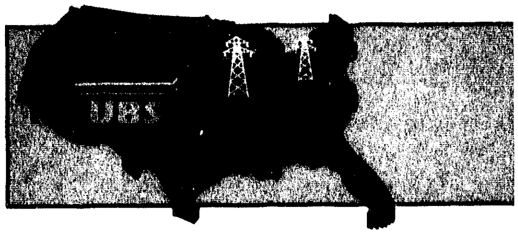
Foreword

Batteries have been used for more than 100 years for many essential applications, and the ability to store energy efficiently, economically, and safely has been a critical development in improving the quality of life throughout the world. An emerging application for batteries is the storage of energy for electric utilities. These batteries are the largest electric storage systems ever built. Battery systems the size of football fields with power and energy capacities of tens of megawatts and megawatt-hours are possible. The feasibility of such systems has been proven in several demonstrations around the world. However, these demonstrations have also identified improvements necessary before these systems can significantly benefit electricity consumers.

The Utility Battery Storage Systems Program, sponsored by the U.S. Department of Energy (DOE), is addressing the needed improvements so that the full benefits of these systems can be realized. A key element of the Program is the quantification of the benefits of batteries used in utility applications. The analyses of the applications and benefits are ongoing, but preliminary results indicate that the widespread introduction of battery storage by utilities could benefit the U.S. economy by more than $26 billion by 2010 and create thousands of new jobs. Other critical elements of the DOE Program focus on improving the batteries, power electronics, and control subsystems and reducing their costs. These subsystems are then integrated and the systems undergo field evaluation.

Finally, the most important element of the Program is the communication of the capabilities and benefits of battery systems to utility companies. Justifiably conservative, utilities must have proven, reliable equipment that is economical before they can adopt new technologies. While several utilities are leading the industry by demonstrating battery systems, a key task of the DOE program is to inform the entire industry of the value, characteristics, and availability of utility battery systems so that knowledgeable decisions can be made regarding future investments.

This program plan for the DOE Utility Battery Storage Systems Program describes the technical and programmatic activities needed to bring about the widespread use of batteries by utilities. By following this plan, the DOE anticipates that many of the significant national benefits from battery storage will be achieved in the near future.



Contents

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Acronyms & Abbreviations

BES	battery energy storage
CAES	compressed-air energy storage
DOE	Department of Energy
EMF	electric and magnetic fields
EPRI	Electric Power Research Institute
FIM	factory-integrated modular
GTO	gate turn off
IGBT	integrated gate bipolar transistor(s)
IRP	integrated resource planning
JCBGI	Johnson Controls Battery Group, Inc.
MGTF	Modular Generation Test Facility
OEM	Office of Energy Management
PCS	power conditioning system
PG&E	Pacific Gas and Electric Company
PREPA	Puerto Rico Electric Power Authority
PV	photovoltaic(s)
R&D	research and development
SES	stationary energy source
SIM	site-integrated modular
SMUD	Sacramento Municipal Utility District
SNL	Sandia National Laboratories
T&D	transmission and distribution
TBS	transportable battery system
UBG	Utility Battery Group
UBS	Utility Battery Storage
UES	utility energy storage
UPS	uninterruptible power supply
USBD	utility-scale battery demonstration
VRLA	valve-regulated lead-acid

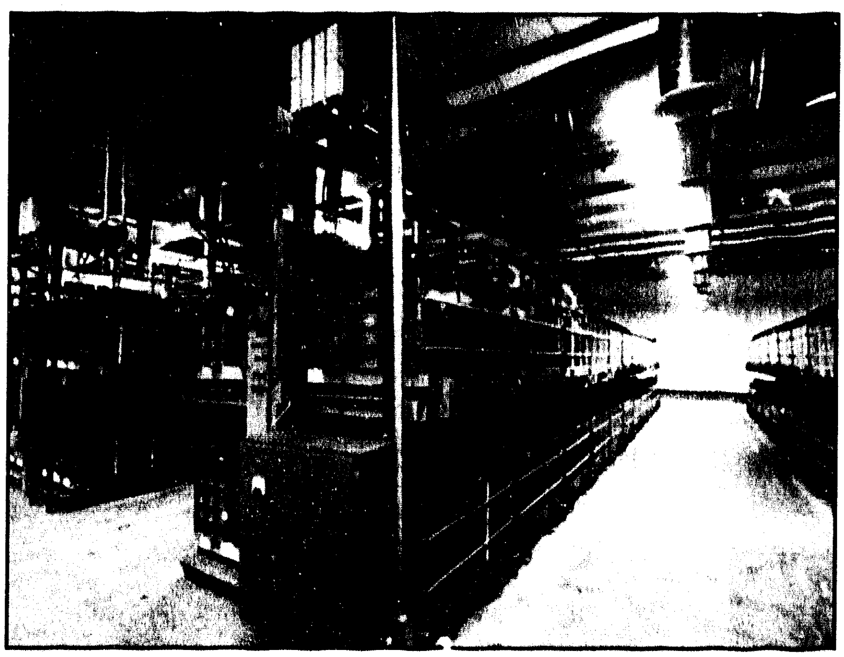
Executive Summary

The U.S. Department of Energy (DOE) is sponsoring a program that cooperates with the electric utility and manufacturing industries to develop battery storage systems as an economically attractive utility resource option by the end of this decade. Utilities are planning now for the generation, transmission, distribution, and demand-side management resources that will be needed in the future. During this planning process, utilities must consider several new strategic factors that include increased competition with respect to electricity supply, greater required energy efficiency, and more restrictive environmental regulations.

Battery energy storage (BES) is an option that, when developed, can help utilities address the new strategic factors by improving cost-effectiveness, reliability, and power quality and by reducing the environmental impact of electricity generation and distribution. BES systems function over a wide range of conditions, permitting flexible utility dispatch of energy. For example, as a generation resource, battery systems can store off-peak energy and provide power when it is needed. Battery systems located on the distribution system can defer or eliminate new transmission or distribution lines, resulting in cost savings and greater asset utilization. The incorporation of battery storage with renewable energy generators will provide greater utility grid stability, thus allowing increased use of this resource. Battery systems can also serve as a controllable demand-side management option that can provide customers improved power quality and uninterruptible power. A single BES system can be used to satisfy more than one of these applications, thereby greatly enhancing the value of the system. From an economic perspective alone, preliminary analyses predict a benefit-to-cost ratio of about two for the installation of 11 gigawatts of BES by 2010.

The Utility Battery Storage (UBS) Systems Program, established by DOE, performs needed analysis, development, testing, and technology transfer to enable battery systems to become a viable utility resource. Sandia National Laboratories (SNL) directs the UBS Program and works in close cooperation with private industry to accomplish this mission. The elements of this comprehensive program are (1) Battery Systems Analysis, (2) Subsystems Engineering, (3) System Integration, (4) System Field Evaluation, and (5) Industry Outreach.

In the **Battery Systems Analysis** element, high-value (BES) utility applications are identified and characterized. This element is the foundation for the entire program. Key tasks include national impact analyses and specific utility studies to quantify the costs and benefits of battery



Battery energy storage assists utilities such as Southern California Edison. Pictured here is the 10-MW/40-MWh Chino, California, facility.

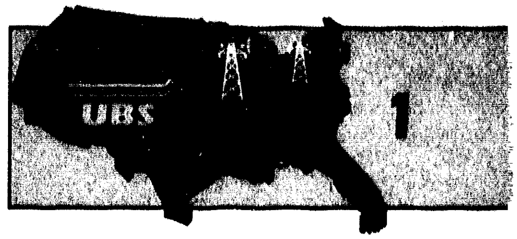
systems. Feasibility and conceptual studies are conducted, and application specifications and requirements are developed.

In **Subsystems Engineering**, both battery and electronic components are developed by industrial companies under cost-sharing contracts. Engineering and manufacturing development is being conducted for near-term batteries (valve-regulated lead-acid [VRLA]). Two advanced batteries, sodium/sulfur and zinc/bromine, will serve to develop future applications and increase market penetration. Power electronics and balance of plant components will also be developed as required to meet application needs.

As the various components of a BES system reach a mature development stage, the required engineering and manufacturing development is conducted in the **System Integration** element to bring the entire system to a test and demonstration stage. A modular battery system approach has been adopted as the preferred method to achieve maximum flexibility at the lowest possible cost. These systems may be factory integrated or site integrated. Cost predictions indicate that factory-integrated systems will be more cost effective and are receiving significant program focus.

The **System Field Evaluation** element involves taking prototype hardware that results from the System Integration element and conducting application testing to characterize system performance and life. In many cases, tests are conducted at utility sites under real conditions. In other cases, simulated tests are performed at facilities such as Pacific Gas and Electric Company's (PG&E) Modular Generation Test Facility. All test results are openly shared to provide utilities with battery system operating data and to allow developers to improve their designs.

Through the **Industry Outreach** element, the results of the UBS Program are communicated to all interested organizations. Presently, this activity consists of participation in the Utility Battery Group, an industry association, and through coordination with the Electric Power Research Institute (EPRI) and individual utilities. A Battery Technology Assistance Center for BES systems is planned that will permit utilities to obtain design characteristics and objective information easily.



Background

Electric utilities in the United States are entering the 1990s having to maintain electric service reliability in the face of increased competition, growing interest in greater energy efficiency, and heightened environmental awareness. In addition to these challenges, utilities in several regions are finding it increasingly difficult to meet demand with their existing generation resources. U.S. electricity consumption is expected to rise from 2.7 trillion kilowatt-hours (kWh) in 1990 to 4.5 trillion kWh in 2010, a 1.7% annual increase.[1] To meet the projected load growth, U.S. utilities will need new generation resources. As shown in Exhibit 1-1 (p. 10), even if utilities can maintain existing capacities by vigorous life-extension programs, approximately 200 gigawatts (GW) of new generation resources must be acquired to meet the future demand for electric power.

The U.S. electricity system consists of **generation, transmission and distribution,** and **end-use** components, which enable the production, delivery, and use of electricity for economic gain. The **generation** component provides the power plant capacity (megawatts) needed to produce electricity; **transmission and distribution** (T&D) provides the miles of lines (circuit miles) and equipment required to deliver the capacity; and **end use** refers to applications by the residential, commercial, and industrial consumers of electricity.

The need for additional T&D resources is increasing because of increased electric demand. Utility industry analysts project that the United States will require 170,000 miles of new high-voltage transmission lines by 2010, with a cost estimated to exceed $170 billion.[2] Concerns about environmental impacts and potential health effects of electric and magnetic fields (EMF) are delaying or preventing construction of most new transmission lines. The uncertain availability of adequate transmission resources will further weaken the national electric network.

Battery storage can reduce future need for additional transmission and distribution resources.

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1 National Energy Strategy (NES) Technical Annex 2, First Edition 1991/1992, DOE/S-008GP, U.S. DOE, Washington, D.C.

2 Staff Report, Electric Power Supply and Demand for the Contiguous United States 1989-1998, DOE/IE 0018, U.S. DOE, Washington, D.C., March 1990, pp.5-7.

Starting in 1990 (and each year thereafter), utilities began making larger capital investments in T&D than in generating capacity. Although this reflects a willingness by utilities to consider alternatives to traditional supply technologies (such as demand reduction, cogeneration, and third-party generation), it also reflects a significant escalation in the cost of installing T&D facilities. These costs result from more stringent local code restrictions, limits imposed by new state legislation, a growing NIMBY (not in my backyard) attitude, and a substantial rise in objections resulting from concerns about the possible health effects of EMFs. In a growing number of cases, these same factors prevent the installation of needed electric lines, requiring utilities to consider inefficient substitutes. This has caused negative repercussions on the economic growth potential of those affected areas.

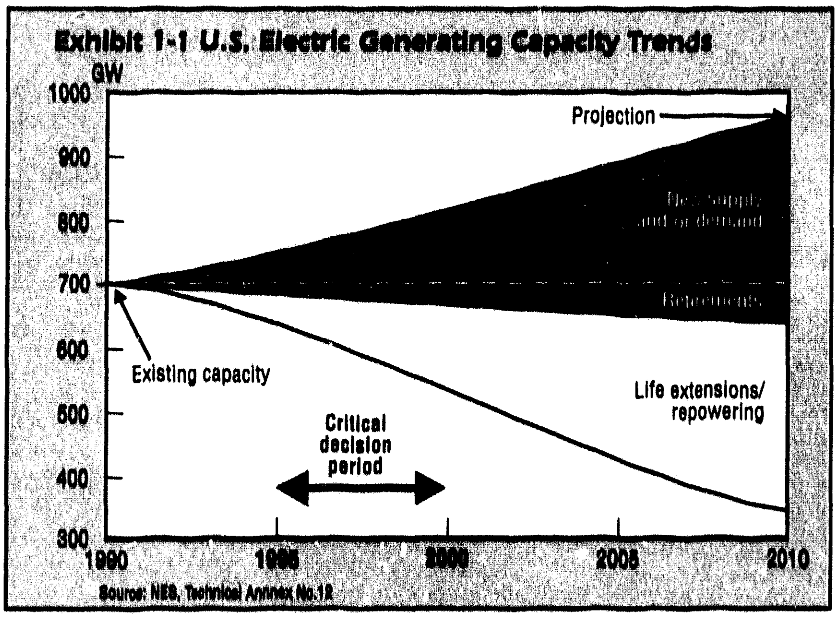


Exhibit 1-1. A need of more than 900 GW of generating capacity by the year 2010, up from 700 GW in 1990, has been projected. To meet this need, more than 350 GW of plant life extensions must be implemented, and more than 200 GW of new generating capacity must be acquired at a cost approaching $300 billion.

Given this environment, utility system planners have fewer options when seeking T&D expansion. Legal challenges and court delays are now part of virtually every new T&D project. Unless this trend can be reversed, the nation faces a substantial decline in reliable, on-demand electric service. Fortunately, new technology, such as battery storage, can alleviate many of the T&D problems. With battery storage, the existing system can handle large increases in power demand, and utilities can have far greater control over the routing and levels of power flows. They can also realize benefits such as improved efficiency of power transfer, avoidance of unwanted line loading, and reductions in backup or spinning reserve. For the consumer, the new technology can lower electricity costs. Furthermore, incorporation of battery storage into the T&D network can alleviate instability concerns, allowing utilities to incorporate greater percentages of renewables, cogeneration, and other distributed technologies. Thus, battery storage can help utilities move toward a distributed system with greater control and reliability.

