1/9k
2/9k

UTILITY BATTERY STORAGE SYSTEMS

Program Overview

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

THE UTILITY BATTERY STORAGE SYSTEMS PROGRAM OVERVIEW

U.S. Department of Energy Sponsorship

The U.S. Department of Energy (DOE) sponsors and manages the Utility Battery Storage (UBS) Systems Program through the Advanced Utility Concepts Division of the Office of Energy Management in Washington, DC. In support of UBS Program goals, Sandia National Laboratories' (Sandia's) Storage Batteries Department in Albuquerque, New Mexico, closely interacts with utilities and manufacturers on activities that promise to develop battery energy storage as a commercially attractive utility resource by the year 2000.

Contents

Why is Utility Battery Storage Important?	2
What is a Utility Battery Energy-Storage System?	3
Why is the Utility Battery Storage Systems Program Important?	4
What is the Utility Battery Storage Systems Program?	6
What has the Utility Battery Storage Systems Program Achieved?	7
What Activities are Planned by the Utility Battery Storage Systems Program?	12

UBS Program Management

Paul C. Butler, Manager
Storage Batteries Department
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-0613
(505) 844-7874

Russell Eaton, III, Director
Advanced Utility Concepts Division, EE-142
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585
(202) 586-0205

Marvin E. Gunn, Jr., Director
Office of Energy Management, EE-14
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585
(202) 586-2826

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *ed*

WHY IS UTILITY BATTERY STORAGE IMPORTANT?

Utilities in the United States collect more than \$150 billion in revenues each year and employ more than 450,000 people. The energy that utilities supply is essential for the nation's economic growth and global competitiveness. Therefore, the issues that face electrical utilities affect everyone in the nation. These issues include dwindling resources, increasing demand, and the high-risk investments associated with new generation, transmission, and distribution capacities.

Battery energy storage can help utilities use their existing assets to minimize the need for high-risk investments. By storing electrical energy, utilities can assure reserve power requirements, defer new power plant construction, provide support for existing transmission and distribution systems, and maintain the level of reliability and power quality that customers need and expect. In addition, battery energy storage reduces the environmental impact of generating and delivering electricity by enhancing the usefulness of renewable resources in a utility generation mix, and reducing peak power demands on fossil fuels. The Department of Energy's (DOE's) Utility Battery Storage (UBS) Systems Program, a part of the Advanced Utility Concepts Division of the Office of Energy Management, focuses on developing cost-effective utility battery storage systems.

Currently, more than 20 utilities are evaluating battery storage as a resource option to reduce or defer capital investment, respond to load growth, improve operations, address environmental issues, and provide special services to customers (see Figure 1). The UBS Program will continue to work with these and other utilities to help them realize the benefits of battery energy storage.

Figure 1. Utilities actively involved in utility battery energy storage.

WHAT IS A UTILITY BATTERY ENERGY-STORAGE SYSTEM?

Concept

A utility battery energy-storage system allows a utility or a utility's customer to store electrical energy for dispatch at a time when its use is more economical, strategic, or efficient. The battery system accepts electricity from the utility grid, stores it, and returns it to the grid on demand. Numerous components in the system work together to perform these functions.

Components

The system consists of a power-conditioning system, batteries, a control system, and auxiliary devices (typically considered the balance of plant) that include transformers, electrical ties and interconnections, support structures for batteries, and a shelter for the entire assembly (see Figure 2).

Figure 2. A utility battery energy-storage system.

