APPLICATION TESTING OF BATTERIES FOR UTILITY LOAD LEVELING AND CUSTOMER APPLICATIONS AT THE BATTERY ENERGY STORAGE TEST (BEST) FACILITY

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Summary

The demand for electric energy varies hourly, daily, weekly, monthly and seasonally. A study of energy storage performed by Public Service Electric and Gas Company during the last decade concluded that energy storage by electric utilities could yield substantial economic benefits to utilities and customers, and, indeed, the world, by shifting a significant amount of present oil use to more abundant fuel resources. In that study, large-scale energy storage in batteries was identified as an important, near-term technology. This paper describes briefly test methods and programs for testing and evaluation of battery energy storage systems for utility and customer applications.

Introduction

The Battery Energy Storage Test (BEST) Facility is a joint program by the U.S. Department of Energy (DOE), Public Service Electric and Gas Company (PSE & G), and the Electric Power Research Institute (EPRI). It serves energy technology developers, electric utilities and the project sponsors in their mutual desire to perfect commercialization of battery energy storage technologies. The primary objectives of the BEST Facility are the impartial testing and assessment of battery energy storage systems in a utility environment. BEST Facility test programs provide a focus for development and a means for users to assess the acceptability of new technologies.

Following dedication and successful acceptance testing in 1981, the BEST Facility commenced operation in 1982 with the cycling of a 1.8 MW h lead–acid battery. In parallel with the primarily utility-applications-oriented test program for this battery, the capability of the test facility and the underlying testing methodology were expanded to include testing and evaluation of customer-side-of-the-meter battery energy storage systems.

TABLE 1

Test programs

	Phase 1 testing	Phase 2 testing	Phase 3 testing
Objectives	Verify system design concepts	Assess performance in utility environment	Field trial, demonstration
Hardware	Pre-prototype; nominally 500 kW h	Prototype (0.5 - 10 MW h)	Commercial (0.5 - 10 MW h)
Instrumentation	As required	Comprehensive monitoring	Commercial level + additional monitoring as required
Testing	Developer-oriented evaluative testing	Utility- and customer-oriented evaluative testing	Utility/ customer dispatch operation

Test programs at the BEST facility

Testing of battery systems at the BEST Facility is specific to electric utility and customer applications and proceeds in accordance with test methods and schedules developed jointly between electric utility advisors, program sponsors, equipment developers and PSE & G, as set forth in the BEST Facility Test Program Guidelines. These guidelines were developed by the BEST Facility Developer Users Group, whose membership consists primarily of battery and converter developers.

BEST Facility testing results in an information base describing battery performance, maintenance requirements, and utility/customer environment compatibility. Three general categories of test services are provided, as depicted in Table 1. These categories are intended to be responsive to selected major phases of emerging new technologies. They include batteries, power conversion equipment, and complete battery energy storage systems. The system under test may include components submitted by more than one developer, and may contain subsystems provided by the BEST Facility. The three phases of testing described are believed to be sufficient for state-of-the-art and presently-developing advanced battery energy storage systems. Since test programs must be flexible to meet evolutionary needs, modifications of the plans presented here will be considered if they address specific end user requirements.

Phase 1 testing

This phase provides the equipment developer with a test bed to verify basic system design concepts and to develop a technical information base. The technical objectives of this service will be defined by the developer as part of a test plan. The testing methodology will first employ simple charge/discharge cycles to assess system performance and, later, variant duty cycles involving charged-stand and fast charge-to-discharge turnaround. The programmed tests allow for flexibility to make and incorporate design changes to equipment based on the test results.

Phase 2 testing

This phase provides the equipment developer with performance data and operating experience in a utility environment, and also provides the developer and interested utilities and customers with a performance record of operations under conditions which are conducive to product evaluation. A battery tested in this program will typically be made up of full-size prototype strings of a construction which has a potential for commercialization, together with battery subsystems and energy systems controllers. The average power and energy capacity of such a test system is in the 0.1 - 2 MW, 0.5 - 10 MW h range when discharged at the 5 h rate. A high degree of success in meeting performance goals in the first 15% of life will strengthen confidence of the developer and his potential customers in the product by addressing the issues described below during start-up and operation. The technical objectives are:

(i) To test and evaluate prototype energy storage systems and subsystems operating in a utility environment and in a number of functional use modes for the first 15% of projected life.

(ii) To assess performance in the application for which the unit is designed and to validate developer's system performance predictions.

(iii) To develop a data base useful to developers and utilities, providing the following information:

(a) a definition of the system under test;

(b) capacity, efficiency, power quality and dynamic response in the operating modes tested;

(c) capability to withstand faults, power system transients, and other severe operating conditions normally present in utility service;

(d) electrical and physical conditions within the system during normal operation;

(e) changes in performance characteristics during testing and effects, and

(f) information impacting system reliability and maintenance in the form of system or component outage history, prior circumstances or concurrent indications, equipment affected, responses of control and safety

systems, availability, duration of outages, remedial measures and probable causes, and correlation with data from preinstallation testing;

(g) safety and environmental acceptability during testing;

(h) procedures for qualification, shipping, installation, start-up, operation, maintenance and repair, and an assessment of the effectiveness of procedures exercised.

Phase 3 testing

Phase 3 testing and evaluation will provide equipment developers and interested utilities and customers with the experience of commercial operation. A battery tested in this phase is made up of strings identical in construction with that of a product which can be commercially available. The typical power and capacity of the battery will be in the 0.1 - 2 MW, 0.5 - 10 MW h range when discharged at the 5 h rate. Subsystems submitted by more than one developer, or BEST Facility subsystems, may be included within the energy storage system tested. Integration of these subsystems will be the responsibility of the participating developer and PSE & G. A successful operating experience will strengthen confidence of the developer and customers in the product, and will serve as a vehicle for introducing potential customers to the product. The following are the technical objectives of phase 3 testing:

(i) obtain field operating experience with complete, commercializable energy storage systems;

(ii) assess instrumentation, controls, environmental-withstand and operating performance when dispatched as utility- or customer-operating equipment;

(iii) serve as a "showcase" for exposure of personnel to operation of the battery energy storage system;

(iv) serve as a test bed for continued life-testing, as appropriate;

(v) assemble an information base for use by a developer and potential customers similar to that described for Phase 2 testing.

In contrast with the predetermined test schedule provided for prototype testing, Phase 3 testing may have a utility- or customer-driven test schedule, rather than the generic BEST Facility program-driven test schedule. This means that a battery is subjected to the daily operating requirements of the utility load dispatcher or utility customer.

Typical test results

Typical test results illustrating the testing methodology and data analysis are presented and discussed for:

(i) a 1.8 MW h calcium-grid, lead–acid battery system for BEST Facility shakedown testing;

(ii) a developmental 500 kW h zinc–chloride battery system;

(iii) a 500 kW h antimony-grid, lead–acid, load-leveling battery system.

Conclusion

Testing and evaluation of large-scale battery energy storage systems for load-leveling and peak-shaving applications by electric utilities and their customers requires testing methodologies and test programs different from those used for mobile and uninterruptible power supply battery applications. Appropriate methodologies and test programs have been developed and successfully applied at the BEST Facility. Experience has shown that this process is evolutionary and subject to modifications for different battery technologies.