Electric utilities must plan *now* for the generation, T&D, and end-use resources they will need for the next two decades. However, the rules that have traditionally guided utilities in their resource planning are changing. New rules have been promulgated as part of the National Energy Policy Act of 1992 that impact utility resource decisions over this planning horizon. The following strategic "drivers" have necessitated changes in these rules that will affect the entire utility industry:

Competition—The desire to foster competition for electric service is resulting in an "unbundling" of the generation, T&D, and customer-service aspects of the industry. Rules regarding

Exhibit 1-2 Electrical Power Network of Today and Tomorrow

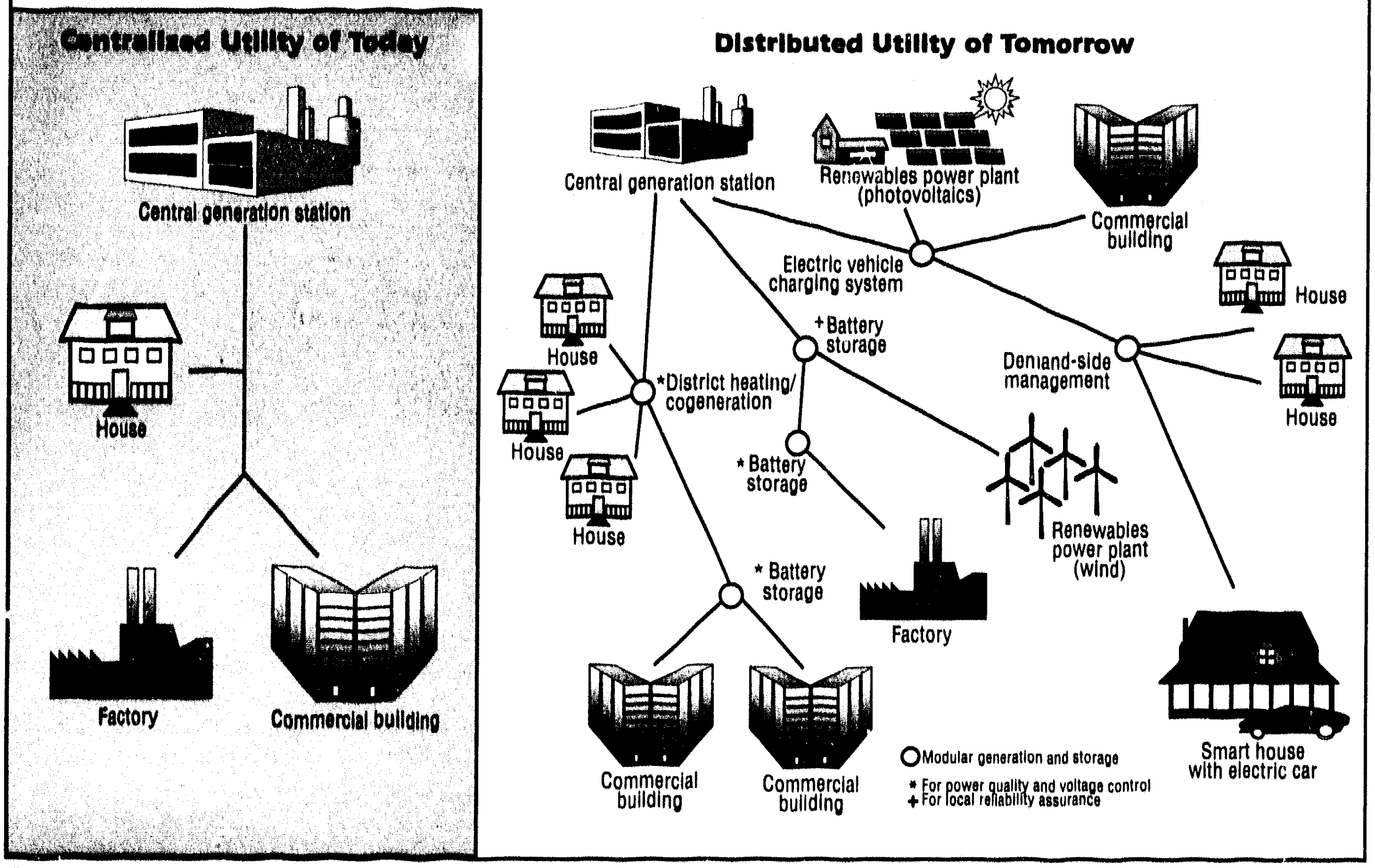


Exhibit 1-2. The traditional utility supplies customers with electricity produced at centralized power plants. This concept is expected to undergo changes in which the utility of the future will likely provide its customers with a larger array of services and will obtain its power from a variety of energy sources.

generation capacity acquisition, transmission access, and large-customer service are reshaping the traditional regulated monopoly.

Efficiency—Greater emphasis is being placed on avoiding the acquisition of new resources through demand-side management, conservation, and increased use of existing assets. Improving power quality and encouraging conservation and demand-side management through customer service are also being recognized as ways to improve efficiency.

Environmental Concerns—New regulations (e.g., the Clean Air Act) and greater public sensitivity to environmental issues are forcing utilities to consider future resources that will minimize environmental impacts.

Reflecting the emergence of these drivers, traditional utility resource planning is giving way to integrated resource planning (IRP). This new resource acquisition method considers the overall value of supply and demand resources, thereby ensuring cost-effective, efficient, cleaner, and more reliable use of electricity. Furthermore, the traditional utility is giving way to the distributed utility illustrated in Exhibit 1-2 (p.11). This new structure increases the complexity of the electric network in an effort to employ those utility resources with the greatest value. Utilization of technologies such as energy storage, photovoltaics (PV), or wind generation is a possible solution to the problem of how to achieve greater asset utilization and greater operating efficiency while reducing environmental impact and maintaining reliability.

Exhibit 1-3 Components of a Utility Battery System

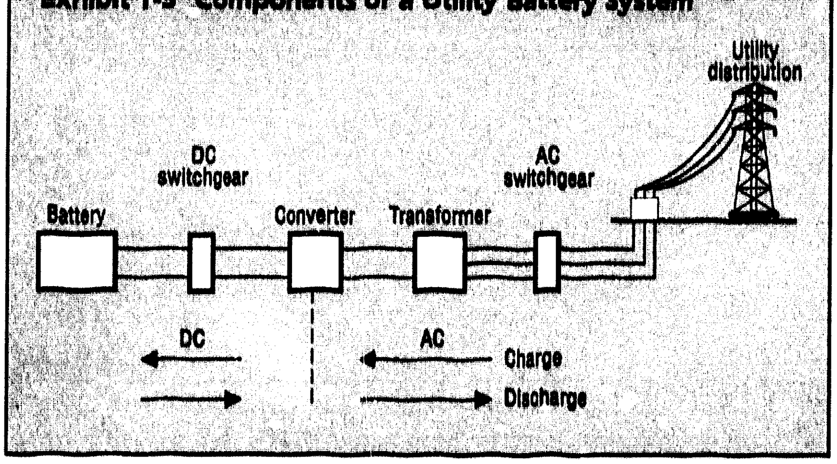


Exhibit 1-3. A battery system is usually remotely operated and consists of batteries, a power converter, and a supervisory control and data acquisition system, usually housed in the same building. The batteries for today's systems are lead-acid, but improved lead-acid and advanced battery types (sodium/sulfur and zinc/bromine) are under development. The power converter inverts DC battery power to utility-grade 60-Hz AC and rectifies 60-Hz AC line power to DC. To charge the battery, there may be a separate transformer between the transmission line and the converter, and there may be a separate float charger to top off the battery charge. The typical system also has a variety of control and safety features, such as circuit breakers, fuses, and disconnects.

Exhibit 1-3 is a simple schematic of a utility battery system. However, utilities have not adopted battery storage because its costs continue to outweigh its benefits for single-purpose applications. Batteries have been promoted for more than a decade for load-leveling and peak-power-supply applications. Battery storage can help utilities manage their generation, transmission, and distribution assets by increasing utilization of existing equipment and can also help them defer or eliminate the need for costly capital improvements. Furthermore, there currently is a lack of commercially available, integrated battery systems for utility applications. In the last few years, the IRP perspective has emerged, which recognizes the range of mutually compatible benefits offered by battery systems that will be important in the utility system of the future. Battery systems can be used to reduce the stress on individual transmission lines that are near their peak rating by reducing substation peak load. The same battery system also can provide area regulation, voltage stabilization, and voltage regulation, and it may increase power quality and reliability for specific customers. On the customer side, battery systems can supply peak power requirements, thereby benefiting customers while providing demand-side management resources to utilities. In combination with renewable generation systems, batteries can enhance utility network stability and allow greater utilization of photovoltaics and wind resources. Battery systems, with their siting flexibility and minimal environmental impact, can also address several environmental concerns affecting utilities today, including air emission standards and EMF effects.

The prospect of generation requirements of 200 GW of new capacity in the next two decades has prompted a variety of federal efforts to reduce capital investment and to expand the options for satisfying growing demand. The resulting research and development (R&D) programs support both traditional and alternative supply technologies as well as energy-efficiency R&D and conservation programs, which limit demand, further helping utilities to meet generation requirements.

DOE has recognized the nationwide potential for battery storage and is helping industry develop the technology as a competitive resource option for electric utilities to use beginning in the mid- to late-1990s. Thus, DOE is supporting a program to assist the utility industry in making battery storage a resource option worthy of utility consideration in the 1990s. The DOE UBS Program, sponsored by the DOE/ Office of Energy Management (OEM) and directed by SNL, focuses on identifying the value returned for utility investment in battery storage, developing improved batteries and components for utility applications, integrating components into well-designed systems available to utilities, and coordinating activities with the utility sector to promote battery storage.

SNL has been involved with DOE in the development of advanced rechargeable batteries for stationary energy source (SES) applications for more than 10 years. This UBS program is implemented primarily through development contracts with private industry. Recently, the focus of this program shifted to encompass not only battery development, but also specific utility systems analyses that seek to quantify the benefits of battery storage and system development.

Specific utility systems analyses have been conducted with several interested utilities. These analyses have identified a number of potential benefits for battery storage in utility systems that have increased significantly during the last few years. Studies by EPRI and others have also identified many utility scenarios for which battery storage is economically and environmentally important. These applications may provide significant economic and operational benefits to utilities, well beyond those of the traditional load-leveling concept.

In other UBS-related projects, a contract for engineering improvements of VRLA batteries is in progress. The project is focusing on increasing life, reducing cost, and understanding utility needs of VRLA batteries. The contract has significant utility involvement to ensure that systems issues and requirements are addressed.

DOE's Utility Battery Storage Systems Program is conducted at Sandia National Laboratories, Albuquerque, New Mexico.

Another lead-acid engineering development is with the AC Battery concept. The idea, patented by AC Battery Corporation, consists of truckable power systems complete with battery, inverters, and connections that are ready for installation at utility or customer substations. This reduces the engineering and manpower costs of setting up a storage system and gives users a turnkey, portable system with 250 kW/167 kWh of storage.

Other battery development contracts are in progress for sodium/sulfur and zinc/bromine technologies. A contract with Silent Power, Inc. (SPI), is in place to continue development of sodium/sulfur battery system designs specifically for utility applications. For the zinc/bromine technology, a $1-million-per-year contract was placed in August 1990 with Johnson Controls Battery Group, Inc., to develop a 100-kWh design for utility applications. Promising concepts are being pursued to resolve cell stack sealing and electrolyte flow nonuniformity problems.

In addition to the above work, SNL has in-house efforts for contract management, prototype evaluation, and applied research activities. The evaluation activities consist of standardized testing of deliverables to characterize performance, determine safety, and identify life-limiting mechanisms. Applied research tasks focus on reclamation of sodium/sulfur cells and improved materials for zinc/bromine batteries.

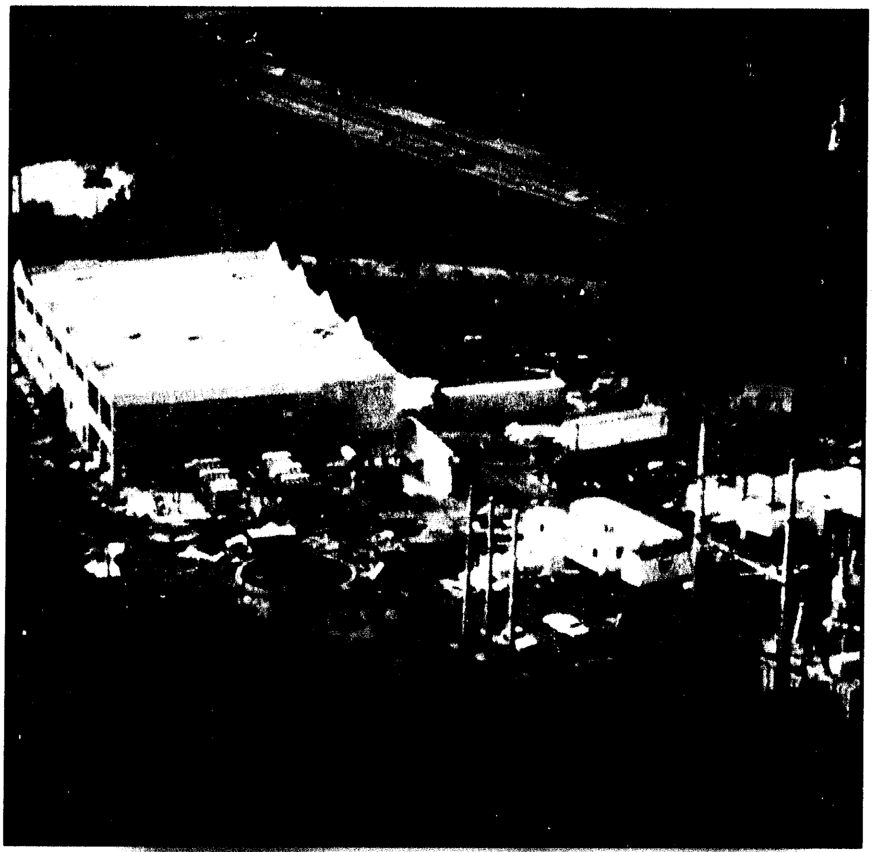
Battery Systems in Utility Applications

Role and Potential Benefits

In the late 1980s, utilities began moving away from large, centrally located generation and storage facilities to a more distributed utility network (e.g., Exhibit 1-2, p.11) as they began to recognize the operational and economic advantages of these smaller, distributed sources of generation and storage. These sources gained wider acceptance and were supported by planning concepts such as distributed utility planning and IRP. In these concepts, the value of storage increased as it was used in smaller sizes, located lower in the utility network, and sited closer to the end user.

Formerly, pumped hydroelectric was the only storage technology available that utilities accepted as technically and economically viable. Other storage technologies, such as compressed-air energy storage (CAES), had some success in Europe, but had not found acceptance among U.S. utilities. Despite its attractive economic attributes, pumped hydroelectric storage is limited by siting constraints and environmental opposition. Most sites suitable for pumped storage have already been developed, and permits for new sites will face serious environmental opposition. CAES has similar siting disadvantages, and both technologies are more economical at larger sizes, typically greater than several thousand megawatt-hours of storage capacity.