COMPONENTS OF A UTILITY BATTERY ENERGY-STORAGE SYSTEM

- **Power-Conditioning System:** Utilities in the United States deliver electricity as alternating current (AC). The means by which batteries store energy is through direct current (DC). Therefore, battery storage systems employ power-conditioning systems to interface between utility AC and battery DC power.
- **Battery:** In a chemical battery, charging causes reactions in electrochemical compounds to store energy as chemical potential. During discharge, reverse chemical reactions cause electricity to flow out of the battery. Of the existing battery technologies, lead-acid dominates in near-term utility applications. Sodium/sulfur and zinc/bromine battery technologies are in advanced stages of development.
- **Monitoring and Control System:** To function, a battery energy-storage system must sense and respond to conditions that require its operation. The system must also sense and respond to the state of the battery. The devices that perform such monitoring interact with the controls of the battery energy-storage system and regulate system actuation. These devices can be on-site or remote, manual or electronic, or a combination of these options.
- **Balance of Plant:** A battery storage system requires many auxiliary components to connect the devices to each other and to enable their functions in the system. Components in existing battery energy-storage facilities have been categorized in several ways. Components that do not clearly belong in one category fall into "Balance of Plant," or BOP. The BOP typically includes transformers, electrical ties and interconnections, protection devices, the support racks for batteries, a shelter for the assembly, heating and air conditioning, permitting and landscaping, and safety equipment. New approaches to categorizing battery system components will be necessary to enable utilities to directly compare dissimilar systems.

WHY IS THE UTILITY BATTERY STORAGE SYSTEMS PROGRAM IMPORTANT?

Applications and Benefits

Battery energy-storage systems can be designed to perform multiple utility applications in generation, transmission and distribution (T&D), and customer service. As a generation resource, battery energy storage can defer generation capacity installation, support renewable generation, and provide spinning reserve and load leveling. As a T&D resource, battery energy storage can provide voltage regulation and transmission line stability and defer T&D facility upgrades. As a customer service resource, battery energy storage can reduce customer peak demands, and improve power quality and service reliability. A battery energy-storage system able to simultaneously satisfy multiple applications has greater value than a resource that performs a single function. Preliminary estimates from UBS analyses indicate that the United States could install as much as 11 gigawatts (GW) of battery energy storage by the year 2010. Such installation represents \$17.2 billion in benefits to utilities. Coupled with \$9.1 billion in battery system purchases, the total national benefits reach \$26 billion.¹

GENERATION APPLICATIONS

- **Spinning Reserve:** If an electrical generation unit fails, the utility that operates it must have an alternative power source to prevent interruption of service to customers. Traditional reserve power sources require generators to be spinning in standby operation to respond to an instantaneous demand. Battery energy storage can eliminate the need for expensive standby operation and provide reserve power while utilities bring alternate power sources on-line.
- **Generation Capacity Deferral:** With growing electrical demand, utilities must increase generation capacity and face increasing procurement costs, environmental constraints, and public opposition to siting. Battery energy storage enables utilities to store electricity for dispatch at peak demand times. This efficient use of existing facilities allows utilities with constrained generation capacity to meet growing demands without immediate large capital investments.
- **Renewable Generation Support:** Renewable energy sources do not always provide their maximum energy at times when utilities have the greatest need. Also, most renewable energy sources provide fluctuating power that is less consistent than the power utilities need to deliver to their customers. Battery energy storage allows owners of renewable generation facilities to store energy for dispatch during peak demand and to deliver a constant power level from a fluctuating source.
- **Load Leveling:** During peak load times, utilities often need to operate expensive generation sources to meet customer demands. With battery energy storage, utilities can store electricity produced by inexpensive units during off-peak times and deliver the power during peak demand. Such load leveling is not economical for utilities with small differences between on- and off-peak costs, but can increase profitability for utilities with large differences in costs.

