Battery Asset Management: VRLA ageing characteristics

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A lot of time and money is spent on the electrical and mechanical design of mission critical facilities. These facilities have very large and complex infrastructures. Redundancies designed and built into the facility infrastructure are important to maintain end-to-end reliability.

When we talk about end-to-end, this starts from the power company service entrance and ends with the computers and telecommunications systems located on the computer room floor. In between, we have all of the emergency power systems that include the service entrance/distribution switchgear, UPS complexes, generator sets, static switches, secondary power distribution, and power management modules. These systems are all there to serve the facilities' customers. These critical facilities can encompass hundreds of thousands of square feet of processing and communications space.

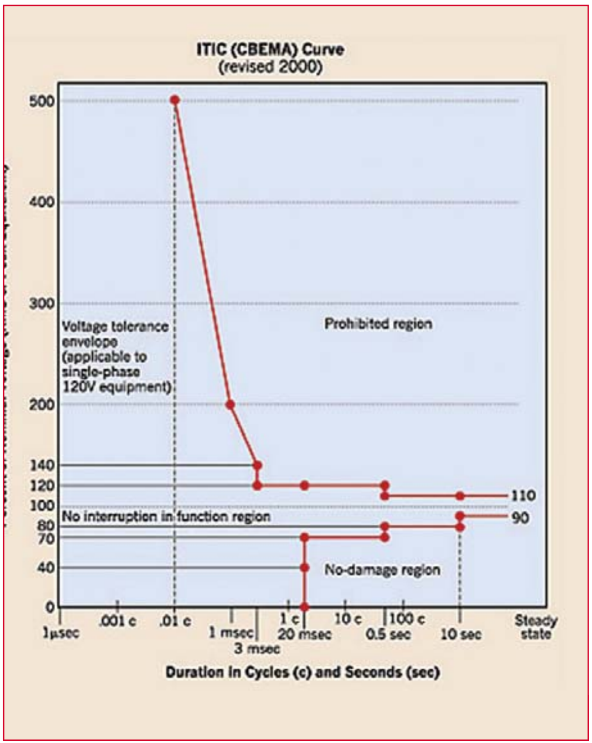
In order to keep this all humming, levels of redundancy are designed into the system to ensure that the communications and data processing are failsafe. A lot of time and money is spent to making sure that power is available at least 99.999 percent of the time to the equipment that needs it. In special and super critical situations, designs are contrived that will ensure availability to 99.9x percent. Some centres are designed as high as 99.9999999 percent or 9 – 9's. These designs result in many millions of dollars invested into this infrastructure.

Consider the following:

A centre that is built to 99.999 percent (5 – 9's) availability, means that power will be available all year except for about five minutes a year to mission critical equipment. In the case of 7 – 9's, power will be lost for about three seconds, and with 9 – 9's, we will lose about 30 milliseconds per year. All current computer and telecommunications equipment can withstand a loss of power up to 20 milliseconds before it goes down.

The following chart which addresses the 9's:

What this really means, is that at 3 – 9's of reliability designed into the facility, there would be 526 minutes of down time during one year. In the case of 9 – 9's, there would be 30 milliseconds of down time in one year. Below is the Information Technology Industry Council (ITIC) curve on computer power tolerance limits. Note that the total loss of power tolerance is 20 milliseconds.



THE BATTERY ASSET

In the process of managing end to end reliability in critical facilities, there is a very large battery asset that is often overlooked in these reliability designs. This battery asset is independent of the reliability calculations, which become meaningless if the battery asset integrity is compromised in any way.

The generators can start and be on line in as little as seven seconds, but 15 to 20 seconds is more typical. In addition, we not only have to get them started, and up to speed, but we have to transfer the load (i.e. the facility) reliably to generator power. Depending on the condition of the generators, and their control switchgear, it can take a few more seconds. And transferring to generator power from utility power, or during the transfer back to utility power after the outage is over, can represent a double whammy for each power interruption.

It should always be remembered that the complete integrity of the x – 9's centre is 100 percent dependent on the battery asset. All the energy required to keep things up and running during a power emergency starts with the battery. Even generators and switchgear use batteries to start, in addition to the hundreds and thousands of battery cells used by the UPS systems.