Until recently, BES for utility applications was regarded as a long-duration, large central-station storage device and had to compete with pumped hydroelectric storage and CAES in utility evaluations. Although the capital costs per kilowatt-hour of stored energy decrease for both pumped hydroelectric storage and CAES with increasing capacity, the capital costs per kWh remain relatively flat for battery systems as their capacity increases. Under these economic assumptions, in which battery storage was required to provide eight hours or more of storage capacity, it was not always a viable option in utility planning. Thus, until the mid-1980s, utilities that needed storage had few options; both pumped hydroelectric storage and CAES were limited by siting constraints, and BES appeared too expensive in the larger sizes.



The UBS Program assists industry in developing battery storage facilities such as this 20-MW plant at the Sabana Llana Substation of the Puerto Rico Electric Power Authority.

Exhibit 2-1 Uses and Benefits of Battery Systems

Generation Applications

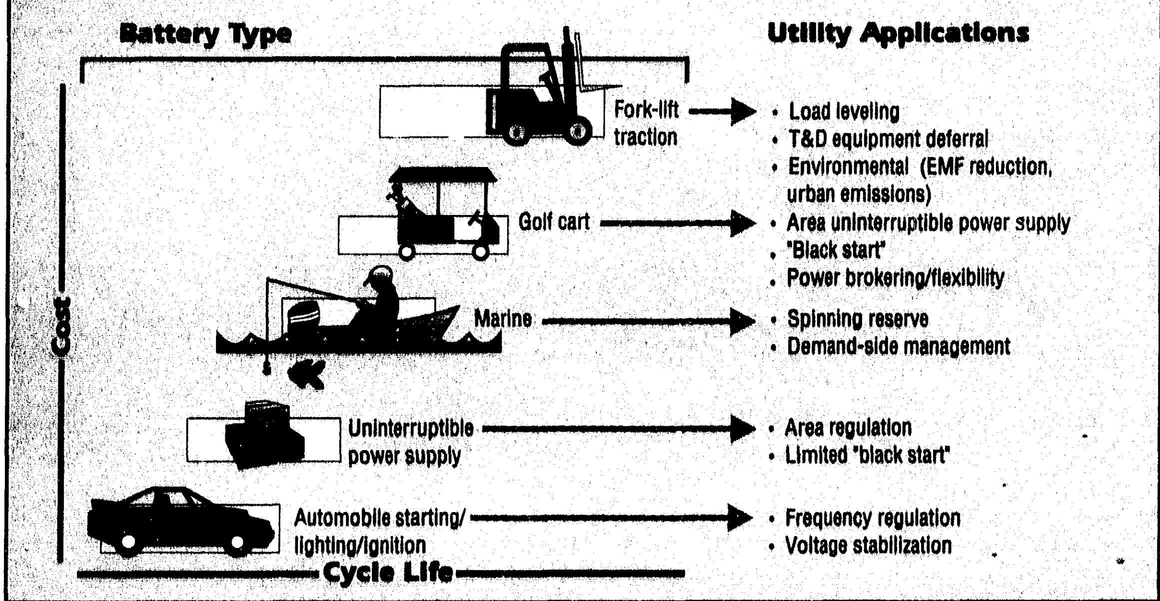
Load Leveling and Generation Deferral
Utilities can realize great savings by reducing or "leveling" their peak loads. When a utility shifts a portion of its peak load to off-peak hours, it utilizes baseload power more and saves the expense of running costly peak-load units. When a utility uses off-peak generation capacity to meet peak load demand, it delays the need to build expensive new generation capacity to meet the demand. One way to level loads is to store energy generated at baseload plants in a battery system during off-peak periods for later use.

Load Following
Load following requires frequent but modest power variations that can reduce plant life and increase maintenance costs. When rapid changes of load occur, power must be run from no load to full load over the shortest possible amount of time. Batteries can constantly switch from charge to discharge to help the system meet the actual load curve. Battery power can be varied over the full battery capacity range with essentially no loss of converter life and with little effect on battery life.

Area and Frequency Regulation
According to the North American Electric Reliability Council, every utility must provide the power required by its customers without sending unwanted power to, or absorbing power from, neighboring utilities. This ensures that each utility provides an equitable contribution to resolving any generation imbalances. Both area regulation and frequency regulation result in the utilities maintaining their 60-Hz operating frequency. Battery systems can be used to provide area regulation by varying battery power from minute to minute to meet the actual system load.

Spinning Reserve
Spinning reserve is the reserve capacity that utilities must have available at all times to replace their largest unit in case of failure. Spinning reserve is costly to utilities because it requires them to use units that are powered but loaded below their maximum capacity. Because batteries can be quickly started or changed from charging to discharging, they can be used economically to meet spinning reserve requirements. Batteries can offset the need to run plants at partial load or offset the need to run high-cost plants.

Exhibit 2-2 Commercially Available Batteries for Many of Today's Utility Applications



Transmission and Distribution Applications

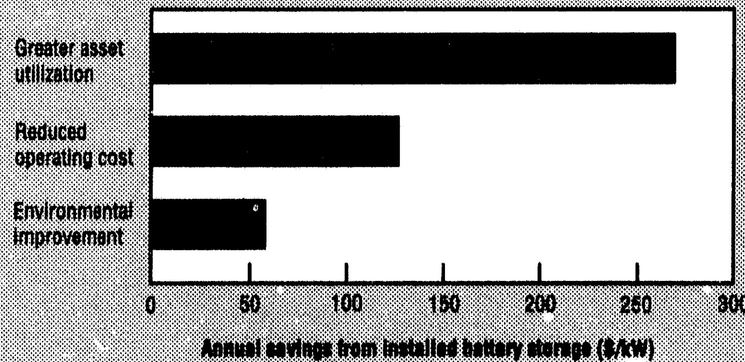
Line and Transformer Deferral
When the T&D system reaches its threshold, a utility must add a new line or transformer. Because load grows gradually over time, this expensive line or transformer is underutilized during its first years. If utilities could defer the investment in lines and transformers, they could save a great deal of money. Because battery systems are modular, they can be added in stages as the load increases. Batteries defer investment by supplying a portion of the peak load and by supplying capacity to meet load growth wherever needed on the T&D system.

Voltage Stability and Regulation
Utilities use operators and automatic voltage controls to regulate drops in voltage caused by an increase in electricity demand or a transmission outage. When disturbances on a heavily loaded network cause voltage to drop quickly, the system is considered unstable. One costly solution to this problem is to add lines and transformers to strengthen the system. Battery systems are a very fast, cost-effective way to improve voltage regulation because they can supply active power when heavy transmission loading or transmission outages cause low voltage.

First Swing Stability and Damping
When a transmission line fault decreases the power transfer in a network, generators at the "sending end" start to spin faster, and generators at the "receiving end" begin to slow down. If this "first-swing response" is not stabilized, the generators can lose synchronism, and the power system will collapse. Batteries can stabilize a system after a fault by absorbing or delivering power to the generators as needed to keep them turning at the same speed.

Damping
Without sufficient damping, oscillations (see first swing stability) sometimes grow to a point at which there is no longer synchronism in the system, and eventually these oscillations can cause the whole system to collapse. Batteries can reduce oscillations in generators by absorbing power when machine speeds are high and supplying power when machine speeds are low.

Exhibit 2-3 Projected Annual National Benefits* in 2010 from Incorporation of Utility Battery Storage Systems



* Preliminary results of site-specific utility systems studies; the benefits are not mutally exclusive for each battery installation.

Battery systems at the sending and receiving generators help to reduce oscillation over time.

End-Use Applications

Peak Shaving
Utilities employ incentives to encourage consumers to use less electricity by reducing load during peak periods, building load during off-peak periods, and shifting loads. By siting batteries so that they provide power to large customers, utilities can influence and manage these customers' load patterns. Additionally, customers can use the technology to take advantage of specially designed innovative rates such as interruptible and time-of-use rates.

Improved Power Quality and UPS
A growing number of utility customers are sensitive to computers and microprocessors that require uninterruptible power supply (UPS). Because even a brief interruption can incur a large expense, these businesses are willing to pay extra for a guarantee of uninterrupted service. Batteries can improve the reliability of service by providing a source of uninterruptible power in the event of a generator or transmission line failure. Battery storage also can meet the needs of these "premium grade" customers by supplying power that is free from surges, spikes, harmonics, and millisecond distortions.

Now that utilities are moving toward distributed networks, BES plays a flexible, multifunction role in the entire utility system. It is no longer a large, centrally located, single-function option. Instead, it can perform multiple roles and potentially provide much needed relief sought by utilities in managing their system resources. Exhibit 2-1 (p. 16) depicts the range of applications that battery storage can provide to electric utilities. For instance, battery systems can provide spinning reserve capacity that would otherwise require combustion turbines or a small coal unit. Batteries can also provide frequency regulation and reduce the loading of substation transformers, thereby extending their life and stabilizing transmission line oscillations. This would also increase their load capability and reliability. On the customer side of the meter, battery systems can improve power quality and reduce peaks, reducing the demand charges paid by customers for peak-power usage.

The many benefits of battery storage apply to every aspect of the electrical system: generation, transmission and distribution, and end use. The value of these benefits varies widely, depending on the type of utility, geographic location, generation mix, and other operational problems. For example, a primary attribute of a battery system is its extremely fast response to changes in electrical load. Conventional generating units take minutes or even hours to ramp up, whereas battery systems can deliver full power in fractions of a second. Another benefit is that battery systems will allow utilities to cut costs by using their plants more efficiently and by enabling them to defer investment in new plants. This is especially relevant because regulations restrict utilities from passing on the costs of new construction to their customers. With storage batteries, utilities can meet load growth, use their plants more efficiently, and avoid financial risks associated with new construction. Some ways that batteries can serve utilities are described in Exhibit 2-2 (p. 16).

Although it is difficult to accurately estimate the value of these national benefits, forecasts have been made by extrapolating the value from site-specific case studies. Preliminary estimates of annual savings to the nation can be found in Exhibit 2-3 (p. 17), which shows the major benefits of battery energy storage to utilities.

Acceptance of Battery Systems

Battery systems offer significant potential benefits to utilities, but several technical, institutional, and market-related barriers prevent the introduction of battery storage technology into the commercial marketplace. The barriers are discussed in Exhibit 2-4 (p. 20) and highlighted in Exhibit 2-5 (p. 21). The following are primary barriers:

- Difficulty in quantifying the value of battery storage benefits for multiple utility applications
- Nonavailability of a single supplier for utility battery storage systems
- Lack of detailed data on the performance, reliability, and costs of batteries and battery storage systems
- Lack of awareness that battery storage can perform a wide range of applications for electric utilities
- High capital cost of battery and power converter components for single-purpose applications when compared with technology alternatives (e.g., combustion turbines, static var compensators).

The last issue, high capital cost of battery and power converter components, is particularly important. Reevaluating the capital costs of key components is critical to reducing the life-cycle cost of battery systems for utility applications. Additional development to improve the cost and cycle life of candidate battery technologies is still necessary. Conventional, flooded lead-acid batteries are the only currently available technology that is mature and cost-effective enough to have widespread impact on near-term utility needs. Improved lead-acid batteries that could be ready for commercialization within five years, such as the VRLA battery, could further reduce battery operation and maintenance costs by eliminating the need to add wate Other VRLA benefits are increased battery system life and a reduced battery footprint. The use of advanced batteries (potentially available within six to eight years) offers still greater potential for reduced cost and could enhance market opportunities. The two advanced battery technologies currently being developed for utility energy storage are sodium/sulfur and zinc/bromine. Both batteries use low-cost materials and offer cost advantages over lead-acid because of their higher performance (sodium/sulfur) or low-cost manufacturability (zinc/bromine).

Finally, improving the design and manufacture of the power conversion system also will greatly reduce battery system costs. There is a strong need for developing lower cost, standardized power conditioning system (PCS) designs with improved performance characteristics. Rapid advances in power conversion technology could have significant impact on PCS designs. Until recently, gate turn off (GTO) switches were the preferred device for high-rate PCS designs because of their higher power ratings. Integrated gate bipolar transistors (IGBT), which were previously available only for lower power ratings, are now being designed for higher power ratings and offer operational as well as cost advantages over GTOs. Eventually, IGBTs or similar devices could replace GTOs as the preferred device for large PCSs. The fundamental circuit design of power conversion devices is also changing, and new circuits, such as the resonant frequency power converter, are being designed that will have higher power capabilities and promise lower costs. A PCS improvement effort for battery systems also offers benefits for renewable technologies, such as PV and wind, which have similar needs regarding the availability of PCS hardware.

Exhibit 2-4 Barriers to Battery System Acceptance

Technical Barriers

Insufficient Operating Data and Experience

Private industry generally requires considerable testing, evaluation, and experience before it is willing to invest in a new technology. The amount of data on lead-acid battery systems is limited, and the confidence level that utilities place in the technology must be boosted through additional testing, evaluation, and application before large-scale deployment can occur. There are a number of lead-acid battery storage projects in progress that will aid in building confidence in the technology, but the results of these projects will need to be verified and replicated before utilities will invest.

Insufficient Understanding of Power Regulation Applications

Until recently, battery systems were viewed primarily as load-leveling technology, and the development focus has been strictly for energy storage applications. However, there is growing evidence that the benefits of battery storage in power regulation applications may be substantial enough to justify the design of battery systems specifically for these applications. Since potential savings are significant, there is a need to gain a better understanding of utility storage applications and to design systems to perform power management functions.

Uncertain Battery Life

There have not been enough utility battery projects in existence for long enough to generate sufficient information on the expected life of a battery in a utility application. This makes it difficult to calculate the total cost of a battery project over a 30-year lifetime. More testing in the field and under simulated laboratory conditions is needed.

Integrated Modular Designs Not Readily Available

Simple, integrated, and modular battery systems can reduce costs, diminish installation and operation requirements, and allow utilities and industrial customers to match capacity with load growth. Smaller modular construction allows the user to meet the projected load growth incrementally instead of building one large system to meet growth for the next 10 or 20 years. Despite these advantages, modular integrated systems are not commercially available.

Battery Research and Development Needs

Despite the fact that the lead-acid battery has been in use for a wide variety of applications for over a century, the technology (particularly VRLA battery technology) could benefit from fundamental R&D efforts. There is a need for near-term R&D aimed at correcting some deficiencies of lead-acid batteries and developing a new generation of products with improved performance at lower cost.

State-of-the-Art Power Conversion Systems Not Readily Available

Although the technology exists for producing converters able to meet utility system requirements, and there are a number of modular products on the market, state-of-the-art power conversion systems specifically designed to meet battery storage energy management needs are not readily available and are expensive. There is a need for lower cost power conversion systems and control designs for BES systems.