TRANSMISSION AND DISTRIBUTION APPLICATIONS

- **Transmission and Distribution Facility Deferral:** Utilities upgrade transmission and distribution lines in large increments of power capacity to meet projected load demands. Battery energy-storage facilities can dispatch energy at peak load times and support the existing transmission and distribution facilities. By adding small increments of battery storage, utilities can defer transformers and lines until load demands justify a large increase in capacity.
- **Transmission Line Stability:** Many routine events can cause generators in a utility to fall out of synch with the rest of the system. If the utility cannot quickly reestablish synchronous operation, the whole system can collapse. Battery energy storage can help utilities maintain system stability by discharging to provide power and charging to absorb excess power as system loading conditions change.
- **Voltage Regulation:** Without corrective measures, the voltage at the generation end of a transmission line is greater than at the other end of the line. Traditionally, utilities have used fixed and switched capacitors to regulate transmission line voltages. However, a battery energy-storage system that a utility has installed for another primary application can also regulate voltage, thereby augmenting the capabilities of existing capacitors and deferring the need for additional capacitors in the system.

¹ "Battery Energy Storage: A Preliminary Assessment of National Benefits" (The Gateway Benefits Study), SAND 93-3900, December 1993.

Utilities are moving away from large, centralized power plants toward smaller generation sources that are distributed geographically according to need (see Figure 3). The resulting functional and corporate changes will make the diverse and flexible capabilities of battery energy storage more valuable and cost effective. Distributed strategically in a utility network, a group of battery energy-storage units, each sized between 1 and 10 megawatts (MW), can yield greater benefits than a single centrally located unit of equivalent total capacity.

CUSTOMER SERVICE APPLICATIONS

- [illegible]

5

WHAT IS THE UTILITY BATTERY STORAGE SYSTEMS PROGRAM?

PROGRAM MISSION

DOE's Office of Utility Technologies sponsors the UBS Program at Sandia National Laboratories to identify utility applications and develop cost-effective battery energy-storage systems for utilities by the year 2000. The program supports development and testing of battery systems that utilities can use to meet growing technical and business demands. The program identifies markets for existing battery technologies and develops new technologies for existing applications.

Program Elements

The UBS Program sponsors systems analyses, technology development of subsystems and systems integration, laboratory and field evaluation, and industry outreach (see Figure 4). These efforts promote the development and acceptance of utility battery energy-storage systems.

Systems analyses identify and characterize utility-specific and national impacts of utility applications of battery energy storage. The UBS Program has quantified benefits of battery energy storage for specific utilities, refined the definitions of utility battery energy-storage applications, and estimated the dollar value of benefits of utility battery energy-storage for the nation by the year 2010.

Through cost sharing with industrial partners in *technology development of subsystems and systems integration*, the UBS Program improves battery energy-storage technologies. Subsystems engineering identifies ways to lower costs and increase performance of lead-acid batteries, to develop zinc/bromine and sodium/sulfur batteries, and to develop standard power-conditioning systems, control systems, and switchgear. System integration improves the ability of existing subsystems technologies to function together, and develops complete, modular units that include all of the required components of a battery energy-storage system.

Evaluation includes laboratory and field evaluations of battery energy-storage systems. Characterization of performance, maintenance requirements, and reliability of systems helps utilities evaluate battery storage, and helps manufacturers improve their products.

Industry outreach shares new information about batteries and battery systems with utilities. Efforts involve individual utilities, manufacturers, and the Electric Power Research Institute (EPRI). Journal articles and presentations for engineering and utility audiences, and other industry outreach efforts, publicize UBS Program activities and foster interaction among stakeholders in utility battery energy storage. For example, the UBS Program assists a utility interest group, the Utility Battery Group (UBG), to promote battery energy storage as a resource option for utilities.

Each program element develops and promotes battery technologies that utilities can use to address increasingly complex issues and meet the projected 115-GW increase in generating capacity needs by the year 2010.² The UBS Program develops battery energy-storage technologies that offer the most flexibility at the least cost.

Figure 4. UBS Program activity road map.

² "Annual Energy Outlook 1994 with Projections to 2010," DOE/EIA-0383(94), January 1994.

WHAT HAS THE UTILITY BATTERY STORAGE SYSTEMS PROGRAM ACHIEVED?

Systems Analyses

Systems analyses to identify utility applications with the greatest benefits included systems studies, feasibility studies, and opportunities analyses.

