Where would we be without batteries?

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Batteries are extremely important, not least as a source of power when the main supply of electricity is unavailable.

Battery Basics

All batteries use chemical reactions to make electricity, and all comprise two dissimilar metallic materials in a current-carrying medium. In lead-acid batteries, the metallic materials are lead and lead oxide in a sulphuric acid medium. Nickel-cadmium (NiCd) batteries use nickel and cadmium compounds in a potassium hydro-xide medium.

Nickel metal hydride (NiMH) batteries use the same nickel compound as NiCd cells, but the cadmium compound is replaced with a metallic hydride and the liquid electrolyte is replaced with a paste. NiMH and NiCd cells are virtually identical in performance; even their voltages are the same. For the purposes of stationary battery testing, however, this article focuses on lead-acid batteries.

How do we know if lead-acid batteries are good or bad? The traditional approach of testing only the voltage and specific gravity doesn't work - never has and never will! The reasons are explained later in this article. Nevertheless, it is still possible to evaluate the performance and condition of a battery by well planned testing, as we shall see.

Battery TestsSome users carry out no battery testing, whichis not a good idea assuming the battery support is needed. Others carry out comprehensive, time-consuming and expensive exercises involving virtually every available test. In most cases, this is an equally bad idea.

Routinely available battery tests involve measuring float voltage, specific gravity, float current, ripplecurrent, cell temperature, ambient temperature, discharge current and time, inter-cell connection resistance, capacity and impedance. Let us examine these in more detail.

Float Voltage

Measuring float voltage (the voltage at the battery's terminals while it is on charge) can be misleading. Float voltage is un-doubtedly important and, if it is abnormal, there is a need for further investigation. If it is normal, however, it indicates nothing at all about the battery's condition, although it does probably confirm that the charger is functioning properly!

Specific Gravity

Similar comments apply to measuring the specific gravity of the electrolyte. Sulphate is part of the electrochemical reaction. If the battery is discharged, some of the sulphate migrates to the plates and the electrolyte's specific gravity falls. If the battery is fully charged, all of the sulphate is in the electrolyte and the specific gravity is normal.

There are no studies which indicate any correlation between specific gravity and battery capacity. In fact, the American IEEE 450 standard has de-emphasized specific gravity measurements to the point where it now only requires that 10% of the batteries should have their specific gravity checked each quarter, with the full bank checked annually.

Float Current

In order to keep a battery charged, there is a balance between the battery's self-discharge and the action of the charger. The battery is always in a state of self-discharge which means that there is always a difference in EMF between the battery bank and the charger.

This difference allows a small current (the float current) to flow to keep the battery fully charged. The passage of the float current through the battery generates heat. In ordinary flooded lead-acid batteries, this is unlikely to be a problem, as evaporation of the electrolyte keeps the battery cool. However, many modern batteries are of the valve-regulated lead acid (VRLA) type. These have no surplus electrolyte, nor is their electrolyte in a free liquid form. Therefore, if the float current in a VRLA battery increases because of an impending failure or because of overcharging, the battery temperature increases.

This increase in temperature allows more current to flow, which fur ther increases the temperature of the battery. The result is thermal runaway, which may ultimately result in the battery melting. The interval between the initial increase in float current and the onset of thermal runaway is typically between one and four months. For this reason, regular measurement of float current in VRLA batteries is essential.

Ripple Current

Chargers convert AC from the mains supply into the DC needed to charge the battery. This conversion process is not perfect, however, and in all practical charges, residual AC appears at the charger out-put. This is the ripple current and it can, if necessary, be reduced by the use of filters.

Ripple current generally increases slowly over time as the electronic components in the charger degrade. If, however, a rectifier diode fails in the charger, the ripple current can double instantly. An increase in ripple current above about 5A RMS for every 100Ah of battery capacity (5%) leads to increased temperature and shortened battery life. Ripple current is, therefore, another para-meter that should be measured regularly.