Institutional Barriers

Utility Aversion to Unnecessary Risk

The regulatory and economic environment in the late 1970s and 1980s caused the electric utility industry to become increasingly aware of the risks involved with investing in and building electricity supply facilities. Consequently, many utilities avoid unnecessary corporate and financial risk. As deregulation continues, however, competition in the electric power industry will cause utilities to become aware of low-cost, innovative, and effective ways to meet their customers' needs. Although in the past utilities tended to emphasize the risks involved with adopting battery storage, competition will force utilities to change strategies and emphasize the opportunities afforded by battery storage.

Utility Rate Structures
The economic attractiveness of deploying battery storage depends not only on the customers' energy demand profile but also on the rate structure of the utility supplying the power. Whereas traditional rates are most widely used and do not vary with the time when electricity is consumed, battery storage is generally more favorable because it offers time-of-day pricing.

Market-Related Barriers

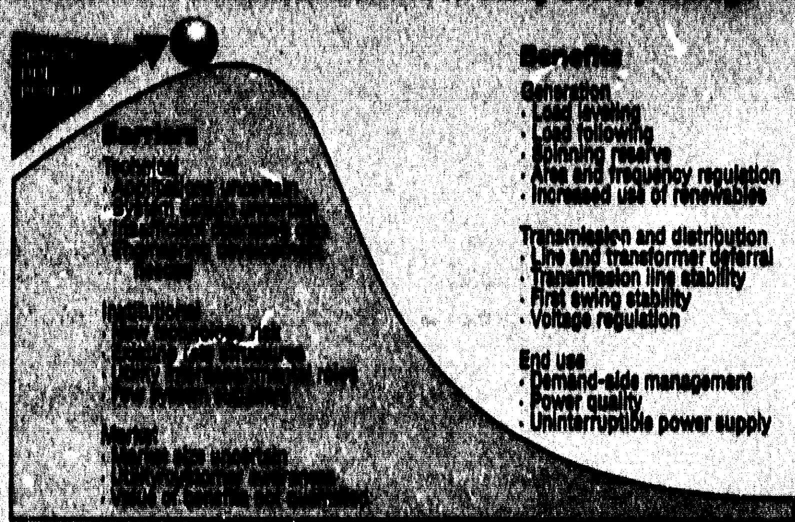
Large First Cost
Battery storage typically requires a large initial capital investment. These costs can be significantly reduced by decreasing the one-of-a-kind engineering that goes into each system by introducing standardized system integration approaches and compatible subsystems. Also, there is substantial potential for cost reduction through standardized designs in volume markets, which will require a sufficient increase in demand for battery systems for market forces to drive initial investment costs down.

Market Size and Stability
The aggressive marketing of battery systems and the development of new product lines require significant investment on the part of battery manufacturers. In the past, vendors have been unable to justify making these large investments because of uncertainties related to the size and stability of the potential market. Recently, vendors have become aware of the many benefits of battery storage and the potential savings the technology offers to users. Additionally, as the number of battery projects in operation worldwide increases, manufacturers are becoming convinced that there is a stable, potentially large BES market and are only beginning aggressive pursuit of it.

Utility/Customer Awareness
Despite efforts to educate utilities and other potential buyers about the benefits of battery storage, there remains insufficient awareness of the technology. Communication and literature must be improved to educate the market more effectively regarding the opportunities provided by battery storage.

Difficulty in Quantifying Dynamic Benefits
The dynamic benefits of battery storage can represent a substantial amount of the total savings from storage, but because these benefits are difficult to quantify, utilities are only beginning to examine the dynamic benefits of storage to determine their full worth.

Exhibit 2-5 Benefits and Barriers to Utility Battery Storage



Program Description

Program Mission and Goals

The mission of the UBS Program is to assist industry in developing cost-effective battery storage systems as a utility resource option by the year 2000. To be viable, future resource options must be commercially available as complete systems, and providing these systems in coordination with industry is the focus of the UBS Program. To accomplish this mission, DOE has established the following goals for the UBS Program:

- Identify and evaluate the benefits of battery storage in specific utility applications
- Develop improved battery system components including energy storage and power conversion devices
- Develop optimized, modular, multifunction battery storage systems
- Characterize the performance of integrated systems with on-site demonstrations
- Increase industry awareness of the benefits of battery storage and options for providing it.

Researchers in the UBS Program work to develop improved battery system components and to identify and evaluate the benefits of battery storage in specific utility applications.

Program Strategy and Tactics

DOE will achieve the UBS Program goals through its strategy of direct assistance to private industry, specifically in the development, evaluation, and implementation of battery storage system technology. The commercial introduction of battery systems will likely occur after validation of benefits analysis and field testing at utilities. The approach is aimed at analyzing applications through system and feasibility studies and then assisting utilities in developing, installing, and testing battery systems. DOE serves as the catalyst for coordinating activities among developers, manufacturers, and users of battery systems, and DOE is providing the impetus to assure that cost-effective UBS systems are available by the year 2000.

To achieve its mission, the UBS Program uses the following tactics:

- Soliciting industry commitment through cost sharing
- Identifying as many uses for batteries as possible and quantifying the value of multiple-benefit applications to utilities
- Reducing capital and life-cycle costs of batteries, converters, and controllers and introducing integrated systems for purchase

- Increasing utility awareness of, and interest in, battery systems.

The expected results of the UBS Program are that utilities

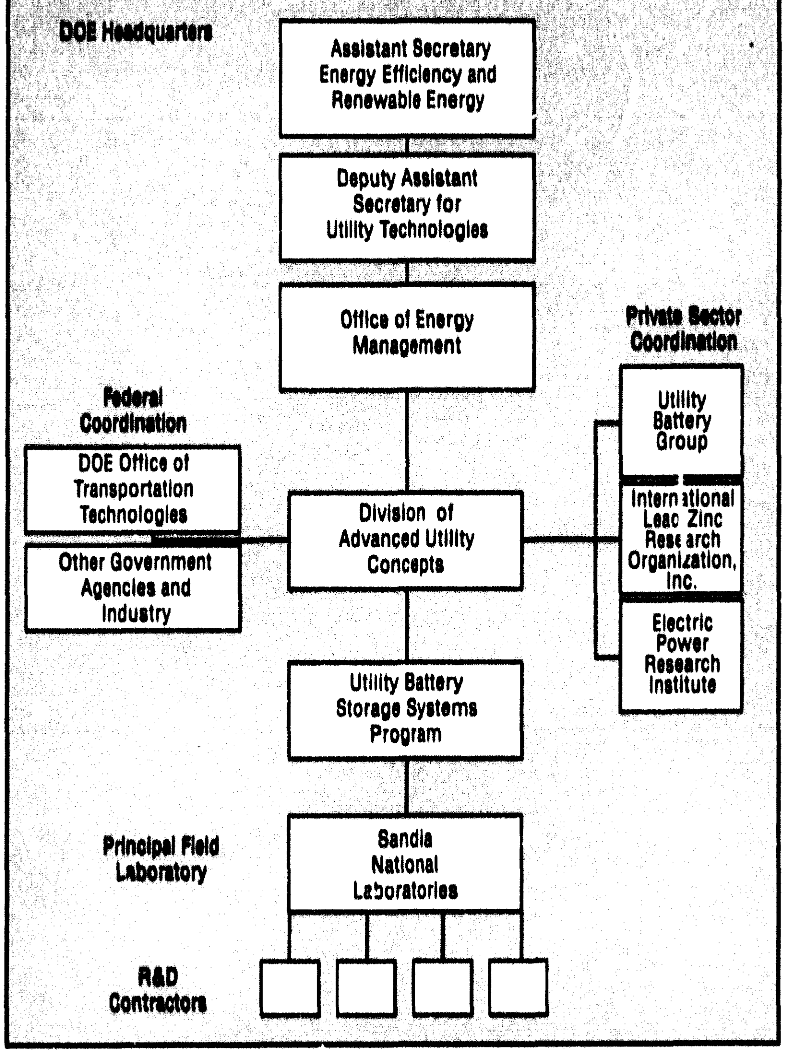
- Will be fully informed of battery storage as a resource option
- Will have access to tools and techniques to assess the costs and benefits of battery storage
- Can call on qualified vendors to install integrated or "packaged" systems quickly to solve utility problems
- Can integrate higher performance batteries into future systems to capture a wider variety of utility benefits at increasingly competitive costs.

The UBS strategy includes working with utilities in each element of the program to provide credible validation of these benefits.

Program Management

The UBS Program is one of seven R&D programs assigned to OEM. This office is one of three organizational units reporting through the Deputy Assistant Secretary for Utility Technologies to the Assistant Secretary for Energy Efficiency and Renewable Energy. A decentralized management scheme is employed by the UBS Program. SNL is the cognizant laboratory responsible for the day-to-day activities of the UBS Program. Exhibit 3-1 presents the UBS Program management structure.

Exhibit 3-1 UBS Management Structure



The management, operation, and direction of the UBS Program are established by federal energy policy as most recently represented in the National Energy Strategy and the Energy Policy Act of 1992. The broad policy outlined there is interpreted by DOE officials to establish programmatic missions and goals, which results in general guidance and directives to ensure that federal programs are consistent with energy policy. Congress significantly affects the activities and directions of the UBS Program through budget appropriations and other legislation. Furthermore, special advisory boards, interagency and international committees, and technology participants in the private sector submit recommendations for the program, which are then given serious consideration by program management.

DOE Headquarters assigns areas of responsibility to SNL, which is then responsible for the achievement of program goals and milestones. Specific responsibilities of SNL include the following:

- Implementing DOE Headquarters' programmatic and budget guidance at the element level
- Preparing program plans that specify goals, milestones, and major participants
- Managing research tasks to ensure that the research is completed in a timely and cost-effective manner
- Establishing collaborative efforts with private industry to further program goals

Exhibit 2-2 UES Program Milestones FY 1994-FY 1998

Battery Systems Analysis

- Complete preliminary opportunities analysis (December 1993)
- Complete utility feasibility study (February 1995)

Subsystems Engineering

- Deliver GNB intermediate design valve-regulated lead-acid (VLRA) battery modules (October 1993)
- Conduct Power Processing Workshop and issue proceedings (February 1994)
- Deliver Silent Power, Inc. 12-kWh sodium/sulfur battery (March 1994)
- Deliver Johnson Controls Battery Group, Inc. 100-kWh zinc/bromine battery (June 1994)

System Integration

- Deliver Omnion AC Battery to PG&E (October 1993)
- Complete PV/battery hybrid units (July 1994)
- Complete system integration phase of USBD (August 1994)

System Integration (continued)

- Install 500-kW transportable utility battery at first substation (December 1996)
- Deliver 500-kW/1000-kWh zinc/bromine battery system at specific utility (March 1997)
- Deliver 300-kW/600-kWh sodium/sulfur battery system at specific utility (September 1997)

System Field Evaluation

- Complete testing of AC Battery at PG&E (October 1994)
- Complete testing of USBD at PG&E (August 1995)
- Complete testing of zinc/bromine battery system at utility sites (March 1998)
- Complete testing of sodium/sulfur battery system at utility sites (March 1998)

Industry Outreach

- Initiate operation of Battery Technology Assistance Center (September 1995)

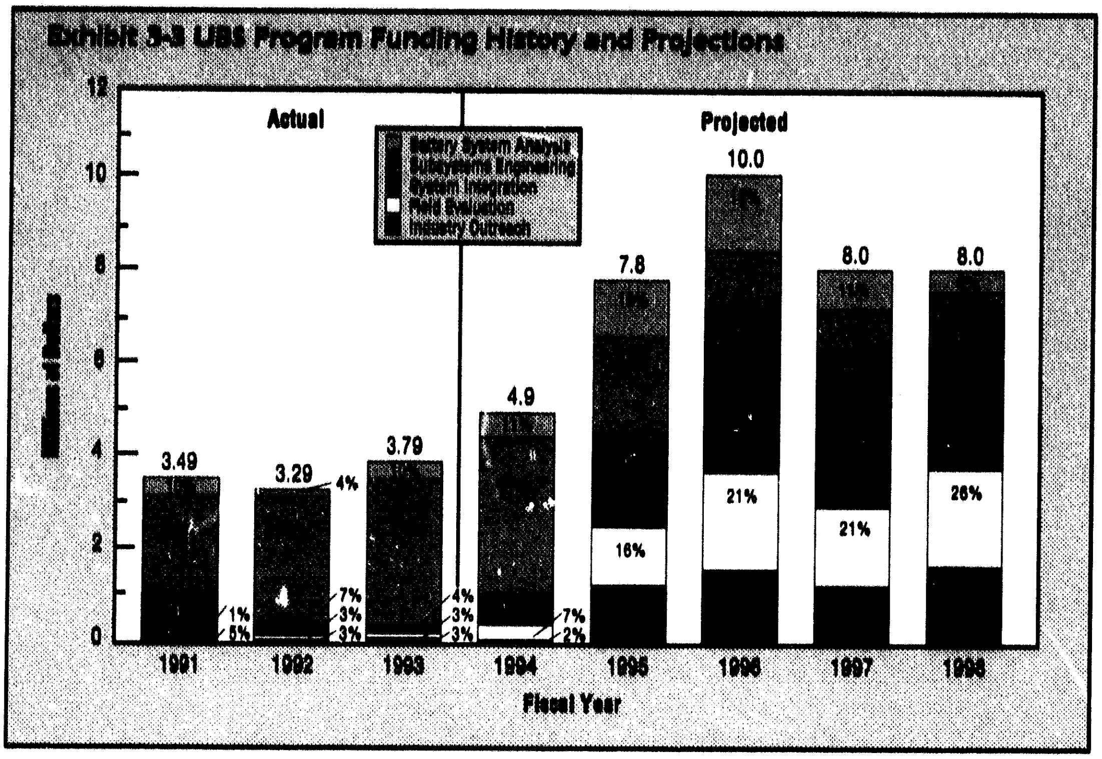


Exhibit 3-3 UBS Program Funding History and Projections

- Disseminating research results and transferring technology to industry
- Reporting on progress to DOE Headquarters on a regular basis.

Schedule

The UBS Program has a schedule that includes a set of milestones. The purpose of this schedule is to establish a programmatic framework that ensures adherence to policy and provides for the overall success of the program. Milestones and decision points are established for each project to guide management in evaluating the progress and direction of research tasks. These milestones and decision points become target dates for technical achievement by researchers. Program schedules are subject to an annual reevaluation, and intermittent adjustments are made to reflect policy shifts, fluctuating budgets, changing program priorities, and research progress. Milestones for the UBS Program are presented in Exhibit 3-2.

Resources

Budgets for the UBS Program are recommended by DOE through OEM. The budget is established by Congress as part of the Energy and Water Development Appropriation each year. The funding projections for the UBS Program are depicted in Exhibit 3-3. The percentage breakout for each program element is shown.