- *Opportunities Analysis Meetings (Phase 1)*: A series of working meetings were initiated in an effort to identify and characterize utility applications, define application requirements, establish standard cost breakdowns, assess national benefits, and identify market niches for battery energy-storage systems. Participants in the Phase 1 meetings included utility representatives, EPRI, battery and battery system manufacturers, Sandia, and consultants. A report of the findings will be published early in FY 1995.
- *National Benefits Study*: A benefits study that focused on spinning reserve, generation capacity deferral, generation dispatch, transmission line deferral, distribution substation deferral, and demand-side management, estimated that the capacity potential for battery energy storage through the year 2010 is approximately 11 GW. In addition, it was found that money saved through installation of 11 GW of battery energy storage is approximately 1.9 times the cost of installing the storage.
- *Qualitative Assessment of Battery and Superconducting Magnetic Energy Storage (SMES) Technologies*: A qualitative comparison of battery energy storage and SMES for utility applications was performed. A report that identifies the potential roles of each technology and necessary technology development was published in early FY 1994.
- *Chugach Electric Feasibility Study*: A feasibility study with the Chugach Electric Association was initiated as a follow-on to one of four systems studies conducted for utilities in FY 1992. The study will be a cost-shared venture between the UBS Program, Chugach, a neighboring utility (Golden Valley Electric Association), EPRI, and the National Rural Electric Cooperative Association (NRECA).
- *Sacramento Municipal Feasibility Study*: A feasibility study was initiated to determine the benefits, site requirements, and specifications for battery system applications throughout the Sacramento Municipal Utility District (SMUD) system. The study will also investigate the value of providing storage for the 40 MW of wind turbine capacity scheduled for installation and an additional 300 MW of other renewable energy capacity planned for the future.
- *Utility Energy-Storage Plan*: Preliminary concepts for an umbrella program to coordinate all of the energy-storage efforts within DOE's Office of Energy Management were developed. These efforts include batteries, SMES, hydrogen, pumped hydropower, compressed air energy storage, supercapacitors, and flywheels.

WHAT HAS THE UTILITY BATTERY STORAGE SYSTEMS PROGRAM ACHIEVED?

—continued

LEAD-ACID BATTERY TECHNOLOGY

Existing utility battery installations use lead-acid batteries. The first installations had high power and energy requirements and fixed, centralized applications. These facilities are large, and the flooded-cell battery systems regularly require both air agitation of the electrolyte and addition of water. These characteristics, and the ongoing shift toward a distributed utility, make utilities desire smaller, more flexible systems that require less maintenance than their predecessors. Therefore, UBS development efforts have focused on modular, transportable, and compact battery systems that require less maintenance than their predecessors. The AC Battery is a product of program efforts that exhibits progress in these areas (see Figure 5). The new VRLA batteries by GNB, cosponsored through program efforts, have smaller "footprints" and need less maintenance because they do not require watering (see Figure 6).

Subsystems Engineering

In cost-shared contracts, subsystems engineering efforts were focused on developing valve-regulated lead-acid (VRLA) battery technology. The goals of these efforts included increasing the number and type of utility applications that batteries can serve, reducing the size of batteries, and increasing their cycle life.

- *Lead-Acid Battery Technology:* In a cost-shared contract with GNB Battery Technologies Industrial Battery Company, testing of pressure relief valves in VRLA batteries was completed. Materials research to enhance the reliability of the valves was also performed. Joint UBS and GNB efforts to mitigate "growth" of the positive plates in batteries, minimize the amount of time necessary to recharge batteries, and reduce the possibility for short circuits had promising results.

Partly as a result of GNB/UBS Program efforts, an improved ABSOLYTE II VRLA battery, the ABSOLYTE IIP (see Figure 9, page 10), was introduced. Testing and analysis suggested design modifications to improve manufacturing, modular concepts to increase applications flexibility, and alternative materials to reduce internal electrical resistance and increase capacity of the battery. Capacity tests of the battery modules were performed in FY 1994.

