Technical Bits … *of knowledge*

Substation Battery System – TB001

One of the most important (if not the most important) components of a high-voltage industrial/utility substation is the DC system. The DC system provides the energy required to operate protective devices and high-voltage components for proper isolation of electrical faults. In the event that the DC system is not available when required, severe damage to equipment as well as harm to personnel is a high probability. A typical high-voltage industrial/utility substation DC system consists of a flooded-cell battery bank (typically 60 cells providing a nominal 125 VDC system) and a battery charger (***see TB002***). Too often, too little attention is given to the maintenance and testing of the DC system, primarily the battery bank.

Under normal operating conditions, the battery provides very little current. The battery charger (when sized properly) provides the continuous load current (i.e. relay/meter power supplies, indication lights, etc) and maintains a charge on the battery bank. The battery bank begins to contribute current when the load increases beyond the output capability of the battery charger (i.e. trip/close coils, charging motors, etc). Typically, such operations last between several cycles to several seconds. The true test of a battery comes about when the battery charger is removed (i.e. battery charger fails or feeder to battery charger trips) and the battery alone must support the DC load. A typical battery load profile is composed of three (3) distinct loads over an eight (8) hour period (720 minutes).

- Time 0-1 minute: Initial operation (i.e. relays, lockouts, trip coils, etc) plus continuous load
- Time 1 – 719 minute: Continuous load
- Time 719-720 minute: Continuous load plus restoration operation (i.e. close coils, charging motors, etc)

The eight (8) hour period is a fairly common load profile duration, but the actual duration can be adjusted as required by the installation/application. The design of the DC system is such that the battery cell voltage will not drop below the minimum voltage (typically 1.75 VDC per cell) for the duration of the load profile period.

IEEE 450, "IEEE Recommended Practice for Maintenance, Testing and replacement of Vented Lead-Acid Batteries for Stationary Applications" provides guidance for maintenance and testing of flooded-cell batteries to ensure that the batteries are capable of supporting this load profile. IEEE 450 specifies recommended monthly, quarterly, and annual inspections as well as performance tests. Inspections include:

- Electrolyte level
- Ambient and electrolyte temperature
- Cell voltage and specific gravity
- Cell temperature
- Cell to cell connection resistance

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The performance tests recommended by IEEE 450 measure/estimate the battery's remaining capacity. Furthermore, IEEE 450 also recommends replacement of the batteries when the capacity falls below 80% of the manufacturer's rating. Figure 1 below shows the basis of this recommendation.

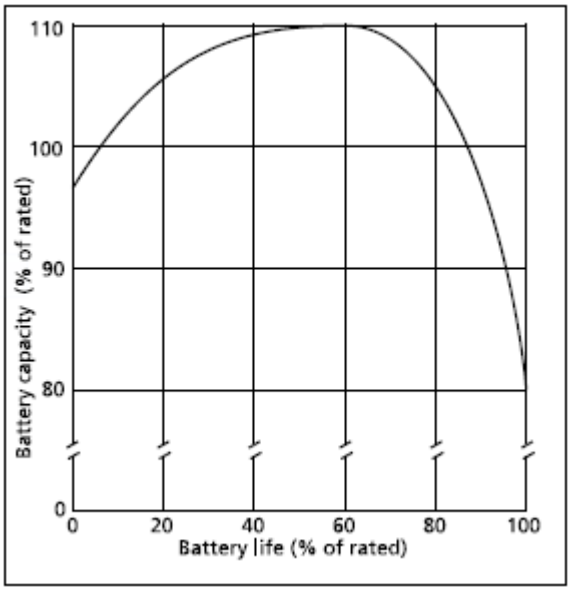

Figure 1. Typical Battery Life Curve

It is seen that the battery capacity actually increases after initial installation. However, at approximately 60% of battery life, the battery capacity begins to drop off sharply. It can be seen that the performance of the battery below 80% of battery capacity is unpredictable, hence, the recommendation to replace the batteries when the capacity drops below 80%. Unfortunately, many facilities do not perform the recommended capacity tests.

It is a misconception that the inspections alone are adequate to determine the condition of the battery system. In reality, these measurements/inspections may help detect failing cells, however, the measurements/inspections alone cannot accurately identify the condition of the battery nor can they estimate the remaining life of a battery.

Some of the reasons that the facilities do not perform the capacity tests include:

- Cost
- Labor and effort required to disconnect the battery and install a temporary system during the capacity test
- Perceived risk associated with paralleling of a battery bank in an energized facility
- Concerns that the capacity test will remove life from the battery bank
- Unaware of the recommendations provided in IEEE 450

Regardless of reason, the pros of performing a full battery of tests as recommended by IEEE 450 significantly outweigh the cons. It should also be recognized that due to the nature of the design of lead-acid batteries, there are a number of factors which can significantly affect the life and performance of a battery. These include:

- Electrolyte level
- Ambient room temperature
- Load profile (specifically growth in load over time)
- Float and equalize voltage levels
- Altitude
- Maintenance history

Recommendations for maintaining and testing lead-acid, flooded-cell station batteries include:

- Perform testing in accordance with IEEE 450
- Maintain testing records to identify trending data
- Maintain the battery sizing calculations and update the load profile to reflect growth
- Maintain the proper room temperature
- Replace the battery bank when the capacity drops below 80% as recommended by IEEE 450 (typically in the range of 16-18 years for a 20 year life battery).

Proper maintenance of the DC system (more specifically the battery bank) will greatly improve the safety and reliability of an electrical substation.