Several trends should be noted from the budget projections. An active systems analysis element will continue through 1996 to determine specific quantitative values of a range of battery storage benefits. Subsystems engineering funding will decline as major battery development contracts are completed, but system integration activities will increase as efforts are undertaken to optimize those improved components in developing an overall system. An aggressive system field-evaluation thrust beginning in FY 1994, the Transportable Battery System Project, is planned to provide cost-shared testing of integrated battery systems to utilities for benefits validation and to gain operating experience. Finally, industry outreach activities will increase as the Battery Technology Assistance Center becomes active in 1995 and continues during the program. Overall, the program will peak at $10 million in 1996 and be concluded by the end of the decade.

Expected Outcomes

The expected results of the UBS Program will be a set of outcomes that will help the utility industry and all electricity consumers by

- Reducing operating cost (e.g., manpower, fuel, etc.) by increasing operating efficiency through the employment of storage to provide peak power

- Avoiding much of the anticipated capital asset acquisition (combustion turbines, transmission lines, distribution transformers, transmission line stabilizers, etc.) projected by achieving greater utilization of existing assets

- Improving the overall environmental quality of electricity generation, delivery, and use by including more renewable sources in the generation mix, reducing peak power requirements from fossil fuels, and reducing EMF exposure by the avoidance of new transmission lines.

The UBS Program is already having an impact on the utility industry. Exhibit 3-4 shows more than 20 utilities that are in the process of evaluating battery storage as a resource option. Their interest in battery storage stems from their need to improve operations, reduce capital investment, curtail demand growth, or assist specific customers. The UBS Program will continue to work with these and other utilities as battery storage emerges as a significant resource option for the nation's utilities.

Metrics

The performance of the UBS Program will be monitored via a set of metrics geared to program progress. These performance indicators may include the following:

- Cost per kilowatt/kilowatt-hour of battery storage systems procured by individual utilities

- Number of battery storage installations

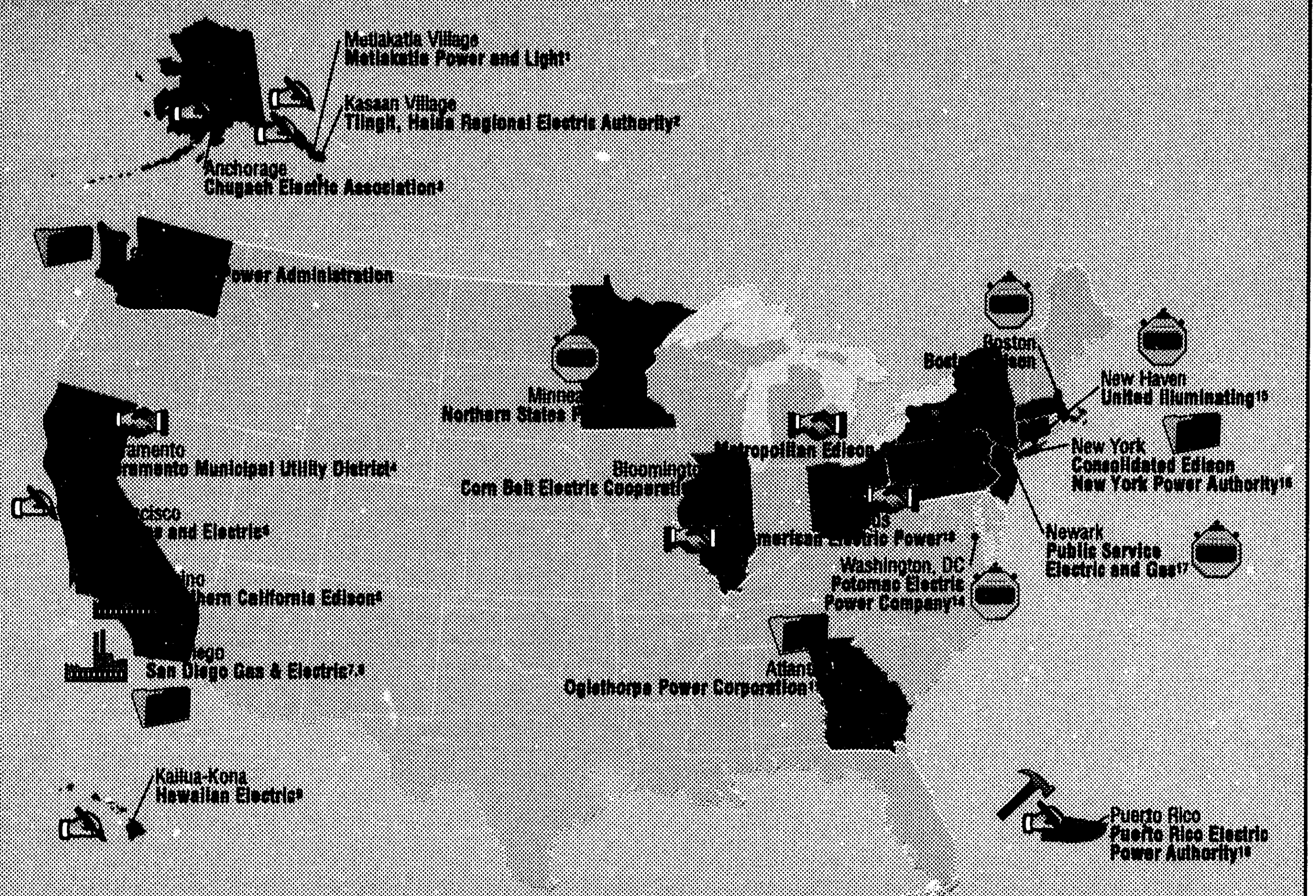
- Amount (installed megawatts) of utility battery storage

- Number of circuit miles of transmission and distribution lines and/or substations deferred because of battery storage additions

- Amount (megawatts) of installed renewable resource capacity facilitated by the addition of battery storage.

By tracking the performance of these indicators, DOE will assure that the UBS Program is realizing the estimated national benefits. This continuity will be a direct measure of the taxpayer investment toward development and implementation of the new technology.

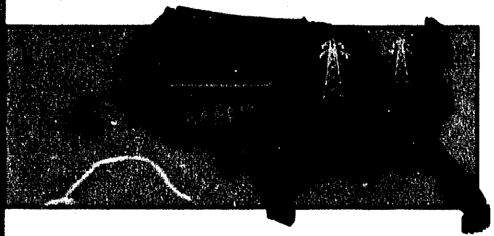
Exhibit 3-4 Utilities with Interest in Battery Storage



- Facility in operation
- Under construction
- Planned conceptual design
- Completed system study
- Planned system study
- Monitoring technology

Primary Application	Size (MW/MWh)
1 Improve village diesel generation, loading	01.00/01.60
2 Same as above	0.03/0.09
3 Spinning reserve, frequency regulation	10.00/20.00
4 Distributed storage benefits	
5 T&D benefits	1.00/2.00
6 Load leveling, other	10.00/40.00
7 Trolley peak shaving	0.20/0.42
8 System-wide benefits	20.00/60.00
9 Frequency regulation	10.00/10.00

Primary Application	Size (MW/MWh)
10	1.00/3.00
11	6.00/19.00
12 Demand-side management	3.00/6.00
13 Transmission line deferral	
14 Peak shaving	
15 Peak shaving	
16 Railway peak shaving	2.00/4.00
17 Area regulation and spinning reserve	
18 1st & 2nd of 5 planned installations	20.00/14.10



Technical Plan

Program Organization

The UBS Program consists of five interrelated elements designed to bring battery storage systems to commercial readiness by the end of the decade. The five UBS elements are

- 1.0 Battery Systems Analysis
- 2.0 Subsystems Engineering
- 3.0 System Integration
- 4.0 System Field Evaluation
- 5.0 Industry Outreach.

These elements reflect the *systems* emphasis of the program, while recognizing the efforts to incorporate improved technology into these systems. These elements are further divided into subelements and projects, as shown in the program outline in Exhibit 4-1. The relationship between the program elements and the technology evolution is depicted in Exhibit 4-2 (p. 30). To satisfy the mission of the UBS Program, DOE and SNL have developed goals, objectives, and milestones for achieving the desired outcomes for each element. Each element is summarized in the following technical plan.

These elements reflect the systems emphasis of the program, while recognizing the efforts to incorporate improved technology into these systems.

Element 1.0 Battery Systems Analysis

In the Battery Systems Analysis program element, DOE will study battery benefits and quantify the value of these benefits to utilities. Already, 20 benefits of battery storage for utility use have been identified. Assessments of battery storage thus far have primarily involved specific utilities, and the results have been correspondingly specific to the individual utility. DOE will now attempt to establish benefit values that apply to utilities nationwide. DOE also will take the methodologies used in assessments and incorporate them into a screening tool, making it much easier for any utility to perform its own preliminary assessment of the value of the technology. Some of these benefits have been verified from data obtained from field tests of battery systems installed at several utilities. Several other benefits will need to be verified by the utilities in tests during the upcoming years. The information developed in identifying the benefits also feeds to other elements of the program by establishing battery performance requirements and compatibility of various battery technologies to the range of identified utility applications.

As with any emerging technology, operating benefits to utilities in terms of economic worth must be established for BES before it is widely applied in utility applications. Battery storage has the further disadvantage that it has been traditionally viewed only as a load-leveling resource by utility planners and its wider range of applications has neither been fully identified nor quantified. Few evaluation tools are available to utility planners that quantify the value of battery storage to their specific situations and that would allow a comparative evaluation with other planning options.

Exhibit 4-1 Utility Battery Storage Systems Program Outline

1.0 Battery Systems Analysis

1.1 Applications Analysis/Systems Studies
- Bonneville Power Administration
- Oglethorpe Power Corporation
- San Diego Gas and Electric
- Chugach Electric Association
- Sacramento Municipal Utility District
- American Electric Power
- Corn Belt Electric
- Others

1.2 Feasibility Studies
- Chugach Electric
- T&D (Sacramento Municipal Utility District)
- Others

1.3 Opportunities Analysis
- National Benefits
- Applications and Requirements
- Battery Technology Compatibility Study

2.0 Subsystems Engineering

2.1 Battery Subsystems
- Improved VRLA Battery Development
- Sodium/Sulfur Battery Development
- Zinc/Bromine Battery Development

2.2 Electrical Subsystems
- Improved Power-Conditioning System (PCS) Design
- PCS, Controls, and Interface

2.3 Laboratory Evaluation at SNL
- Subsystems Characterization

3.0 System Integration

3.1 Factory-Integrated Modular Systems
- AC Battery (Flooded Cell Battery)
- NaS-PAC (Sodium/Sulfur) Battery

3.2 Site-Integrated Modular Systems
- GNB Modular Battery (VRLA Battery)
- Zinc/Bromine Battery

3.3 Transportable Systems
- USBD Project with PG&E
- Design and Build Prototype TBS
- Coordinate with EPRI TBS

3.4 Laboratory Evaluation at SNL
- Testing of AC Battery Modules

4.0 System Field Evaluation

4.1 Factory-Integrated Modular Systems
- AC Battery
- NaS-PAC (Sodium/Sulfur)

4.2 Site-Integrated Modular Systems
- GNB Modular Battery
- Zinc/Bromine Battery

4.3 Transportable Systems
- Testing of TBS Prototype at Utility Site(s)

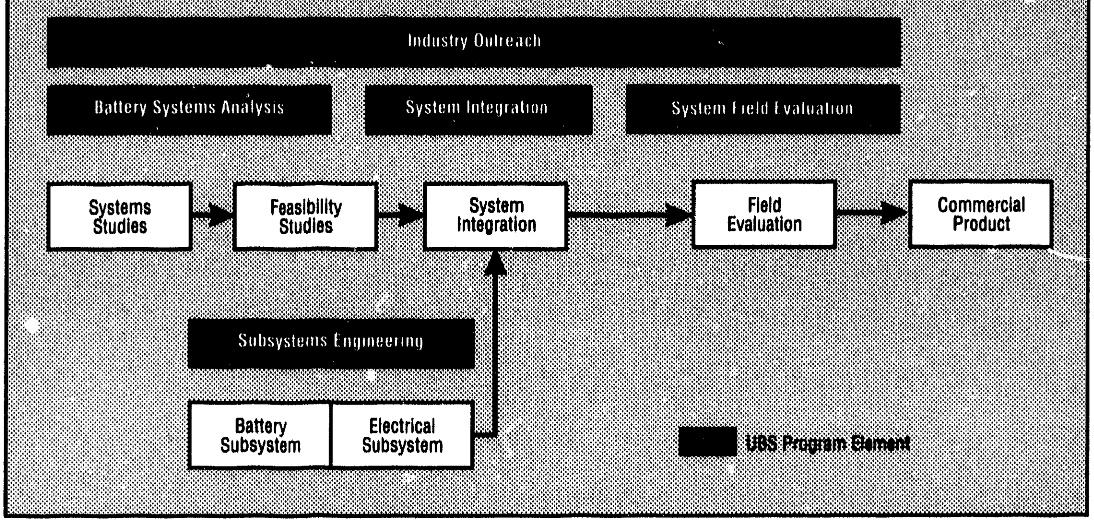
4.4 Special Evaluations
- Thermal Test of C&D Batteries

5.0 Industry Outreach

5.1 Industry Coordination
- Utility Battery Group Activities
- EPRI Coordination
- Industry-Utility Meetings

5.2 Battery Technology Assistance Center
- Design Information Collection
- Operation

Exhibit 4-2 UBS Program Activity Roadmap



The three subelements in the Battery Systems Analysis program element are aimed at identifying a wide range of battery applications and their related economic value. Following is a description of each subelement and a summary of the expected outcomes of each.

1.1 Applications Analysis/ Systems Studies

A "systems study" is an initial screening-level study performed in cooperation with a host utility to identify and evaluate the potential benefits that BES could offer that utility. Such a screening-level study establishes a rough estimate of a battery benefits-to-cost ratio based on a limited examination of utility-specific operation and financial data. The exact size of the BES facility, its location in the utility network, and any operational details of the battery energy storage system are not defined at this time.

In this subelement, specific applications of BES in selected utility networks are identified and quantified. Already, four site-specific, cost-shared studies have been completed with utilities. The findings of three of the four studies showed potentially strong benefits of battery storage in each utility's network, and more detailed, follow-on feasibility studies have been recommended. Because these studies were a first-of-a-kind effort, there is a need to examine all aspects of the activity and to document these findings comprehensively. Particularly, the methodology, findings, and the lessons learned from the utility interactions will be studied to guide future activity. Following the completion of this analysis, a second round of studies will focus on applications such as renewables and T&D that were not included in the first set of four studies.

