Battery Sizing and Maintenance at a Small Electric Utility

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ABSTRACT

The increase in continuous loads such as radio transmitters and microprocessors in substations has led some utilities, including ours, to take a closer look at the sizing of the stationary batteries that operate those stations when commercial power is lost. Critical functions, such as tripping circuit breakers and communicating information to dispatch centers, are placed on DC power. When station power is present, that DC power for the continuous loads is supplied by the charger. When commercial power is lost, however, the continuous loads are carried by the batteries, which must also have the capacity to operate tripping mechanisms. IEEE Standard 485 [1] is widely accepted as the guideline for sizing of stationary batteries, and its application is discussed. Once a battery is placed in service, its maintenance, monitoring and periodic testing protocols are the next issues that the utility considers. Those practiced by this utility are discussed, including monitoring of the presence of DC power at certain critical points by SCADA equipment.

BATTERY SIZING CRITERIA

The common voltages in electric utility substations are 48 and 120. 48 volt systems are more common, and are the preferred choice when allowable because of their smaller physical size and ease of maintenance. In some stations, however, the physical size of the station requires the higher voltage in order to lower the current and thus the voltage drop.

Changes in equipment over the last twenty years have caused an increase in the continuous loads placed on substation batteries. In the 1970s, the continuous loads were generally these[2]:

indicator lights on circuit breakers	0.3 amps
indicator lights on annunciator panel	0.1 amp
	0.4 amp total

The desire for remote control and monitoring of events in the substation, however, has caused additional equipment to be added to the load on the DC system. Today, a typical station will have these continuous loads:

indicator lights on circuit breakers	0.3 amp
indicator lights on annunciator panel	0.1 amp
Feeder overcurrent relays	1.0 amp
Feeder monitor relays	1.7 amp
backup overcurrent relays	0.1 amp
Differential relay	0.1 amp
RTU	2.0 amp
900 MHz radio for SCADA	1.5 amp
DC monitoring relays	0.2 amp
	7 amps total

While the additional equipment was added incrementally over the years, the DC power system remained in place, unchanged.

Another change that has occurred over the same years at many stations is the conversion from fuses to circuit switchers for transformer protection. This affects the short-duration loads that are placed on the DC power system because the circuit switchers trip on a stored charge (usually a spring), but upon tripping immediately run a motor to recharge the spring. So where the short-duration loads once were:

trip four circuit breakers	53 amps for a few seconds

They are now:

trip four circuit breakers	53 amps for a few seconds
Operate Lockout Relay	3.7 amps, momentary
trip circuit switcher	22 amps for a few seconds

The first step in sizing a battery system is producing a duty cycle diagram. Figure 1 shows a typical duty cycle found at a distribution substation in the 1970s or early 80s, before the addition of new equipment that increased the continuous loading. At that time, indicating lights were the only continuous load at most stations.

Figure 1
Typical Substation Loads in the 1970s

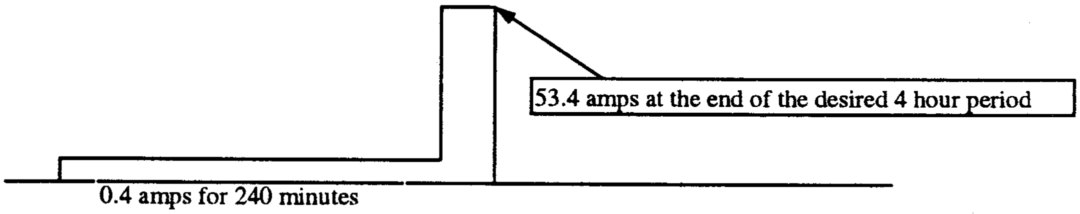
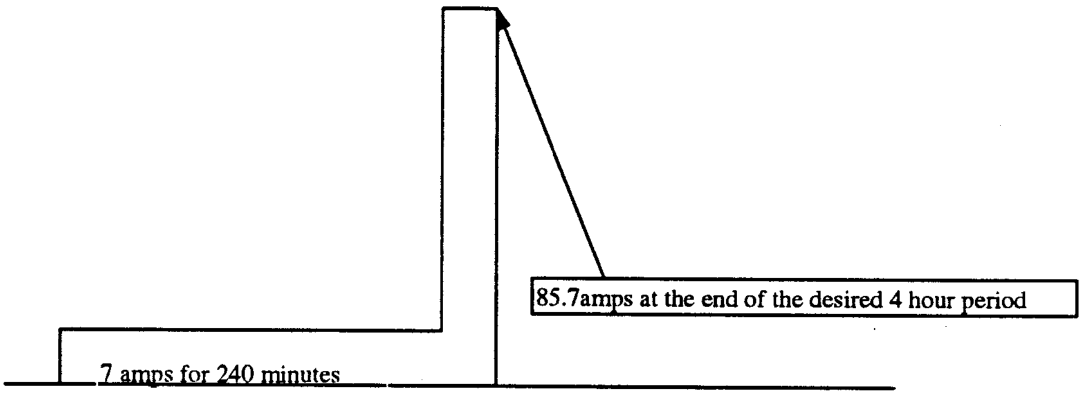


