annual Cost Per Site	$2,000	$6,000

Note: These hours and costs do not include logging, tracking, reviewing / analyzing the maintenance data that is collected, which requires additional man-hours and is normally completed by surveillance and/or engineering personnel.

The following table displays an estimate of a medium sized communication company and its $ costs resulting from a power plant failure (and network outage).

Projected Outage Costs At Switch Site

DC Power System Failure	**1 Hour**	**6 Hours**	**12 Hours**	**24 Hours**	**7 Days**
Outage Revenue Loss	$115,200	$691,200	$1,382,400	$2,764,800	$19,353,600
Power Plant Repair & Repl. (@$500/Amp)	$750,000	$750,000	$750,000	$750,000	$750,000
Company & Contract Labor $$	$3,360	$3,360	$3,360	$6,720	$47,040
Total	**$868,560**	**$1,444,560**	**$2,135,760**	**$3,521,520**	**$20,150,640**
Battery Thermal Runaway	**1 Hour**	**6 Hours**	**12 Hours**	**24 Hours**	**7 Days**
Switch Damage	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000
Office Damage	$500,000	$500,000	$500,000	$500,000	$500,000
Total	**$2,500,000**	**$2,500,000**	**$2,500,000**	**$2,500,000**	**$2,500,000**
Total Outage Costs	**$3,368,560**	**$3,944,560**	**$4,635,760**	**$6,021,520**	**$22,650,640**

These costs represent a power failure and network outage at ONE switch site as compared against the annual $ cost of a maintenance program applied to 100 switch sites in the network. At $600,000 per year for the total annual switch site battery maintenance commitment, this table indicates during a typical busy hour loss of revenue, that much greater $ costs are incurred in a Single Office outage – which has occurred due to the lack of power system and or battery maintenance.

More Economics for Maintenance:

The maintenance & testing routines will rely upon a technician's availability and ability to reach (all) the locations requiring service. The telephone technician routinely visits the Cabinet or Site to perform service and routines on telecommunications equipment. This provides a regular and periodic opportunity to perform battery system maintenance during these visits. These regular or periodic visits take away the need to make a special trip dedicated only for battery maintenance. Hence, the economics of travel and time are minimized while the battery routine itself is normally very brief.

Is Maintenance Enough?

It is this author's opinion that manual maintenance performed at optimal intervals can suffice. If Telco company personnel perform the maintenance; these site personnel will have a greater sense of awareness and responsibility for the power plant. This is the best possible situation although quite difficult to achieve.

BATTERY MONITORING

When considering a battery monitoring system, we must determine / examine some basic items: the $ cost, features &inputs; the physical size and mechanical connections at the battery and at the device terminals, the overall system interface and Telco network communication channel requirements to access and retrieve the monitored information at both local and remote station, and most important of all is dedicating the resources (trained personnel) in the Telco - to manage, read, interpret and act on any data presented by the monitoring system(s) to local or remote surveillance personnel. Oh yeah, there is one other important thing that must be considered. The monitoring system's job is to obtain and present data for analysis and trending, which leads to indications of system performance (past, present, and predictive). However, what the monitoring system cannot do is to replace on site maintenance. The monitoring system does not "see" or detect terminal and post corrosion, acid leakage, conductive acid traces and paths leading to ground shorts, case ruptures and cracks, plate shedding, discoloration, heat buildups, high resistance connection problems, thermal runaways, etc. Most or all of these manually correctable potential points of failure can only be discerned and detected by visual inspections and/or hands on maintenance / testing.

What Monitors Can and Cannot Do:

What the automatic monitor **can do** is measure many different parameters, record events, generate alarms, store history, etc., and present this information locally and remotely to the user for interpreting, trending, etc. The system can automatically provide and store a large percentage of the performance measurements and test data that are obtained manually during routine maintenance visits.