Together with the University of Missouri, Pacific Gas & Electric Company (PG&E), and Puerto Rico Electric Power Authority (PREPA), the UBS Program and GNB completed a study that indicated that batteries represent less than 40% of the total cost of two battery storage facilities (see Figure 10, page 10). The study included a distributed peaking application at PG&E and a spinning reserve/area-frequency regulation application at PREPA.

- *Zinc/Bromine Battery Technology:* A cost-shared venture between Johnson Controls Battery Group Incorporated (JCBGI), and the UBS Program continued to focus on design, fabrication, and testing of parts for a 100-kilowatt-hour (kWh) zinc/bromine battery. The design for a system controller is complete and prototype testing is under way. Delivery of an eight-cell battery prototype will permit zinc/bromine battery testing in FY 1995.

To improve safety and efficiency of zinc/bromine batteries (see Figure 7), the UBS Program and JCBGI worked in conjunction with the University of New Mexico to find chemical agents to make bromine complexes that are less hazardous and more efficient than the present electrolytes. Many candidate agents were eliminated, and some agents were identified for further study.

Figure 5. An AC Battery is on test at Pacific Gas & Electric Company's test facility in San Ramon, California.

Figure 6. Low-maintenance, VRLA cells by GNB Industrial Battery Company can help reduce the footprint and cost of battery systems.

Figure 7. A 15-kWh zinc/bromine battery by Johnson Controls Battery Group Incorporated is on test at Sandia.

- **Sodium/Sulfur Battery Technology:** A cost-shared effort between Silent Power Incorporated (SPI) and the UBS Program focused on the design and fabrication of a 13-kWh sodium/sulfur battery. The design for sodium/sulfur prototype modules contains all of the features proposed for a modular, utility-scale, 600-kWh battery system (see Figure 11, page 11). At the end of FY 1993, all of the cell banks for the 13-kWh unit were ready for assembly and testing in FY 1994.

The second focus area of the UBS/SPI joint effort in FY 1993 involved the development of a 50-Wh sodium/sulfur battery cell with sulfur in the center of the cell. The design promises to achieve long service life for batteries in utility applications. Expectations that the seal that isolates the sulfur center will need improvement were confirmed by testing.

- **Electrical Technology:** Engineers from Sandia's energy storage and renewable energy centers gathered representatives from utilities and manufacturers, and individuals with expertise in batteries, photovoltaics (PV), wind, and superconducting magnetic storage for a meeting to develop a better understanding of several key power-conditioning system (PCS) issues, including costs of PCS design and manufacture, applications requirements for PCSs, and challenges inherent in developing PCSs for diverse applications. Findings from the meeting were published in FY 1994.

System Integration

Technology development in system integration focused on analysis and design modifications of a modular, lead-acid battery system for utility applications. Lead-acid technology was chosen for development over sodium/sulfur and zinc/bromine battery technologies because it has more near-term applications.

- **AC Battery:** In a collaborative effort between Omnion Power Engineering Company, Delco Remy, and the UBS Program, electrical and structural safety analyses were conducted and enhancements for a modular, lead-acid battery system were identified. Omnion formed a new company, called AC Battery Corporation, to produce a commercial product (also called AC Battery) for utilities and their industrial customers.
- **AC Battery/PV Hybrid System:** The UBS Program placed a contract with AC Battery Corporation to develop an AC Battery module for field testing in a hybrid PV system at a utility.
- **Utility-Scale Battery Demonstration:** The UBS Program assisted PG&E in the planning of a project to develop a transportable 2-MW/4-MWh battery system designed to meet distribution peak-load demands. UBS Program activities will include cost-shared development of a turnkey battery system from a single vendor. The contract will be awarded in FY 1995.

Evaluation

Testing efforts included field and laboratory evaluations of batteries and battery systems being developed for utility applications.