Figure 2
Typical Substation Loads in the 1990s



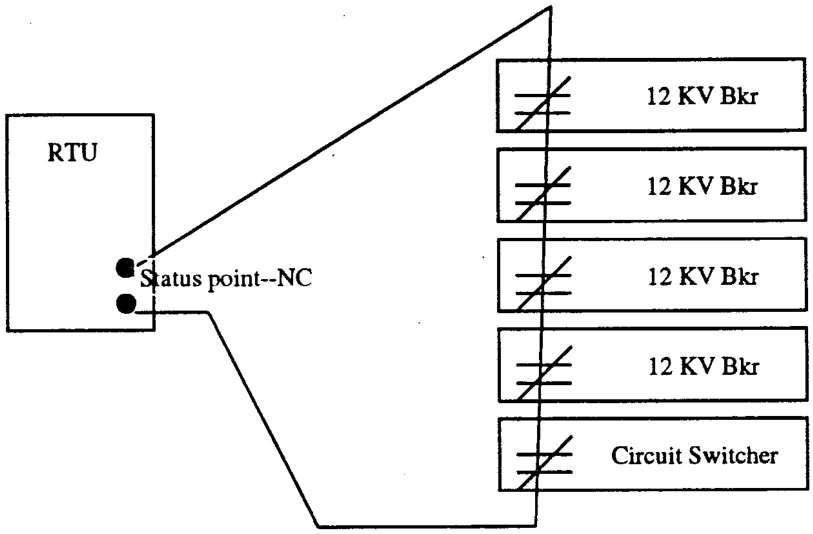
While the tripping of breakers is shown here as occuring a the end of the four hour period of desired battery operation, it could occur at any time. Placing it at the end of the period is the worst case from the standpoint of battery service, however, and is our normal practice.

The determination of battery size using these duty cycles is described in IEEE Standard 485. The calculation of battery size can be made in terms of positive plates or ampere-hours. Some battery manufacturers will provide sizing software at no charge with which to accomplish these calculations quickly and easily. At our utility, the growth in loads has caused us to increase our desired capacity at most stations from 100 amp-hour systems to 150 amp-hour.

MONITORING FOR LOSS OF DC POWER

After losing a transformer to failure of its circuit switcher to trip in April of 1994, we embarked on a more aggressive monitoring program to ensure availability of DC power to all devices. We locate 12 volt DC relays at each piece of equipment, and hold the normally open contacts closed with current flow through their coils. A monitoring circuit goes from the RTU in series to each set of relay contacts, so that if any device loses DC power, the circuit changes from closed to open and an alarm is generated. Figure 3 shows a typical layout of the monitoring system. The sensing relays are placed on the load side of any fusing or DC circuit breakers serving the device monitored, so a cut wire, tripped breaker or blown fuse will be detected.

Figure 3
Monitoring for Loss of DC Power at Equipment



TESTING AND DATA COLLECTION

We have a technician who goes to every station once a month to do maintenance and take measurements. We have monthly, quarterly, and annual protocols for battery maintenance, and in a typical day the technician will do a mix of 3 or 4 monthly checks and two or three quarterly or annual routines. The quantities measured during the annual visits are the best resource we have for triggering additional attention to banks that may have problems, and it may be a few more years before we have enough data accumulated to identify problems based on such quantities as cell voltage, internal resistance and specific gravity, except in glaring cases. We are now only beginning to look at correlation between those quantities as observed during annual data collection and the results of load testing.

An example is found in the case of internal resistance readings seen at Norton substation in September of 1996 and a subsequent load test in January of 1997. In the September readings, cells 14 and 22 were seen to have high resistances (see figure 4) The load test, however, indicated a problem only on cell 14 and its neighbor, cell 13—cell 22, while weaker than most, was not conspicuous as a failure of the load test (see figure 5