What the automatic monitoring system **cannot do** is really the crux of the whole issue. Power plants normally live and operate in a temperature-controlled environment. They have components that heat and cool, motors and fans operating, mechanical and electrical energy conversion devices, electronics, electrochemical systems, mechanically actuated devices, electrically actuated devices, etc. These systems are susceptible to environmental factors (dirt, dust, temperature, humidity, etc.), normal aging, and can easily become unstable due to these and other unforeseen reasons. The monitor does not detect and tighten loose connections. The monitor cannot detect leaking battery cells with battery acid that is beginning to create a conductive acid circuit path to ground. The monitor cannot detect the corroding of connections that may cause high resistance and a fire hazard. The monitor cannot visually inspect the battery nor can it “easily” take specific gravity readings. The monitor cannot perform visual inspections for discoloration, corrosion; jar cracks, leakage, noise, vibration, and grounding. The monitor cannot disassemble and remove blocked air paths, replace fans, or capacitors, or scan and detect hot connections at fuses and circuit breakers. The monitor does not detect the erosion of concrete or overloading of raised floor and overhead structures. The monitor does not detect the ingress of water or moisture or the leakage of water or fluids from overhead mechanical systems. The monitor does not detect ground faults (normally) nor does the monitor detect vibrations and deteriorating connections. The monitor does not test for and detect battery cell capacity. The monitor wiring connected to each battery cell may become difficult to manage and may become damaged or broken after 3-4 battery maintenance routines. The monitor does not disassemble battery straps, clean connections, and reassemble and tighten hardware. The monitor may not be protected against surge currents and could be susceptible to electrical damage.

I do think that some monitoring devices can probably detect some of these conditions I have listed. However those functions that the monitor cannot perform, merely point out that visual inspections, assembly / disassembly, cleanings, component replacements, mechanical issues associated with the environment, and several tests requiring hand held instruments are all beyond the practical limits of a monitoring device. All of these things must be attended to by on site visits and manual completion of these routine maintenance tasks.

Monitoring Costs and Other Considerations: Other considerations include the additional physical footprint and mounting space required for the monitoring hardware; the added system complexity due to wiring and component connections; the potential for wiring and monitoring equipment failure (which may also impact reliable operation of the power plant), accuracy of measurements (i.e. float current), considerations for maintenance of the monitoring equipment itself; the dollar cost of monitoring equipment; dedicated communication facilities for reporting the monitored information, and the resources and number of skilled / trained personnel for receiving, interpreting, and analyzing the reported information.

The costs of monitoring are not easily understood nor calculated until all of the pieces needed for the system are in place and looked at as a whole. This includes hardware, system software, transport facilities, and surveillance personnel (equipped with terminals at the remote location). Other costs will be expended for computer personnel to manage & support the system database and data warehousing and computer platforms on which this system resides. Note: the average installed costs for the basic hardware (monitor) can range from $2,500 - $8,000 per power plant.

Summary

Lets return again to the basic question: What do we REALLY need to know about the battery? The best answer is that regardless of how data is gathered (through monitoring or maintenance) we need to watch the change in voltage over time (dv/dt) as in a battery discharge, the change in current over time (di/dt), and the temperature. These indicators can tell us about the cell capacity and we need cell capacity to know battery system health.

Will maintenance get this for us? Lets take another look. The three types of maintenance are preventive, reactive, and predictive. It is preventive and predictive maintenance that will help us the most. History tells us this works fairly well with VLA batteries, but can this be applied effectively to the VRLA battery system? Common techniques to use are ohmic testing; float current measurements, temperature readings, voltage readings, and maybe insulation breakdown and pressure testing to sense leaks and shorts. A more costly but reliable technique is to load capacity test the battery which normally involves offline testing– and definitely indicates the cell’s capacity. Will any or all of this get us the battery cell capacity and predictive information? YES – when load capacity testing is included. Without load capacity testing, non-intrusive maintenance may come very close, but unless the user is skilled and maintains and tests the battery often, analyzes, trends, and interprets the data, it may not fully reach our goal, which is to reliably indicate current states and predict future conditions.

Will monitoring get this for us? The devices promise this information to us, but can it be realized? To date, I have yet to see a cost effective device or system that is not over engineered and full of unneeded features, that is fully and readily integrable into the Telco environment, that functions as billed and delivers information over the communication channels to the right user. If such a system existed what would it be like*? It would be small, contain minimal features to measure dv/dt, di/dt, and temperature, minimize wiring connections, be designed as a completely wired system for ease of network integration, with* *statistical analysis and historical data trending, and be able to pass data over the designated communication channels to the end user remote device(s). Monitoring manufacturers need to work more closely with their Telecom customers to incorporate complete dial-up modem, IP Internet, and wireless or GPS based call-out communications packages with each system. Additionally, monitoring manufacturers seem to have insufficient interests in partnering with qualified contractors who can complete a quality and fully functioning Monitoring System installation.*

If all this can be done in a reliable and cost effective manner, then there are two additional and major hurdles:

(1) The Telco must have someone designated with the time and knowledge to receive and interpret the data.
(2) The monitor still cannot detect or "see" nor adjust what only the hands on maintenance forces can observe, find and correct or adjust.