- **PG&E AC Battery Tests:** Construction of a test site at PG&E for the AC Battery in San Ramon, California, was completed. Plans for performance and longevity tests of the battery were published. Design and safety reviews were held to ensure that the system conformed to all procedural, performance, and safety requirements. Custom software that successfully performed supervisory control and data acquisition for the system at the manufacturer's site conformed to both PG&E's protocol and to EPRI monitoring instrumentation requirements.

SODIUM/SULFUR AND ZINC/BROMINE BATTERY TECHNOLOGIES

Development of alternative battery technologies will further reduce the size and life-cycle cost of utility battery systems. Sodium/sulfur and zinc/bromine batteries' life-cycle costs and size are lower than those of the lead-acid battery. Sodium/sulfur and zinc/bromine batteries also have better deep-discharge capabilities than lead-acid batteries. Research of both sodium/sulfur and zinc/bromine batteries focuses on developing modular and transportable storage systems that support flexible applications (see Figures 7 and 8). Both battery technologies are in advanced stages of development for utility applications. The UBS Program hopes to have demonstration modules sited with utilities within 5 years.

Figure 8. Testing of this sodium/sulfur battery module will assist in decisions to proceed with prototypes of larger module systems.

WHAT HAS THE UTILITY BATTERY STORAGE SYSTEMS PROGRAM ACHIEVED?

—continued

Figure 9. The improved VRLA battery, the ABSOLYTE IIP, by GNB Industrial Battery Company underwent capacity tests in FY 1994.

- **PREPA C&D Battery Evaluation:** Thermal testing and modeling were performed for flooded lead-acid batteries manufactured by C&D Charter Systems, Incorporated, for PREPA's battery project at Sabana Llana substation (see Figure 12). The testing validated the model of battery performance for frequency regulation. Refinements to the model of battery performance for spinning reserve are needed.

Industry Outreach

Industry outreach established new contacts and reinforced existing contacts between the UBS Program and utilities. This interaction allowed the program to identify and explore new utility applications of battery energy storage.

- **UBS Systems Program Review:** The UBS Program Review meeting was held in Valley Forge, Pennsylvania, in November 1992. At that meeting several utilities expressed interest in UBS Program activities. The next review will be in Baltimore, Maryland, in November 1994.
- **Utility Battery Group (UBG) Meetings:** The fourth UBG meeting was held in conjunction with the UBS Program Review meeting in November 1992. At that meeting DOE and EPRI announced plans to collaborate on design, development, and fabrication of separate, transportable, prototype battery systems for demonstration in utility applications.

The UBG held its fifth meeting in Indianapolis, Indiana, in May 1993. Utilities presented updates on utility battery energy-storage projects. The UBG steering committee invited Sandia and EPRI representatives to take nonvoting, advisory seats.

The sixth UBG meeting was held in Pleasanton, California, in November 1993, and the seventh meeting was held in May of 1994 in Dallas, Texas. At these meetings, the membership discussed and voted to establish a membership fee. The eighth UBG meeting will be held in Baltimore, Maryland, in November 1994.

Figure 10. System cost breakdowns for two utility battery storage facilities.

- *Niagara Mohawk Power Corporation AC Battery/PV System:* The UBS Program arranged to receive and publish operation data from an AC Battery module that Niagara Mohawk Power Corporation purchased to install with grid-connected PV.
- *Battery Energy Storage at the Olympics:* An opportunity to demonstrate battery energy storage as one of the power supply options at the 1996 Olympics in Atlanta, Georgia, is being pursued. Battery energy-storage systems may provide backup power to communications and television trailers and distribute power to remote event locations that local utilities do not support.
- *Fourth International Conference on Batteries for Energy Storage:* UBS representatives presented papers about benefits assessment and technology development at the Fourth International Conference on Batteries for Energy Storage in Berlin, Germany, in October 1993. The UBS Program staff moderated a conference session and will help to plan the Fifth International Conference in Puerto Rico in 1995.
- *International Lead and Zinc Research Organization (ILZRO) Review:* UBS representatives attended a meeting that ILZRO held in conjunction with the Fourth International Conference on Batteries for Energy Storage in Berlin in October 1993. At the meeting, participants reviewed the success of the UBS and discussed progress in distributed applications of utility battery energy storage in the United States.
- *Presentations and Publications:* UBS representatives presented numerous papers about utility battery storage at international and domestic energy conferences. Several technical reports are published by Sandia each year.

