CONTINUOUS STANDBY BATTERY MONITORING VERSUS PERIODIC BATTERY MAINTENANCE

Nigel Scott
Technical and Business Development Manager,
LEM Geneva

ABSTRACT

With the reliability of static and rotary UPS and charger systems proven over many years, the weakest link in a UPS system is still the battery. It makes sense therefore to try to ensure your battery is as reliable as possible. However, why go to the expense of a continuous monitoring system for your standby battery when you have engineers who can carry out planned maintenance routines?

Many standby or stationary batteries have IEEE or other approved maintenance routines regularly carried out and yet still fail, sometimes with catastrophic results to the critical load. Some stationary battery monitoring systems are not structured in such a way that they give maximum protection either. Some reasons for this are explored.

Providing all the significant parameters are monitored and the battery impedance test is carried out properly, it can be shown that continuous monitoring is likely to give a better reliability success rate than annual maintenance. Unfortunately, the cost of battery monitoring can be a very significant percentage of the cost of the battery. How can this be made more attractive, such that the end user has a real choice in ensuring maximum reliability for his system?

THE BATTERY: LEAST RELIABLE COMPONENT OF THE UPS SYSTEM?

Ask a UPS manufacturer the Mean Time Between Failures (MTBF) of his equipment, and it’s likely that his answer will be in tens of years. More than 25 years ago, UPS MTBF was calculated from the reliability sum of all the components, divided by the numbers of each component which could go wrong, a long and complicated calculation when done properly, sometimes more art than science, and a process completed with a certain amount of finger crossing.

It is still done this way today. However, much more is known about the behaviour of active and passive electronic components under stress, and the materials used to make up each component, particularly power components, have improved enormously. In addition, the industry has had over 30 years of manufacturing these systems, and so can say with the confidence of this experience that this or that unit will have an MTBF of perhaps 25 years.

What they can never say is that the battery they supply as an integral part of the UPS system is of the same order of rate of failure. They, and the battery manufacturers, would point out, with truth, that the battery is an electrochemical system and far more unpredictable, even today, than any well designed electronic equipment. Most battery manufacturers would agree that, for a 10 – 12 year design-life battery, a target of 0.3 – 0.4% failures over the first 5 years is very reasonable, and a low failure rate for an electrochemical device. This is true, the problem is that this also means that on average 3 – 4 cells or monoblocs are likely to fail for every 1000 installed.

Of course, this doesn’t apply to every battery. It’s more likely that 7 or 8 cells will fail in some batteries and others will never have a failure until their end of service. Unfortunately, since the battery cells or monoblocs are in series, or series – parallel, any major failure of a even a single cell could cause the battery to fail completely. These figures, and the configuration of the cells, point to the fact that the weakest link in any UPS system, AC or DC, is the battery itself.

PLANNED MAINTENANCE: ENSURES THE BATTERY IS FIT FOR PURPOSE?

Well no, not really. The problem with planned maintenance is that, like the annual test of your car's roadworthiness, it is good for the day it is carried out. Also, depending which parameters are measured or tested, sometimes it's not even that. Many failure modes can progress to cell failure over a very short time, perhaps only weeks, how likely is it that a periodic maintenance visit would be lucky enough to detect this failure before it became catastrophic?

Many planned maintenance routines (when they *are* carried out) mainly involve measuring the cell or monobloc voltages and visually inspecting the connections. This happens perhaps every quarter, with perhaps the 4th quarter including a discharge or autonomy test. This is completely inadequate for sealed lead acid cells as, unless the cell is in catastrophic failure, the cell terminal voltage will not vary a great deal from the norm, so incipient failures are unlikely to be detected.

Even I.E.E.E. recommended maintenance, together with resistance or impedance testing, more comprehensive though it is, still cannot tell the user what is happening to the battery between visits and this is the greatest weakness of periodic maintenance.

Actually, aside from resistance testing, the autonomy test is the only really useful thing about such maintenance. It is the only absolute way of determining whether a battery will perform to specification. Unfortunately it suffers from the same basic problem as quarterly inspections: The day after the test the user can't tell whether the battery will perform or not, in fact it is not uncommon for the recharge following a discharge test to accelerate the failure of weak cells, and often this failure is not detected until the next time the mains supply fails. In addition, autonomy testing, usually over several hours, is a very expensive and disruptive procedure, often in larger systems taking 1-2 days to perform, including re-charge to full capacity.