The results of all the studies will be used to match characteristics of battery systems with specific utility applications (a compatibility evaluation). The performance strengths of different battery system technologies will be assessed, along with their suitability for each specific utility application. The final result of this analysis will be a comprehensive evaluation of the "best fit" of battery types and system components to specific utility requirements. This will enable battery system suppliers to design systems that satisfy specific utility applications. It also will yield insight for future R&D in battery design and performance that can provide feedback to the Subsystem Engineering and System Integration program elements.

Expected Outcomes of Subelement 1.1 Applications Analysis/Systems Studies

Identification and preliminary evaluation of utility benefits from battery storac[illegible]tems in specific applications

Finally, the results of all these analyses will be used to improve the quantitative understanding of battery storage to utilities nationwide. All utilities routinely report operating and planning information to agencies such as the Energy Information Administration and the North American Electric Reliability Council (NERC). The data available from these sources are reliable indicators of generation expansion, operating reserve margins, and transmission-related planning that the utilities are performing. Extrapolation of the results of all UBS studies will lead to a national perspective on BES benefits. Other studies, such as those conducted by individual utilities or EPRI, will also be reviewed and used when appropriate. This will lead to a comprehensive estimate of BES benefits stated in terms of operating and capital cost savings to utilities and their customers.

1.2 Feasibility Studies

The "feasibility study" (a term borrowed from utility terminology) goes beyond the initial system study and establishes the quantitative value of BES benefits to a higher level of confidence by examining detailed forecasts of utility operating costs and other operational parameters for the entire life of the BES project. A site-specific conceptual design of the BES system is included in the feasibility study to determine the cost of the battery system needed to generate these benefits.

A feasibility study is performed if the results of the previous system study indicate a potential for a sufficiently high benefit/cost ratio. There are no widely accepted norms for the benefit/cost ratio that trigger a commitment for a feasibility study, but generally, a ratio of >1.5 may be acceptable justification to proceed to the feasibility study stage. Utilities with the most promising results from the initial system studies group will be encouraged to continue to the feasibility study stage, which will involve more detailed study to establish the economic feasibility of the application and a conceptual design of the BES system. The results of the feasibility study lay the foundation for any future BES project and become an essential part of the project planning. SNL will continue to provide assistance to the utility through this stage and to encourage the

Expected Outcomes of Subelement 1.2 Feasibility Studies

Verification of the cost-effectiveness of implementing battery storage systems at specific utility sites

Conceptual battery system designs for specific utility sites utility to proceed with full-scale projects if the feasibility study shows positive results.

Feasibility studies will be conducted in FY 1994 with the Chugach Electric Association and the Sacramento Municipal Utility District (SMUD). Other studies will be pursued in the future as candidate utilities are identified and as they express commitment to utility battery systems.

1.3 Opportunities Analysis

The principal desired outcomes of the entire Battery Systems Analysis element are produced within this subelement. As such, the results of the other two activities are directly utilized. First, the economic benefits at the national level are characterized; these must include the identification of market size, timing, and specific applications. System-level requirements for each application are defined, but working definitions of these requirements are critically needed to allow effective system design and engineering to proceed. The desired information includes system-level specifications related to power, energy, cost, and duty cycle along with any special needs such as power quality and/or general siting constraints (e.g., environmental, physical). Detailed design-specific information, such as the performance requirements for the various individual components of the system, their configuration, or operating conditions, is not included. Finally, a study will be performed to match specific battery technologies with specific applications.

Expected Outcomes of Subelement 1.3 Opportunities Analysis

National benefits of using battery energy storage and application-specific requirements to be used for designing battery energy storage systems

Element 2.0 Subsystems Engineering

Under the Subsystems Engineering element, improvements are developed in the two primary components of a BES system: the battery itself and the electrical equipment (power conversion and control). For development to be successful, the battery component needs lower costs, higher performance, and improved integration with the other parts of the system. For the near term, a task is under way to ready an improved VRLA battery technology that will increase the quantity and types of utility applications that can be satisfied with BES compared with those capable of using conventional flooded lead-acid batteries.

To increase market size further, the development of advanced batteries is also proceeding. Although several candidate advanced battery technologies are being developed for various applications, sodium/sulfur and zinc/bromine are felt to provide the best opportunity to achieve the desired benefits and also be commercially available for utility applications by the year 2000. Neither technology has the same set of obstacles to overcome, primarily because two types of batteries are represented: high temperature and ambient flow. In the UBS program, development is focusing solely on the needs for utility energy storage (UES) applications. Although substantial efforts are under way to develop these technologies for mobile applications, the design criteria and objectives for UES applications are sufficiently different to warrant dedicated efforts. While both uses mandate safety first, the UES application must emphasize life-cycle cost over weight or volume-based performance. Nevertheless, during prototype engineering of the current advanced technologies

(1995), periodic assessments will be made to determine whether attention should be given to any other emerging technology (e.g., lithium-based, nickel/metal-hydride).

Efforts will be made to improve the performance and reduce the costs of the components of the electrical subsystem. Various activities are planned to bring power conversion system suppliers, electric utilities, and battery manufacturers together to formulate applications requirements and development plans for cooperative projects aimed toward a higher level of functionality and standardization.

2.1 Battery Subsystem Engineering

The focus of this subelement is ensuring availability of rechargeable batteries with improved performance and lower costs compared with those of current batteries. Cost-shared contracts with industrial battery organizations are in place to complete the first phase of dedicated UES development of VRLA, zinc/bromine, and sodium/sulfur battery technologies. VRLA batteries are a new design that are completely sealed and employ pressure relief valves and oxygen recombination technology. These changes allow for less required maintenance and improved safety because water additions are not needed, and evolution of gases under most conditions is prevented.

Existing flooded lead-acid batteries can meet a variety of utility applications, as shown previously in Exhibit 2-2 (p. 16). Some of these lead-acid batteries are available from manufacturers in modular subsystems that are suitable for the utility applications identified in Element 1.0, Battery Systems Analysis, and have the advantage of low cost because of their relatively simple designs and the large quantities

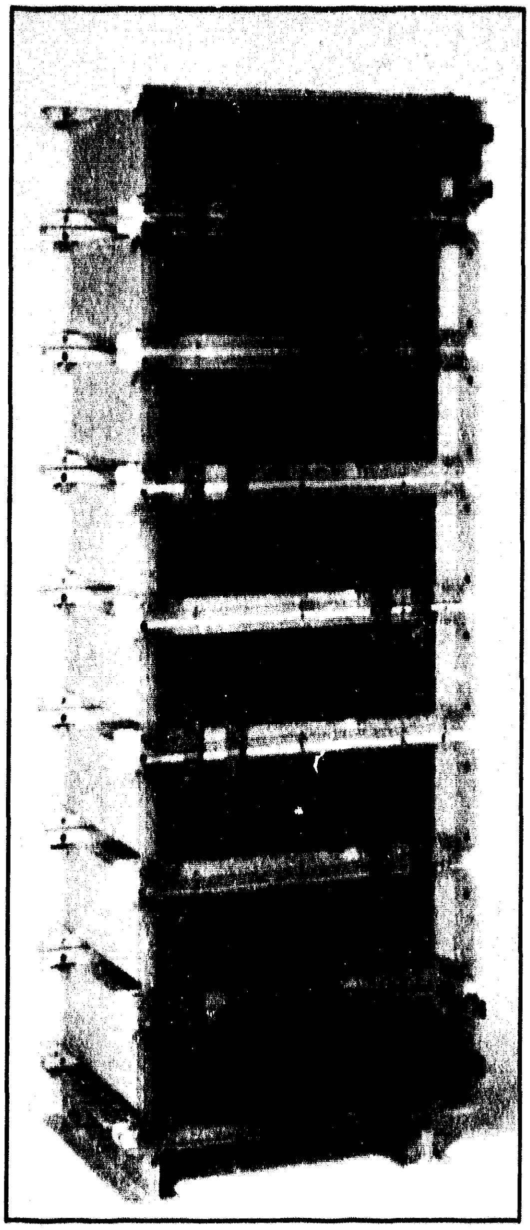


Exhibit 4-3. The GNB Industrial Battery Company's Absolyte IIP Tower with standard top termination.

manufactured. During fiscal year (FY) 1994, prototype engineering of the VRLA technology will be completed. At that time, VRLA technology will be ready for private industry to assume sole responsibility for completing the required manufacturing development and introducing the commercial products. Although the VRLA battery technology is available today, life and performance are inadequate for projected multifunction utility applications.

The present VRLA development effort, through a cost-shared contract with the GNB Industrial Battery Company, (Exhibits 4-3 [p. 33] and 4-4) seeks additional improvement in energy density, footprint, cycle life, and manufacturing costs. The VRLA battery development is proceeding in two phases. Phase 1 goals include matching the performance and costs of flooded lead-acid cells without sacrificing any of the intrinsic maintenance and safety advantages of the VRLA design. Issues such as vent valve reliability, positive plate growth, thermal management, charge-profile optimization, ground fault prevention, improved positive plate active material, and better manufacturing process control are being addressed. During Phase 2, the VRLA battery will be optimized for high-power applications. The optimization involves more radical changes to grid and active materials, improved methods for immobilizing the electrolyte, and methods for improved manufacturing consistency and control. These changes will lead to further improvements in the performance and life of the VRLA battery.

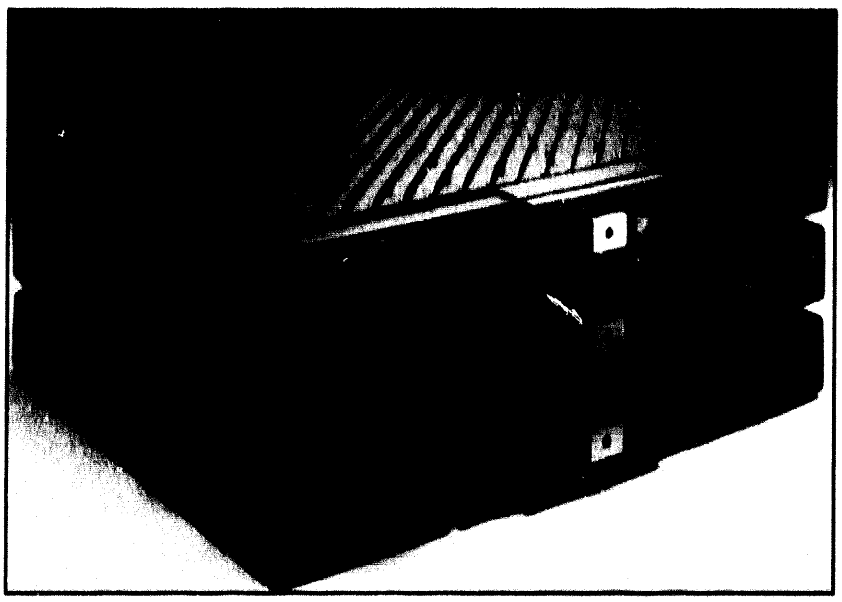


Exhibit 4-4. The GNB Industrial Battery Company's UPSolyte LSB design with terminals at opposite ends of the battery to minimize the current path resistance and voltage losses.

An important system-related task in the GNB VRLA contract includes formulating system designs and specifications and conducting economic analyses to quantify the benefits of these designs. GNB is teaming with PG&E and the Puerto Rico Electric Power Authority (PREPA) for these studies. PG&E has selected an application that requires a two- to three-hour battery to shave the peak on a substation feeder and defer upgrades to the substation for three to five years. In contrast to the PG&E application, PREPA has selected a combined frequency-regulation and spinning-reserve application that requires a large one-hour battery. The PREPA design will allow any performance advantage obtained by using a VRLA battery to be characterized. The comparison will be made to the flooded-cell battery that PREPA is currently installing in its first 20-MW unit scheduled to come on line during 1993.

Successful completion of the present advanced battery development contracts will permit determination of the feasibility of the sodium/sulfur and zinc/bromine technologies. If the advanced battery technologies show promise for stationary

Exhibit 4-5 Utility Battery Subsystem Development Process

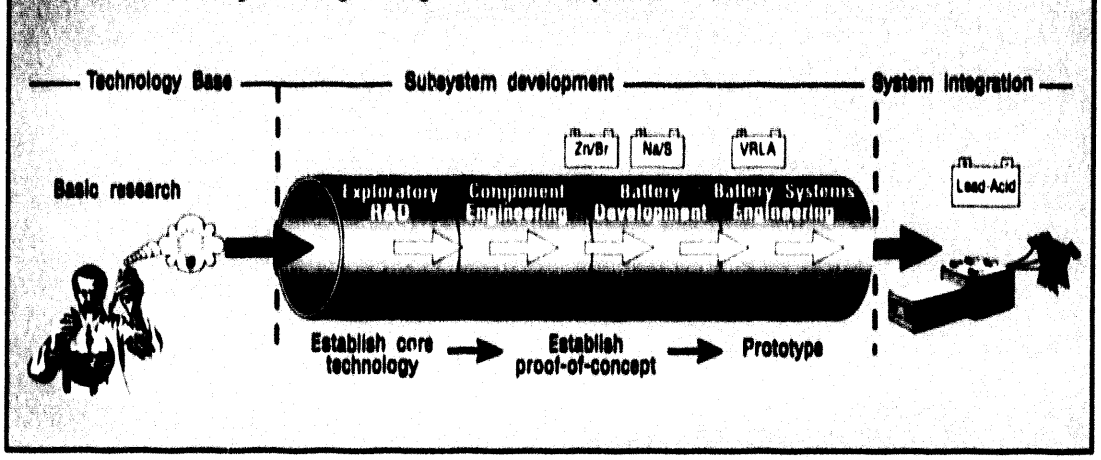


Exhibit 4-5. The development process for utility storage batteries can be likened to a development "pipeline." Promising concepts are investigated in the exploratory R&D phase. Subsystems development results in batteries that can be laboratory tested for utility applications. Integration leads to the installation and testing of utility-scale systems. Icons show the present progress of four battery types in the UBS program: standard lead-acid, improved VRLA, sodium/sulfur, and zinc/bromine.

applications, then prototype engineering will be initiated. Because development of the core technology and preliminary definition of system requirements will also be completed during the present contracts, these new efforts will focus on (1) the engineering of battery-level components (e.g., modules, battery controllers, electrical interconnects, busing, thermal management, safety equipment), (2) the development of pilot manufacturing processes, and (3) the design and fabrication of complete battery systems that are suitable for laboratory evaluation. Exhibit 4-5 graphically depicts the process or approach being used to develop all the candidate battery technologies.

The sodium/sulfur battery (Exhibit 4-6 [p. 36]) is a high-temperature technology being developed primarily because lower life-cycle costs are possible compared to those of conventional lead-acid options. This potential advantage results from projected lower capital costs, less required maintenance, longer service life, and high energy efficiency. Other important benefits of this technology include good energy and power density, operating flexibility, and insensitivity to ambient conditions. A sodium/sulfur system would occupy only 20%-25% of the space required for a lead-acid based system, which is important in many applications.