BATTERY ASSET LIFETIMES

This critical battery asset life is finite in nature, and must be managed economically and reliably. It can be worth millions of dollars that will be spent over time. Today, this asset can be VRLA batteries that typically last about five to ten years – depending on model and construction – before replacement, or vented lead acid, which typically lasts about 20 years. The dominant battery out there today in these critical applications is a five-year life VRLA. The reason for this is an economic one, because the short life VRLA is less expensive, usually requires less maintenance and doesn't present the environmental issues that the longer life VLA (or flooded type) battery does.

We are going to concentrate on this short life VRLA, as it is used in the majority of Mission Critical facilities in this discussion.

Data Power Monitoring Corporation has collected large amounts of battery data over the past decade. In our database, we have compiled over 20 million points of data based on performance of hundreds of thousands of VRLA batteries and it is constantly growing. We collect this data based on several battery monitoring equipment measurement parameters. This data is constantly analysed for failure mechanisms and trends.

A REAL LIFE EXAMPLE

As an example of a typical large UPS user, we apply principles learned from many years of observation and our large database of VRLA battery performance parameters. This typical large user was growing, and installing UPS systems in many large mission critical centres over a period of several years. After several years, the user ended up with a large battery asset that had to be closely managed. This was both for prediction of individual battery failures in order to maintain battery asset reliability and to predict end of life for the battery asset. UPS systems and their associated battery systems were diverse locations that had the typical problems associated with new construction and retrofit situations.

To illustrate the magnitude of this battery asset, if a VRLA battery unit was worth around $250, then the end user's asset was worth several million dollars. Working together, we collectively kept their systems reliable and smoothed out their asset replacement budgets. Rather than spending millions of dollars all at once, when the battery asset was at end of life, we helped to spread out these costs, and replace end of life battery systems.

THE NEW IEEE BATTERY MONITORING STANDARD - TRYING TO HIT A MOVING TARGET

After 10 years, the Institute of Electrical and Electronics Engineers (IEEE) is at the final stages of developing a new battery monitoring standard. While it is close to completion and involves the above measurement parameters that indicate battery failure and aging characteristics - not all are included here – there are presently 17 measurement parameters.

As the technology changes, we find new indicators of battery state of health, and aging mechanisms. Some of these include the following:

Common mode noise – Battery terminals (positive and negative) to earth ground. To date, we see little effect on aging, but this can affect monitoring accuracy, and is a safety issue.

Differential noise – This is caused by rectifier ripple, inverter feedback and other power electronics effects. It contains a very wide harmonic spectrum, and affects the battery aging process dependent on the noise level. We are in constant study of this factor. Its significance is not yet well understood.

Dynamic Noise – This is caused by small UPS input disturbances as small as 1 to 2 percent at the millisecond level. This phenomenon occurs frequently and will cause up to six to eight second light battery discharges. These are not picked up by PQ measuring instruments due to the level of disturbances being within computer tolerance (reference CBEMA, now ITIC curve as shown above).

There have been many studies over the years in the integrity of the national power supply that show these disturbances occurring at varying frequencies. They can cause rectifier electronics to become unbalanced in three-phase application which in turn, can cause shallow discharges to occur for 6 to 10 seconds in the battery system while the rectifier is correcting its internal imbalance.

SPECIFIC AGING FACTORS:

VOLTAGE

The amount of charging current provided to a group of batteries is determined by the ability of each individual battery to maintain a specified voltage level. Some batteries require more or less floating current that is an indication of its state of health.

As string charging current is dependent on the string voltage to be maintained, batteries present more or less resistance to this constant charging current. This change of resistance can affect individual battery voltage levels. High resistance batteries that need more charging current to maintain voltage levels, begin to exhibit dropping voltage trends over time.

Batteries that require less charging current would begin to exhibit rising voltage over time. This sometimes can be the battery drying out, such as loss of electrolyte that is finite in a VRLA. Both rising and dropping trends can be cause by a myriad of other things involved in its construction and chemistry.

In addition, these changing trends can reverse themselves, depending on what is going on inside the battery. The key is to remember is that charging current is based on a group of batteries, not individual battery requirements.

UNIT OHMIC HISTORY AND CHANGE RATES

As batteries age, internal ohmic values will rise over time. By frequent monitoring and trending of these values, aging can be seen as it occurs. This is for both individual batteries, and string average values. All batteries tend to age at different rates, depending on their environment, cycling, plus their physical, and chemical integrity.