Finally, something that is often not considered with planned maintenance is that the UPS / battery system should last for a long time; normal planning is at least 10 years of service life. A lot can happen during this time, companies change and often the maintenance staff can be reduced or transferred. Several years ago British Telecom reduced its maintenance staff from 190,000 to less than 80,000. One of the items hardest hit by this was standby battery maintenance, something not considered essential at the time with VRLA batteries.

CONTINUOUS MONITORING AND MANAGEMENT. MORE SECURE ?

Yes and no. Like anything else, most of the time you get what you pay for. Quality of monitoring data depends heavily on what parameters are being monitored. Fifteen years ago inexpensive systems only monitored total battery voltage, sometimes splitting the battery into half and half, for comparison. Monitoring a battery by measuring the voltage of two halves and comparing them is probably the least successful method, as such a system is unlikely to be sensitive enough to detect a variation of a few thousandths of a volt from a poor cell against perhaps two hundred and thirty volts from a half battery, sometimes against large amounts of system noise from the rectifier / inverter.

At that time, more expensive systems monitored individual cell or monobloc voltage, plus string currents for discharge performance. Since, as mentioned earlier, the total battery voltage is fixed by the charger / rectifier, cell or monobloc voltages will not vary by more than a small amount unless they are in a catastrophic stage of failure. Therefore the main advantage of monitoring individual cell voltage is to capture data during a mains-loss discharge, or autonomy test.

This is, of course, good data and will detect a failing cell if properly recorded. However it suffers from the same weakness as periodic maintenance, - poor cells are only reliably detected when a discharge is in progress, either in a 'for real' situation or once a year in a test.

For several years now however, the more expensive battery monitoring systems have been offering cell and monobloc internal resistance or impedance as standard. Much testing has been carried out and many papers have been written on the subject, which draw parallels between the deterioration of a cell and the internal resistance or impedance values. Although there is no direct relationship, generally gross deviation from the value of the baseline 'new cell' resistance, does indicate incipient failure.

Although impedance has been in use for several years, and would appear to be a good way to detect incipient failure in the cells without costly discharge testing, the industry's perception of resistance testing is that not totally reliable.

MAKING BATTERY MONITORING SYSTEMS MORE SECURE

First, it makes sense to ensure that the monitoring system is measuring all the key parameters. In its work with the University of Aachen, LEM has identified five key elements of any battery system which should be monitored for maximum security of supply. These are:

Individual cell terminal voltage: Most useful for logging the performance of cells during a discharge and subsequent recharge

Individual cell Temperature: A critical parameter in the early detection of incipient cell problems, including thermal runaway. Operating temperature is important in a sealed battery; too long at adverse temperatures will affect the service life dramatically. This can be compensated, but sometimes this can bring its own problems, which will be discussed in more detail.

Individual cell Impedance or Resistance: Together with individual cell temperature probably the two most effective parameters in the detection of cell failure modes, with certain reservations, of which more later.

Charge and Discharge current (per string): For 'instantaneous' detection of discharges and under-performing strings, also for detecting strings that are drawing current during a discharge, a dangerous condition.

String float current (not yet available): Although a reliable float current transducer has yet to be produced, it is well-established that cells in failure mode vary from the norm in the current they draw when on float

If all these parameters are monitored, your battery is likely to have the most comprehensive and reliable (in terms of detecting incipient cell failure) system available today. However, there can still be one or two potential problems in the way that these parameters are measured.

IMPEDANCE OR RESISTANCE MEASUREMENT

Although the value of cell 'simple' impedance (ACV / ACI at a single frequency) or resistance (the DC 'real', as opposed to imaginary or reactive) part is a very powerful tool in the detection of failing cells, it is perceived to have a question mark against it in terms of the reliability of its information. There are many anecdotal stories about the failure of resistance or impedance to detect a poor cell, or that the resistance values will indicate a poor cell which will subsequently prove to be adequate in a discharge test. Some of these may be apocryphal, however enough persist to damage the reputation of this parameter.

One reason for the suspect reliability of resistance / impedance can be that, using a low test current, or an unreliable method of measurement, while the battery is on float charge, can affect the results dramatically.

The open circuit voltage a fully charged cell or monobloc is approximately 2.1 - 2.15 Volts Per Cell (VPC). This is raised to approximately 2.27 VPC when on float charge. Any testing of the cell while on float must use sufficient current to ensure that the voltage response of the cell under test comes from the cell's energy layer and not from the an area which I have termed the 'apparent' energy layer, caused by the overvoltage of the float charge and the 'back EMF' of the electrochemical generation.

Low test currents of one or two amps do not normally draw enough energy from the cell to penetrate the cell's energy layer, and thus give misleading information. The response from bipolar test currents are of course even worse, since they can only oscillate about the set float voltage itself.