The UBS Program is presently focusing on the necessary development to complete a proof-of-concept evaluation. Silent Power, Inc. is sharing the sodium/sulfur development costs with DOE through a cost-shared contract. Key tasks through 1994 include the design and qualification of a long-lived cell specifically intended for utility applications and the production of a small 6-kW/12-kWh battery for testing at SNL. The 6-kW battery will be constructed with "PB" cells from Silent Power Inc.'s sister organization, Silent Power, Ltd. These cells are being developed primarily to power electric vehicles, and

Exhibit 4-6. This sodium/sulfur battery is a 12-kWh utility module (200 cells with active cooling) under development by Silent Power, Ltd.

an automated pilot production facility already exists to manufacture large quantities of these cells with high quality standards. For cost-effectiveness (e.g., availability and cost per cell) and the potential for consistent operation, the decision was made also to use these cells in the first battery for testing at a utility site (38 kW/75 kWh in 1995). The test results from these two batteries will be key indicators of the capabilities of the sodium/sulfur technology in utility applications and thus will assist in the decision whether to proceed with prototype engineering of a 300-kW modular system. Of significance, development will continue during this time on the needed long-lived utility cell. This novel cell will be incorporated into either the first or second 300-kW demonstration module.

The zinc/bromine battery technology (Exhibit 4-7) is at a development stage similar to that of the sodium/sulfur technology. This bipolar, ambient-temperature battery also offers the potential for better performance at lower cost than lead-acid batteries. DOE is cost sharing the zinc/ bromine battery development with Johnson Controls Battery Group, Inc. (JCBGI). The final product of the present contract in 1994 will be a 100-kWh module. The results of the module testing, along with utility interest and market and cost analyses, will determine whether the program will support the prototype engineering of a 200-kWh battery for testing at a utility location.

SNL may assist its contractors by solving specific technical problems when it possesses expertise and capabilities unavailable at the contractors' facilities. For example, a task is being performed in cooperation with JCBGI to identify new complexing agents for a zinc/bromine battery electrolyte that will improve safety and performance.

Expected Outcomes of Subelement 2.1 Battery Subsystems

An improved, maintenance-free, lead-acid battery technology that is optimized for utility applications and suitable for commercial-product engineering

At least one advanced battery technology that has potentially better cost and/or performance advantages compared with those of lead-acid batteries and that is sufficiently developed to integrate effectively with other system components

Finally, as mentioned earlier, when prototype engineering of the sodium/sulfur and/or zinc/bromine technologies is proceeding, periodic assessments will be made to determine whether any emerging advanced technologies (e.g., lithium-based, nickel/metal-hydride) are promising for utility applications. If a positive recommendation results from these assessments, an implementation strategy will be considered.

2.2 Electrical Subsystem Engineering

System requirements will be examined in this subelement to determine how designs of the electrical components are impacted. These components include the PCS and the control system. Novel techniques will be sought to improve the performance and reduce the costs of these components.

Efforts will be made to reduce or eliminate costly one-of-a-kind engineering. All utility battery energy storage projects undertaken to date have used custom-built, one-of-a-kind PCSs because of the lack of a commercially available, off-the-shelf PCS subsystem. Consequently, PCS costs have been high and, at present, constitute a major portion of the overall BES system cost, but rapid advances in power electronics technology hold great potential in reducing the cost and footprint of the PCS subsystem, if they are aggressively applied to the BES system. Until recently, there has been little interaction between power conversion system suppliers, electric utilities, and battery manufacturers to foster the development of standard, state-of-the-art PCS designs that could offer lower subsystem costs. Recent UBS activities in this area have been primarily responsible for starting such interchanges and facilitating PCS development. Continued interactions and an active hardware development and demonstration activity are needed to sustain this interchange and ensure that it leads to the timely availability of the desired hardware.

Exhibit 4-7. This zinc/bromine battery, developed by Johnson Controls Battery Group, Inc., is a 15-kWh unit consisting of two 50-cell parallel stacks and is being tested at SNL.

Specific actions for the near term include conducting a workshop with companies and researchers involved in batteries, power conditioning equipment, and renewable technologies to formulate application requirements and development plans. The development plans will then be used to focus the UBS Program activities toward cooperative projects with industry to produce cost-effective and versatile PCS subsystems.

Expected Outcomes of Subelement 2.2 Electrical Subsystems

Cost-effective, standardized electrical subsystems for utility storage battery applications

Electrical subsystems with enhanced performance based on system requirements

Controls for the battery storage system, which include the hardware and software that operate the system in response to user needs, are another subsystem that requires further evolutionary development. Similar to the customization of the PCS subsystem, customized battery control subsystems have thus far been designed for each project on an as-needed basis. For successful commercialization, however, battery systems need more sophisticated control subsystems capable of remote operation that can be integrated into existing supervisory control and data acquisition (SCADA) networks with which utilities control all operations in their networks.

UBS activity in this area will be similar to PCS subsystem development, and teaming efforts with industry will be initiated to design a higher level of functionality and standardization into the control subsystem.

2.3 Laboratory Evaluation at SNL

Independent evaluation of the performance of both proof-of-concept and prototype battery and electrical subsystems is critical to the success of the UBS Program. Specific hardware deliverables will be tested at SNL to characterize electrical performance, thermal response, and service life (cycle and time) and to identify relevant failure mechanisms. This information will be used in the development of improved hardware. Primarily, deliverables from the battery technology development contracts will be evaluated: VRLA, sodium/sulfur, and zinc/bromine. The qualification of hardware incorporating the prototype design and associated manufacturing methods represents the final step of this phase of engineering development. Additionally, when alternative battery technologies are identified, preliminary tests will determine their attractiveness.

Element 3.0 System Integration

Expected Outcomes of Subelement 2.3 Laboratory Evaluation at SNL

Characterization of battery performance and life for development guidance and independent assessment

During the Systems Integration phase, a strategy will be pursued to reduce the inefficient one-of-a-kind system engineering historically required when a utility battery system is designed and built. A "modular battery" system approach has been adopted as the preferred method to achieve system flexibility and the lowest possible cost. The major subsystem components (battery and electrical) are designed as separate modules so that integration can occur either at a factory or at the actual utility site. From a cost perspective, this modular approach permits more efficient engineering, design, and manufacturing processes.

To satisfy the application requirements, all the components of a battery storage system must be effectively integrated. These components include both primary subsystems engineered under Element 2.0, Subsystem Engineering, and the necessary balance-of-plant. The system integration activities performed under this program element should lead to specific system designs. Once these designs are evaluated (qualified) under Element 4.0, System Field Evaluation, private industry may complete the final "commercial product" phase of engineering development.

Traditionally, the energy storage and electrical subsystems for the few utility-based plants built to date have been custom designed so that little or no flexibility exists to reconfigure the plant. This situation could preclude adaptation of the plant if its requirements or desired use change during its 20- to 30-year planned operational life. Coupled with utilities' recent recognition of the potential of battery storage for distribution-related applications and a new interest in smaller-sized battery systems, a greater flexibility to add energy storage capacity or additional power capability is clearly of great interest to the utilities.

To support this new interest in battery storage capabilities, a "modular" system approach has been adopted by the UBS Program as the preferred method to achieve system flexibility at the lowest possible cost. Each subsystem (i.e., the battery and the electrical PCS and control components) is designed as an independent module. Then, for example, as additional storage capacity is needed, additional battery modules may be added to the existing PCS module. Alternatively, as the system power requirements grow, additional PCS modules may be added to the existing system with minimal impact in both cost and engineering effort. From a cost perspective, the modular approach permits more efficient engineering, design, and manufacturing processes to occur as system requirements expand and contract. Finally, on-site labor required to assemble and start up the initial and expansion systems is minimized.

Two variations of the "modular" battery concept are being pursued under the UBS Program: factory-integrated modular (FIM) and site-integrated modular (SIM). The two primary activities under the System Integration element involve these two concepts. Additionally, a special type of integrated system is being developed for applications that require additional power at a specified site for a short time. These designs are referred to as "transportable systems." Finally, a small subelement addresses any needed laboratory evaluation of the performance of integrated systems.

3.1 FIM Systems

A FIM system is factory-assembled and consists of a battery, a PCS, and a control system. These integrated modules are completely assembled and tested in a factory before they are shipped to the site. Typically, individual modules do not possess the required power and/or energy for the particular application; thus a parallel and/or series configuration of several of these modules may be needed. Using this type of module minimizes both on-site installation labor and start-up times. However, energy and power are available only in discrete increments that must be combined to meet the specified storage and power capacity for the application.

To ensure their usefulness, FIM modules are being designed to be transportable by conventional truck and sea vehicles. Generally, this physical transportation constraint limits the performance of the actual system, both in power and in energy capacity. For applications that require a relatively large system size, the SIM may be the preferred option.

FIM technologies currently under development in the UBS Program are the AC Battery (Exhibit 4-8 [page 40]) and the NaS-PAC. The former is a

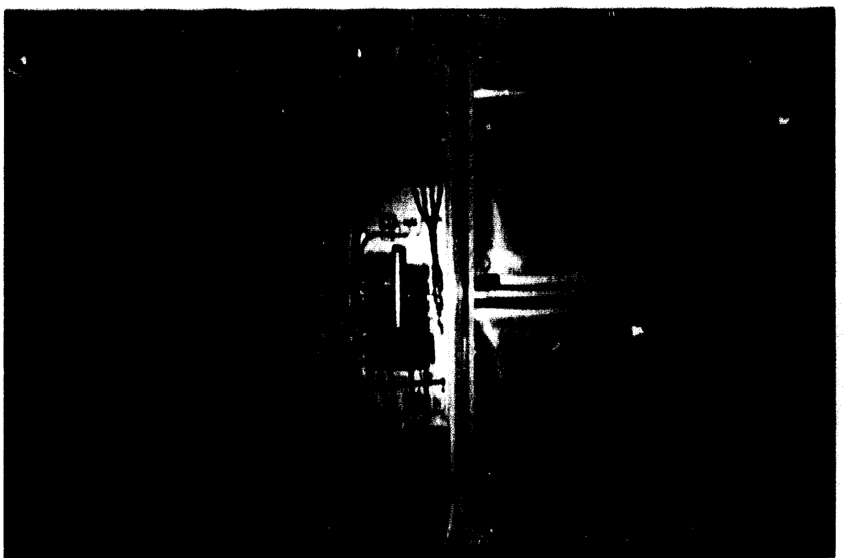
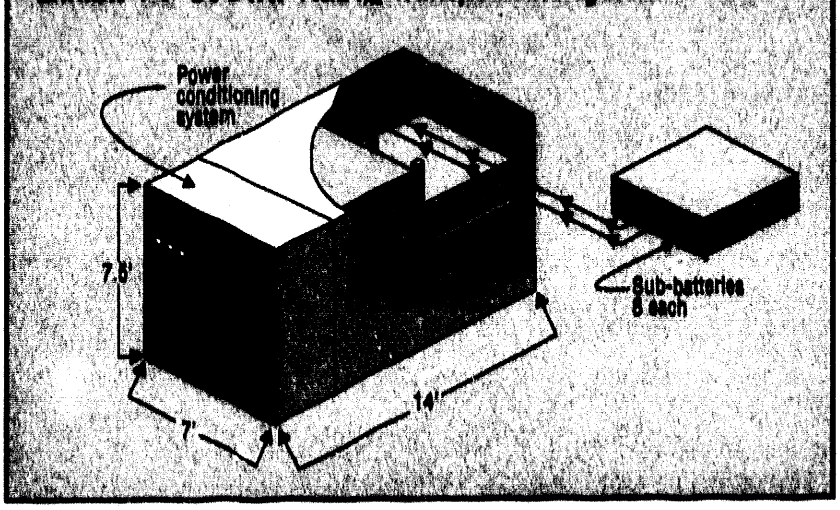


Exhibit 4-8. This AC Battery is undergoing final factory testing at Omnion prior to shipment to PG&E.

Exhibit 4-9 300-kW NaS-PAC Transportable System



250-kW/ 167-kWh lead-acid system packaged in an easily transportable outdoor container. The container is comprised of eight submodules, each containing both the batteries and the PCS. The power output from all the submodules is aggregated to form the total rated output of the AC Battery. The NaS-PAC design (Exhibit 4-9) will utilize the advanced sodium/sulfur technology. It is projected to be a 300-kW/600-kWh module, very similar in concept and function to the AC Battery, but it is based on a different chemistry that is anticipated to yield higher power densities for future systems.

The design and assembly of the first prototype of the AC Battery was completed in mid-1993, and extensive performance evaluation is being conducted at PG&E (Exhibit 4-10). The AC Battery is suitable for utility applications that require discharges for short durations up to several hours, such as frequency control, spinning reserve, and customer-side-of-the-meter power quality correction. If development is successful, a one-eighth-scale NaS-PAC module (75 kWh) will be available for testing in 1995, and a full-scale (600-kWh) modular system will be available in 1997.

B.2 SIM Systems

A SIM system is assembled at the site using separate and modular battery and electrical components. In general, a number of battery modules will be configured together to produce the required system power (DC) or a significant portion of it. This power is conditioned with a network of electrical components (e.g., PCSs). SIM systems can be assembled relatively easily, and are then ready for testing and start-up. Although a SIM system requires more site labor than an FIM system, it is still less labor than that needed for a custom-system design.

Studies completed to date indicate that SIM systems appear to be the most attractive for those applications in which discharge duration of two hours or more is required, such as feeder-peak reduction. The conceptual designs being formulated as part of the lead-acid battery development contract are examples of SIM systems. A 500-kW/500-kWh VRLA battery subsystem with a footprint of 500 to 600 square feet is the objective of the present effort. The battery modules and the PCS would be shipped as pre-assembled as possible. PG&E has announced its intent to evaluate a system of this general type in a utility-scale battery demonstration (USBD) project. In addition, this study will emphasize transportability. The field demonstration is scheduled to commence by mid-1994.

If adequate progress is made during the next two years, engineering of a SIM-based zinc/bromine system will be pursued. Important results will be produced during the laboratory evaluation of an upcoming 200-kWh battery deliverable. If warranted, a 500-kW/500-kWh subscale system will be built and tested in a selected utility application.

3.3 Transportable Systems

Several potential BES applications involve substation distribution. The required siting duration is relatively short, ranging from three to five years, so greater benefit can be achieved if the battery system is transportable because then it can be moved and used again at another substation. The FIM technology, because of its inherent design characteristics, can be easily adapted or used in a transportable configuration. With some design modifications, it may also be possible to have a SIM design that is also "transportable."