As electrolyte volume decreases due to normal venting, electrolyte typically cannot be replaced in VRLAs, this affects both voltage and ohmic values. These changes allow for some mathematical projections as to when battery end of life will occur. It is well known that when batteries have increased ohmic values at about 25 percent of their initial or specified values, their performance capacity has decreased to about 80 percent.

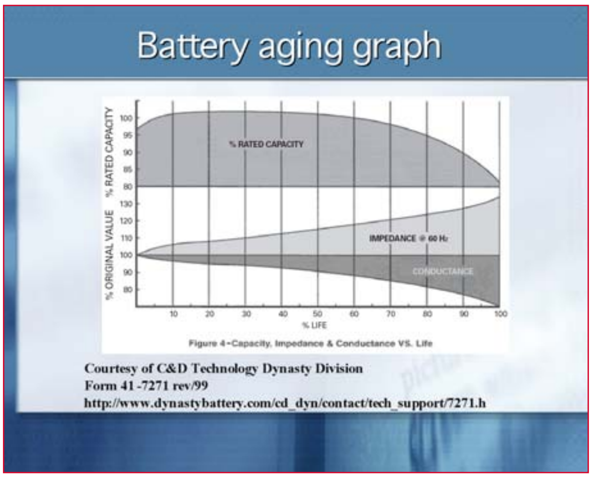
In IEEE recommended practices, the 80 percent capacity value represents a "non-performing", or a battery that is at end of life. This can vary somewhat with large scale VRLAs and vented batteries. Normally, this performance capacity is determined by means of documented discharge testing. When this testing is not performed on a regular basis, the ohmic value capacity determination is the next best thing.

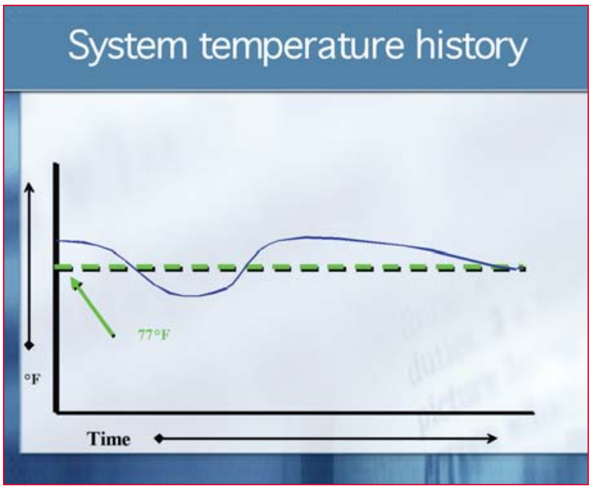
A particular standard that discusses and specifies the 80 percent capacity, and the 25 percent ohmic change is IEEE 1188, the VRLA maintenance standard. The 80 percent capacity is also used in load testing performance specifications, and calculations, to determine a non-performing battery.

Above (top right) is a graph showing ohmic values versus battery life:

SYSTEM TEMPERATURE HISTORY: 77 DEGREES F

All batteries perform at their best at this temperature and typically may run a couple of degrees less. As temperatures rise over 77F, battery life can decrease. With every 15 degrees F above 77 degrees F, battery life can be halved. This generally has to do with battery heating, accelerated deterioration, and excessive venting. Batteries can run under 77 degrees F and perhaps last longer, but capacity is reduced at the lower temperatures. Temperature control is a major factor in battery life.





The timeframe represented above would be about two years in a new construction UPS application. The temperature is for a group of batteries within an enclosed battery cabinet. At the beginning of the installation, temperatures were high because of incompletely commissioned air conditioning systems. When the A/C systems were all commissioned, temperatures became cold in the UPS/Battery cabinet room area, as the A/C settings were for UPS systems with a higher percentage of load than was present at the time. As customer load increased, and the UPS systems generated more heat in the room, A/C controls were not properly set to respond to the rising heat levels. As a result, there was a significant period of time when batteries were running warmer than normal, thus affecting their life.

UNIT REPLACEMENT PERCENTAGE WITHIN BATTERY SYSTEM

As defective or failing batteries are replaced within a string, a battery unit interaction begins. This interaction is exacerbated as additional batteries are replaced. We like to call it the "King of the Hill" effect. This interaction negatively affects string aging.