FIGURE 4

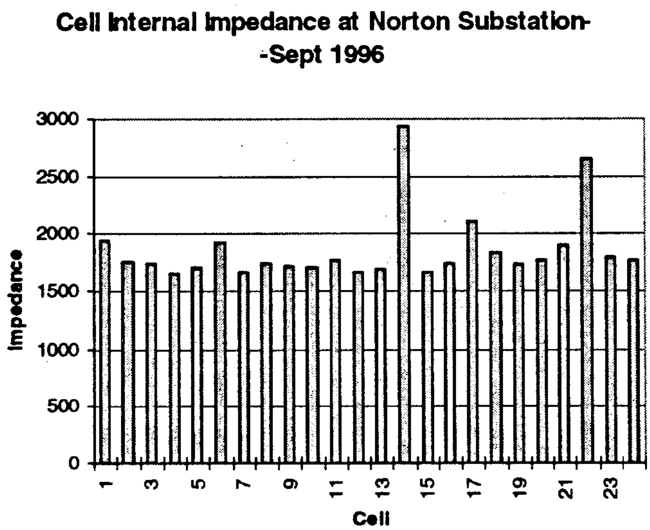
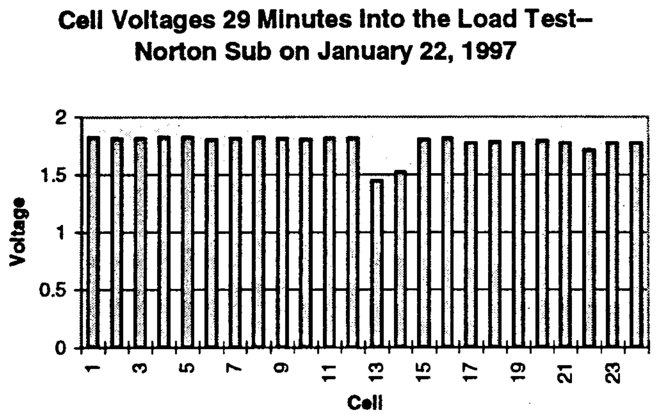
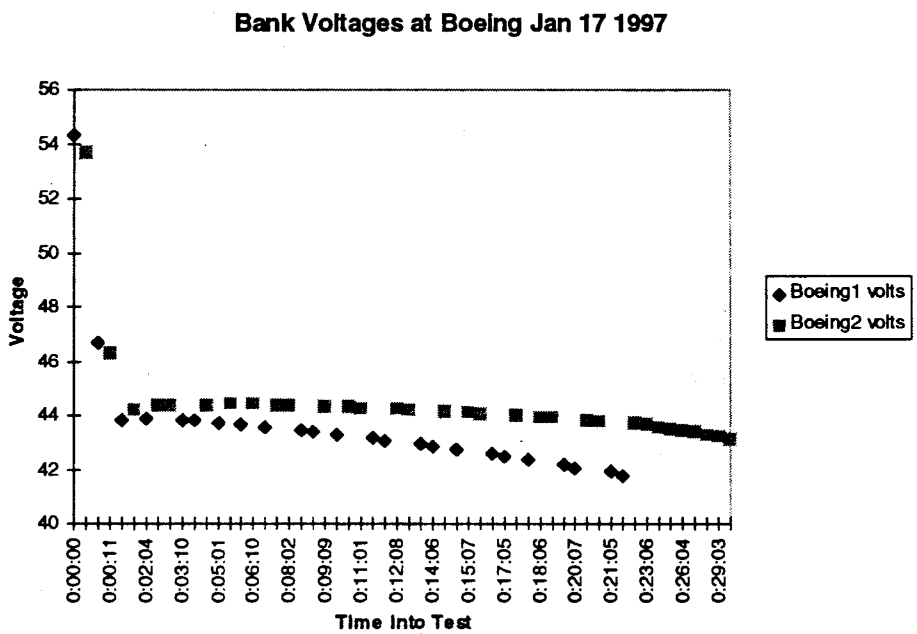


FIGURE 5



Load testing is regarded as the final measure of a battery system's readiness to perform, and the ability of the current equipment to log and export data to spreadsheets is a handy analytical tool. At figure 6 is a comparison of two battery banks that serve our substation at the Boeing plant in Everett. While the two results charted here are for different banks, as time goes by and each bank accumulates test results in the files, the tests for a particular bank can be charted and the changing performance of a battery easily seen.

FIGURE 6



References

1. IEEE Std 485-1983, *Recommended Practice for Sizing Large Lead Storage Batteries for Generating Stations and Substations, 1983.*
2. Coerber and Fate, *The DC System: Heart of a Protective Relaying Scheme*, 22nd Anual Western Protective Relay Conference, October 24-26, 1995 in Spokane, WA.

Bibliography

1. Brennan, *EPRI Power Plant Electrical Reference Series*, 1987, Volume 9
2. IEEE Std 485-1983, *Recommended Practice for Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Generating Stations and Substations, 1987.*
3. Migliaro, M., *Considerations for Selecting and Sizing Batteries,* IEEE Transactions on Industry Applications, vol 23, No. 1, 1987.
4. Seidman & Mahrous, Handbook of Electric Power Calculations, McGraw-Hill, 1983.