Temperature

High temperatures do not spell immediate doom for batteries, but they can lead to premature failure. For every increase of 10° C, battery life is halved. This then means that a 20-year battery maintained at 30° C instead of the specified 20° C will only last about ten years. This can be a significant consideration where banks of batteries in, for instance, a large UPS system are concerned.

Discharge Current and Time

Discharge current and time measurements are being used more frequently in on-line monitors as an aid to determining the amounts of energy removed from and fed into a battery. These measurements, at least in theory, allow the battery capacity to be calculated, and the author believes that there is merit in this calculation.

Inter-cell Connection Resistance

Measurement of inter-cell connection resistance is an essential test, as it has been said that more than 50% of battery bank failures are due to loose inter-cell connectors. Inter-cell connections loosen due to the heating and cooling cycles caused by discharging and re-charging. The cell terminal posts expand and contract and, as the lead from which they are made is very malleable, they cold flow with each cycle.

With the aid of a low-resistance ohmmeter, measuring inter-cell resistance is a straightforward test that can be done either on its own, or in conjunction with other tests.

Capacity

Capacity tests, also known as load tests, have long been seen as a necessary evil. If performed properly, they are expensive and time-consuming. They may also have limited predictive value, depending upon how frequently they are performed.

Let us consider a battery bank that is designed to provide eight hours of back up time. A proper capacity test requires a second battery to take over the duty of the battery under test if a supply failure occurs while the test is in progress. A resistive load bank is also needed, which is connected to the battery bank under test, along with voltage leads for each battery in the bank. It is quite usual for this pre-paratory work to take around a day.

On the second day, everything is ready for the eight-hour discharge test. Frequently, however, this is preceded by measurement of the inter-cell connection resistance. There are two schools of thought about this. The first is that the resistances measured will not be true as-found values. The second is that the

resistance test is a useful aid to ensuring that no major malfunctions occur which could have been avoided. The arguments are finely balanced, leaving the final decision to individual battery users.
With the battery fully discharged on the second day of testing, the third day is occupied by recharging, and the removal of the test leads. Even with this modestly sized battery, therefore, the test has taken three days, and has involved the use of an expensive loadbank and alternate battery. That having been said, it cannot be denied that a properly conducted capacity test is the only guaranteed way of accurately determining the capacity of a battery bank.

Impedance

Impedance testing is a measure of the capability of a cell to deliver current. Impedance correlates with capacity and, although this correlation is not 100%, impedance testing is an excellent way of finding weak batteries in a bank.

In impedance testing, an AC voltage is applied to the battery and the resulting current flow is measured. With knowledge of this current and the applied AC voltage, Ohm's law can be used to calculate the battery impedance. Research has shown impedance to be inversely proportional to battery capacity.

This test is fast (typically taking around 30 minutes for a substation battery bank) and is non-invasive. It is, therefore, an invaluable alternative to capacity testing, provided that it is clearly understood to be an indirect measurement of capacity which can never offer the same degree of accuracy and certainty as is achieved with a conventional capacity test.

Data Analysis

Whatever testing regime is adopted, the result is sure to be a lot of data which, unless it is properly handled, is likely to lead to analysis paralysis. The recommended approach is to use a computerized database to store and trend the data, rather than relying on traditional paper forms and laborious manual comparisons.

A specialized database that stores all measured parameters is almost as important as the tests themselves in determining the condition of batteries and banks. For example, limits can be set on measured and calculated parameters.

If these limits are chosen to reflect the user's required level of confidence in battery reliability, they can be a significant aid in getting the most from the battery and maximizing its service life

Conclusion

Batteries have many failure modes, but with careful use and regular testing, the probability of in-service failures can be reduced dramatically. Proper testing and data analysis can help determine when a battery should be replaced, as well as reducing the need for unplanned battery replacements, thereby aiding budgetary planning and cutting overall costs.

Finally, a well-implemented battery testing regime is a major step toward achieving the primary goal of every battery installation – that of providing dependable standby power whenever it is needed.

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