One effective method of testing the battery while on float charge is to use a single test current pulse of several seconds duration. Using 40-60 amps for its test signal, the initial voltage recovery after the cessation of the test current (N) is divided by the test current at point P. It is one of the most secure methods of resistance testing and has had very reliable results, however the drawback is that it is very expensive to manufacture and install, since the connection cables from every cell carrying the higher current must be taken back to the monitoring cabinet.

Another method, which is much easier to install and uses far less cabling, is to use a small module local to each cell, to draw the test current pulse or pulses. Good design and use of System on Chip (SoC) technology can keep the cost of this method down, however there are limits to the test current which can be employed in a compact module. To ensure reliability in this type of system, the test current of medium magnitude, say up to 10 amps, is coupled with an algorithm which ensures that the response of the cell is derived from the cell's energy layer and the returned values are not contaminated by the cell's apparent energy layer.

INDIVIDUAL CELL TEMPERATURE

VRLA (Valve Regulated Lead Acid) in particular are affected by sustained adverse temperatures. Charge voltage optimisation by the charger can offset the deterioration to a significant extent, but it is much better to have a thermal map of the whole battery than to rely on a single ambient temperature measurement since it may be possible to offset the worst affected areas by other means, rather than make matters worse for certain areas by changing the overall charge voltage to cater for only one temperature point.

At temperatures above 34ºC, the compensation of the float voltage would have to be reduced to such a low figure (below 2.2 VPC) that sulphation would be significantly accelerated and the cure would become worse than the disease.

In measuring the individual cell temperature, the placing of the temperature measuring device can be critical.
In tests on a large data centre battery of 1200 cells, using a calibrated laser temperature probe, differences of over 8ºC were detected between the post and case temperature of the same cell. The most reactive point on the outside of the cell enclosure however is normally the post, which responds relatively quickly to the plate temperature.

CONTINUOUS MONITORING V. PERIODIC MAINTENANCE - SUMMARY

Unless the periodic maintenance is carried out diligently at least once per month and includes cell and interconnection impedance and cell temperatures, it is unlikely to detect all failures before they become serious. This method requires a high investment in manpower resource, which is not suitable for every application. In addition, meticulous records must be kept, so that the data can be trended to detect possible failure excursions. It is a fact that many planned maintenance routines when carried out frequently, such as once per month, tend to be skimped if nothing out of the ordinary is detected month on month, year on year.

On the other hand, a continuous monitoring system is automatic and at its most basic requires no human intervention, other than to respond to alarms. Once the investment is made there is little further capital outlay and many systems can be transferred to a replacement battery in due course if required. Taken over the life of the UPS/battery system the costs can be much less than periodic maintenance. However, with the highest priced continuous monitoring systems the initial cost – including installation, can be off-putting.

HIGH MONITORING COSTS – CAN THEY BE REDUCED ?

Battery management system reporting can be by exception, rather than daily, weekly, etc., reducing the amount of data to be reviewed. Data is always available for examination and, should a problem develop, as evidence. It would seem that there is a good case for asserting that monitoring brings more reliability to a battery system than periodic maintenance, and it can be shown that over the life of the battery monitoring is more cost – effective, so why is there such a low take–up ?

Unfortunately, the traditional cost of a battery monitoring system, including the 'hidden' cost of installation, can often be as high as 100% of the cost of the battery itself. Therefore, it is not surprising that it is difficult to persuade decision makers to include a cost of this magnitude in any but the most sensitive projects.

HIGH VOLUME PRODUCTION METHODS TO BREAK THE PRICE BARRIER

The way that LEM has chosen to reduce the cost of monitoring is by reducing component count, using its own design single System on Chip (SoC) in its battery monitoring transducers. Since LEM already produces over 15 million current and voltage transducers a year, we believe that high volume manufacturing methods can also be employed in producing battery monitoring transducers, and these two key factors, reduced component count together with high volume manufacturing methods have assisted in reducing the cost of its systems by more than 60%.

The long term aim of all battery monitoring manufacturers must be to reduce the traditionally high cost of battery management system ownership to within reach of all standby battery users, typically this would have to be less than 15% of the cost of the battery system itself. This can make battery management systems accessible to a much wider market than at present.

LEM believes that this ultra-low cost approach, together with the benefits of an active management system, will turn the cost of battery management system ownership into a positive quantity, changing the role of the battery monitor from an expensive addition, the cost of which is perceived to be of value only to the most sensitive installations, to that of an extremely cost-effective integral life management system, essential to the service life of every VRLA battery.