There is no standard or recommended practice for this important percentage. With batteries, new ones require less charging current than the older ones, but the charger doesn't know that, and will tend to overcharge the new ones, weakening them in the process. This activity is constantly going on within the string. We use a factor of 25 percent replacement over battery string life since new, as long as it is constantly monitored.) Many UPS service organisations use 10 percent to 25 percent before string replacement. This factor is not based on age of the string, or the individual batteries within the string. We tend to use the higher percentage range because we are looking at many other factors affecting system life.

PARALLEL STRING INTERACTION

When end of life characteristics are developing in individual battery strings within a multi-string system, all strings must be replaced. In case after case, we have found that replacements of individual strings will decrease battery life for the complete system due to interaction between the old and the new strings. Older strings with aging batteries will use larger charging current than the new strings due to differences between average string ohmic values. The charger cannot discriminate between strings.

As the charger generates enough current to keep the older strings charged to proper string voltage levels, the new string does not need this additional current and will tend to overcharge. This process creates heat and some resultant venting, thus decreasing the life of the new string. As this process continues, the older strings will age at their normal rates, and the new string will catch up in the aging process.

INDIVIDUAL BATTERY INTERACTION – "KING OF THE HILL" EFFECT

As batteries are replaced within a string, we end up with batteries with different ohmic values due to age, environment and many other factors. Again, older batteries require more charging current to maintain voltage levels. This in turn causes newer replacement batteries to overcharge, until they tend to raise their ohmic values to somewhat equal to the older batteries.

This process becomes more severe as more individual batteries are replaced within the string.

UNIT VS. STRING VS. SYSTEM

All three affect each other, and must be taken into account when studying aging systems. Some VRLA's can last longer, depending on the types. We cannot age batteries with any real certainty without lifetime monitoring.

CONCLUSION

Battery aging processes affect battery asset management. In the aging process, all factors shown above have a role to play. Customer load levels, individual system criticality, UPS system redundancies, and planning, are additional factors that must be calculated into the mix.

Planning must occur to result in just-in-time battery replacement that can be more easily budgeted for. A running budget planning process, including system changes, additions, deletions, new installations, and load growth are essential. Budgets must be revised minimally on a regular basis – quarterly, half-yearly, or annually, to correct for condition changes, including maintenance issues.

Mandatory Monitoring is necessary to make budget decisions in addition to predicting failure and ensuring the integrity of the battery systems. All battery systems should be monitored on a frequent basis, a minimum of once week or more often, depending on the monitoring vehicle.

All factors, including individual batteries, strings, and systems must be archived, interpreted and watched, for both short and long term data trends and events that can affect this data. This includes outage or cycling information. Lifetime monitoring is essential. Timely and effective battery system management affect profits and reliability.

As we have stated before: "Like any other monitoring system, the investment is worthless unless qualified individuals observe and interpret the information." B

A battery aging technical introduction

Aging factors include some of the following indicators:

- Unit voltage history, rise and fall – individual batteries are constantly charged to maintain a constant voltage. Regardless of what they are supposed to do, they change over time. If we see voltages changing on individual units, this is an indicator of something happening within the battery.
- Unit typical ohmic value – each battery model has an initial ohmic value. This could be in terms of DC resistance, impedance, or conductance, and is expressed in terms of ohms, or milliohms.
- Unit ohmic history and rise rates – as batteries age, internal ohmic values will rise over time. By frequent monitoring of these values, aging can be seen as it occurs.
- System temperature history – battery manufacturer specifications for optimum battery temperature is 25C or 77F. The temperature over time affects aging rates.
- Unit replacement percentage within battery system – this affects string aging. There is no established standard for this important percentage. It can range from about 10 to 25 percent. This percentage varies within this typical range depending on the maintenance organisation, battery manufacturers, and how comfortable the parties involved are.
- Parallel String Interaction – when end of life characteristics are developing in individual battery strings within a multi-string system, all strings must be replaced. The battery charger cannot discriminate between strings, and these strings will interact with each other.
- Individual Battery Interaction ("King of the Hill" Effect) – units affect string health and aging characteristics.
- Battery discharges and data – we know that battery discharges, light and heavy, have a profound effect on battery life. It is reflected further by changes in the above parameters.