Many users find it difficult to justify monitoring systems. They cite mechanical and system integration problems, device failures, or complex readings that cannot be easily understood or that are not repeatable or reliable. There are also the difficulties in assessing the tangible and intangible costs that might be avoided by installing monitoring systems versus the more fixed costs of routine and reactive maintenance procedures. With over designed and over-featured monitors that are too $ costly, instead of monitors equipped with only the features that are really needed, many users are paying little attention to monitoring systems.

CONCLUSIONS

More reliability for the Dollar? Will focused battery maintenance and / or monitoring program lead to high levels of reliability? Which program is most prudent and effective? Here is what we might conclude at this time:

- If VRLA and WET battery systems are manually maintained 3-4 times per year (including annual PM), then I would suggest there is not a clamoring need for automated battery monitoring. You will have completed all necessary maintenance and obtained the needed battery tests and measurements often enough to ascertain battery health and predict remaining life.
- Regardless of all else, the annual maintenance routine on each DC power plant & battery system will always be needed. This is necessary *with or without* an automated monitoring system.
- Automatic monitoring is often marketed as though it will replace and eliminate the need for manual power system maintenance. It should be clear that automated monitoring alone could not be sufficient. Monitoring does not eliminate preventive and corrective maintenance. Monitoring Systems, when properly designed and installed, allow for maintenance activities to be alarmed, pinpointed and more focused, not merely neglected as is often the case in "mandatory cost-reductions".

  Question: What is the first reaction after receiving out of range data from the monitoring system?
  Answer: Dispatch maintenance technicians to the site to verify the monitor's findings and assess damage or what steps are required next.

- The primary advantage gained with monitoring is having plant information at all times. The primary disadvantage is the equipment cost, complexity, and the manpower required to read, monitor, and analyze.
- There is no clear-cut choice for relying on *manual maintenance* alone versus choosing both *manual maintenance plus automatic monitoring*. Costs must be understood, but in the end, system reliability is the deciding issue. Reliance on nothing more than annual maintenance alone will decrease system reliability and unplanned outages will certainly result. Reliance on a quarterly maintenance program plus annual maintenance will increase reliability and will reduce the risk of system failure(s). This may also provide sufficient plant information to anticipate, plan and install equipment.
- Choosing to deploy both an automatic monitoring system and performing annual maintenance routines will require additional resources. Using this dual plan suggests an increase in network reliability, gained by providing surveillance personnel with up to date plant information at all times, and also providing engineering with the needed information for proactive engineering and planning.
- When effectively designed and deployed, automatic monitoring and manual maintenance together are tools that should help network reliability, and could be attractive to companies focused on reducing operations / maintenance personnel to "trim budgets".

Can we fully achieve our previously stated goals?

- Know the condition (capacity) of the battery at any given time, and
- Obtain predictive information on the remaining service life of the battery?
- Insure the desired performance level and reliability?

As I have already stated, the investment into hands-on battery maintenance offers the most tangible feedback. The user is able to readily understand and immediately use the information obtained by manual testing. To gain this useable information, the investment can be costly and must be repeated frequently. I have also stated that onsite, hands on maintenance is always required at some frequency, and that without this, the risk is very great. The investment into Monitoring offers the opportunity to remotely collect and trend certain battery data, which looks very attractive on the surface. It suggests that plant capacity data can be available at your fingertips. And this might be realized, however, today the process can be overly complex, remote data collection and data parsing is difficult, understanding the data is complex, and Telco's have little or no dedicated resources in place to receive, interpret and act on this data. Moreover, when tabulating all the costs involved for owning, operating and maintaining a system, the monitoring device / system is very difficult to cost justify for the Telco.

Is guaranteed reliability possible? No, not really. We cannot really know the capacity of the battery at every given time. But with skilled analysis, we can use resulting data from maintenance and testing to gauge current conditions and trend future remaining life. Some may opt for a minimal approach to maintenance regardless of the network exposure or risk, *but for every Telecom user, the only reasonable answer lies in a user directed customized approach, which is designed and supported by the user to fit the user's specific variables, resources, economic constraints and specific performance and reliability requirements.*

CLOSE

I am certain that we all wanted clear-cut and direct answers. Unfortunately, there simply are no perfect solutions and no real guarantees for battery system reliability. But, gaining a clearer understanding of what is possible, practical and achievable, the user can make informed choices on how best to develop, implement and manage a customized, effective program for keeping battery systems at peak levels of performance and reliability - that fits within the user's available resources and budget allocations. I hope the paper has paved the way to provide that clearer understanding.