Figure 12. The 20-MW/14-MWh Puerto Rico Electric Power Authority battery energy-storage facility at the Sabana Llana substation (under construction in this photo) began start-up testing in FY 1994. The facility will provide spinning reserve and frequency control for the utility.

Figure 11. This proposed 600-kWh modular sodium/sulfur battery system is similar in concept to the modular lead/acid battery system.

WHAT ACTIVITIES ARE PLANNED BY THE UTILITY BATTERY STORAGE SYSTEMS PROGRAM?

Multiyear Plan

To ensure that the program remains focused on activities that will help to develop battery energy storage as an economically attractive utility resource by the year 2000, the UBS Program developed and published a program plan for fiscal years 1994 to 1998. The plan outlines the program mission and goals, strategies and tactics, management, activity schedule, resources, expected outcomes, and the metrics for measuring success. The plan also identifies the technical and programmatic activities that are necessary to promote widespread acceptance and use of batteries by utilities.

Program Milestones FY 1994 to FY 1998

- *Systems Analyses* milestones include a report of results of the Phase 1 Opportunities Analyses for battery storage (FY 1994). The UBS Program also plans to complete its utility feasibility study at SMUD (FY 1994).
- *Subsystems Engineering* milestones include conducting a power-processing workshop and issuing proceedings (FY 1994); delivering the SPI, 12-kWh, sodium/sulfur battery (FY 1994); delivering the JCBGI, 100-kWh, zinc/bromine battery (FY 1994); and delivering the GNB, VRLA, intermediate-design battery module (FY 1995). Performance of these deliverables will help to direct additional efforts.
- *System Integration* efforts will include delivery of the AC Battery to PG&E (FY 1994); completion of AC Battery/PV hybrid units (FY 1994); completion of the integration phase of PG&E's utility-scale battery demonstration (FY 1995); installation of a 500-kW transportable utility battery at a substation (FY 1997); delivery of a 500-kW/1000-kWh, zinc/bromine battery system to a utility (FY 1997); and delivery of 300-kW/600-kWh, sodium/sulfur battery systems to several utility sites (FY 1998).
- *Evaluation* plans include start-up and field testing of the AC Battery at PG&E (FY 1994); testing of the utility-scale battery demonstration at PG&E (FY 1996); cost-shared field testing at a utility site of a 250-kW/2-h battery system based on GNB VRLA batteries (FY 1995); and testing of zinc/bromine and sodium/sulfur battery systems at utility sites (FY 1998).
- *Industry Outreach* efforts will continue to promote interaction with utilities, manufacturers, EPRI, NRECA, ILZRO, and the UBG. The UBS Program plans to initiate operation of a Battery Technology Assistance Center (FY 1996).

Metrics of Success

The UBS Program has proposed a set of metrics to monitor program progress that will include many indicators: a reduction in cost per kilowatt and kilowatt-hour of commercially available utility battery systems; an increase in the number of installed utility battery systems; an increase in the megawatts of installed utility battery storage; installation of battery systems to defer generation, transmission, and distribution upgrades; an increase in the megawatts of installed renewable generation sources supported by battery energy storage; and connection of battery-supported renewables to the utility grid.

Through these and other indicators, the Advanced Utility Concepts Division of DOE's Office of Energy Management can monitor UBS Program success. The public will be able to evaluate the return on the tax dollars that the UBS Program receives. Utilities will be able to use these metrics to justify installation of additional battery energy-storage systems.