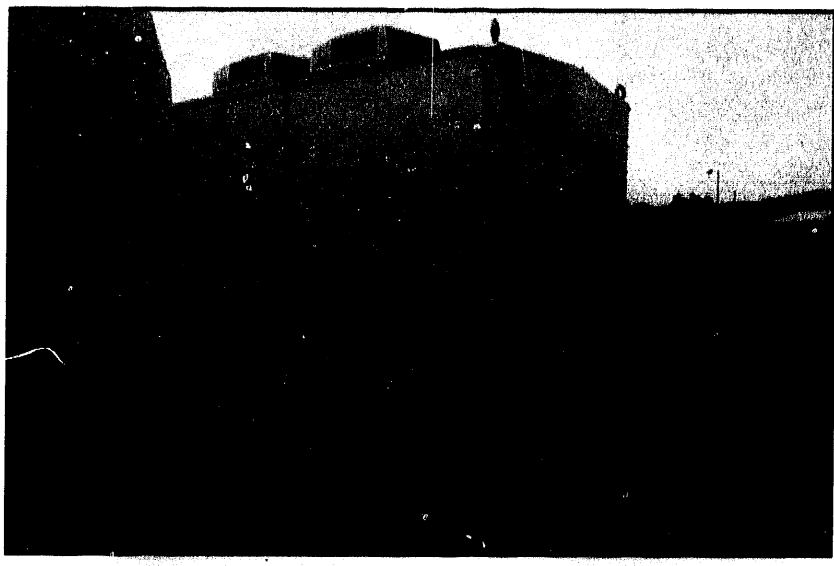


Exhibit 4-10. AC Battery in place and operational at PG&E.

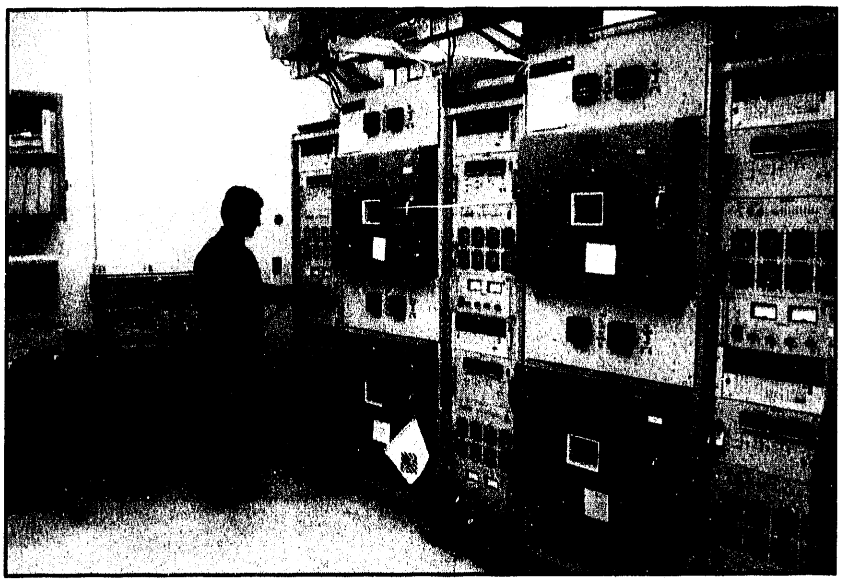
The UBS Program includes specific tasks to study the feasibility of this "transportable" battery concept. If the concept is viable, longer-term design and development activities will begin toward fabrication of a prototype Transportable Battery System (TBS) designed specifically for distribution-related substation applications. The work will be completed in sufficient detail to encourage the commercialization of an actual transportable battery system.

Activity in this subelement will be coordinated with an EPRI effort to develop a TBS during 1994. The DOE and EPRI TBSs are conceptually similar, but differ in physical details. The EPRI objectives for the TBS are near term and are aimed specifically at demonstrating, with first-hand experience at member utilities, the usefulness and benefits of battery storage. Each utility will be able to use the EPRI TBS for a short period (six months or less), after which it will be moved to another utility site. After several such utility site demonstrations, the system will be dismantled.

As part of the transportable utility battery program, in FY 1994 a USBD project, co-funded with PG&E, will begin. The USBD will consist of a 1-MW, 2-hour system made up of two units of one or more transportable battery modules with each unit capable of discharging a minimum of 500 kW for 2 hours. The system integration phase will be completed during the first year.

3.4 Laboratory Evaluation at SNL

FIM battery systems will be evaluated at SNL, primarily to characterize the electrical performance of preprototype deliverables. The detailed evaluation of the products from most of the System Integration activities is performed primarily under Element 4.0, System Field Evaluation, but some independent testing of early products will be useful and cost effective because duplication of expensive facilities and capabilities will be avoided. Any critical problems with the designs will be identified early. During FY 1994, two AC Battery modules (120 V, 32 kWh) constructed with lead-acid batteries will be tested using load-leveling and frequency regulation/spinning reserve regimes. Tests are also planned with the AC Battery module configured as a voltage source (self-commutating) integrated into a hybrid system consisting of a photovoltaic/diesel generator power generation/ storage system.



Tester/software specialist adjusts equipment at the battery test facility at SNL.

Expected Outcomes of Element 3.0 System Integration

Factory-integrated, modular battery system(s) ready for field evaluation in generation, distribution, or end-use applications

Site-integrated, modular battery system(s) ready for field evaluation in generation, transmission, or distribution applications

Transportable battery system(s) ready for field evaluation in distribution and end-use applications

Quantitative characterization of preprototype battery system performance and life for system integration guidance and independent assesement

Element 4.0
System Field Evaluation

Performance and service life qualification of actual hardware incorporating prototype designs will be performed in the System Field Evaluation element of the program. This activity involves the detailed characterization of performance, maintenance requirements, and reliability (service life) of integrated systems at relevant utility sites. The qualification of hardware incorporating the prototype design and associated manufacturing methods represents the final step of this phase of engineering development. For the technology being developed under the UBS Program, the qualification process involves the detailed characterization of performance, maintenance requirements, and reliability of integrated systems at selected utility sites. If these results, along with corresponding cost estimates, are sufficiently encouraging to enable viable and profitable markets to form, industry alone will then be motivated to undertake the final engineering phase leading to the introduction of a commercial product.

Prototype integrated systems will be qualified at various utility locations under this UBS Program element. Initially, some of the systems will be tested in collaboration with PG&E using its Modular Generation Test Facility (MGTF) in San Ramon, California. This excellent facility can simulate many utility requirements, including distribution. Partnerships with other utilities will also be established as opportunities are identified.

Subelement 4.4, Special Evaluations, includes specific studies of hardware components whose development status has progressed to the commercial or precommercial level, but which have not yet been integrated into a utility battery system. The following briefly describes the specific activities already identified for this element. The expectation is that such activities will expand as the UBS Program progresses into the field-demonstration phase.

4.1 FIM Systems

The prototype AC Battery System that was completed in early FY 1994 is being tested at PG&E's MGTF (Exhibit 4-10 [p. 41]). PG&E testing of this system will last six to nine months. PG&E is under contract to the UBS Program to characterize the life-cycle performance of the AC Battery for several representative utility applications. PG&E will determine ease of maintenance and overall system reliability, which are necessary to estimate operating and maintenance costs of commercial AC battery systems. Additionally, PG&E will evaluate the system's ability to operate unattended in remote locations. Other FIM systems with advanced batteries will also be evaluated at the MGTF or other utility site(s) as these systems become available. A 100-kWh NaS-PAC module containing the utility sodium/ sulfur cell will be available about 1997 and also may be tested at the MGTF.

The qualification of hardware incorporating the prototype design and associated manufacturing methods represents the final step of this phase of engineering development.

4.2 SIM Systems

VRLA batteries will be available from the GNB contract and may be installed and tested in SIM systems at utilities. The test site(s) may include the host utilities that have partnered with GNB (PG&E and PREPA), but other sites are also being considered. PG&E has announced a separate utility-scale battery demonstration project for a substation peak-shaving application within its service territory and thus may not test a contract deliverable. PREPA has indicated that it might use the batteries at a customer site. SIM systems are suitable for applications that require larger battery capacity than those supported by FIM systems, and the testing will be for applications such as substation feeder peak reduction and/or customer-side peak-shaving and reliability of service. The specifics of each test and the test plan will be finalized in late 1993. Similarly, fabrication of a prototype 500-kWh zinc/bromine battery system is anticipated to be completed in 1997, when a utility site will be selected for its evaluation.

4.3 Transportable Systems

Testing of the TBS will include performance characterization for its intended application similar to testing for the FIM and SIM systems. In addition, the TBS field evaluation will include the practical aspects and related benefits of a truly "mobile" BES system. Utility planners perceive the value of the TBS, but the transition from a planner's perspective to a working system under the control of utility operations personnel introduces practical constraints that will be demonstrated by the field evaluation of the TBS prototype. A detailed test plan for the TBS will be finalized in FY 1994. In FY 1995, the USBD transportable system will be field tested at selected sites in the PG&E service area.

4.4 Special Evaluations

This subelement will involve any needed laboratory evaluation of hardware that may be used in utility demonstrations and is not covered under other elements of the UBS Program. Those activities presently identified for Special Evaluation include the laboratory evaluation of the performance of flooded lead-acid batteries and post-mortem analysis of failed batteries and aged components from demonstration systems. Presently, twelve 400-Ah, C&D Charter Power Systems, Inc. lead-acid batteries from PREPA are being tested at SNL (Exhibit 4-11). These batteries are being studied for thermal response using SNL's simulated frequency regulation/spinning reserve test profile. The results will be important in the determination of the feasibility of using existing, flooded lead-acid technology in utility applications. This specific activity illustrates the usefulness and need for this subelement.

Expected Outcomes of Element 4.0 System Field Evaluation

Quantitative characterization of prototype integrated systems (FIM, SIM, TBS) to assess readiness for final commercial product engineering

Element 5.0 Industry Outreach

The Industry Outreach element consists of focused communication to promote interest in battery storage systems in the private sector and to provide forums in which ideas are shared, information is exchanged, and cooperative projects are initiated. These forums create opportunities to leverage limited government and private sector resources to projects that can expedite the early commercial introduction of battery storage systems. The private industry coordination must include utilities, customers, and suppliers.

5.1 Industry Coordination

The industry coordination activities are directed toward meetings with various utility groups that have interest in promoting, using, or supplying battery storage systems. Of primary importance is the Utility Battery Group (UBG). This group,

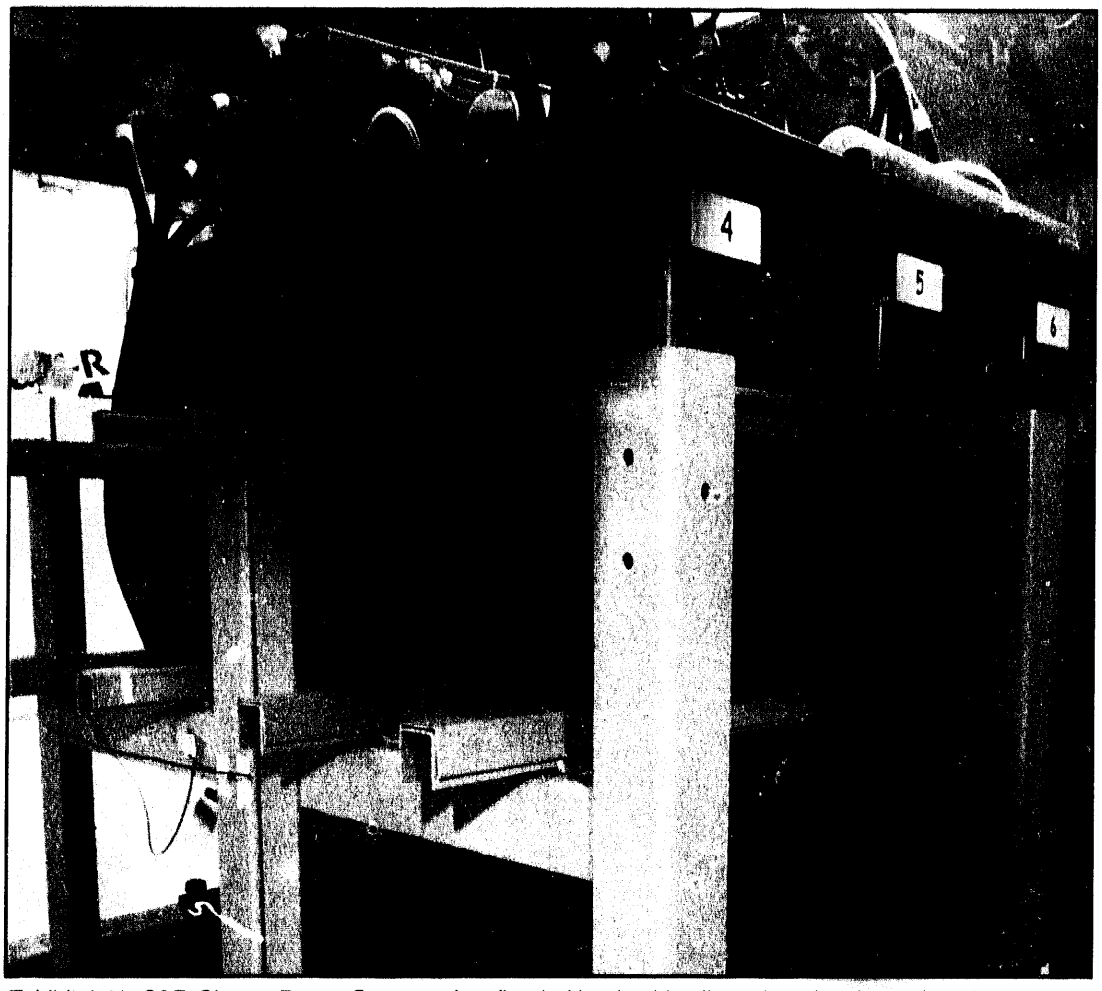


Exhibit 4-11. C&D Charter Power Systems, Inc. flooded lead-acid cells undergoing thermal analysis at SNL for PREPA.

which consists of representatives from utilities, suppliers, associations, and government agencies, meets twice a year to share information regarding battery storage projects and applications. DOE also interacts with EPRI to inform its utility members about battery systems, to develop battery storage evaluation software, and to quantify the benefits of battery storage.

SNL is establishing a Battery Technology Assistance Center to serve as a clearinghouse of current information on battery systems and their design and procurement. DOE and SNL regularly publish articles and attend engineering and utility meetings to inform the public about BES. Additionally, SNL staff will meet with involved organizations to plan coordinated activities including application and feasibility studies, advanced battery development, and the TBS. Most of these activities will be closely coordinated with complementary projects at EPRI. A memorandum of understanding is being negotiated to coordinate the TBS project at EPRI and DOE. Other information and analytical tools will be shared to avoid duplication and accelerate development and demonstration of BES systems.

An additional task planned for FY 1994 is a series of one-on-one meetings with utility executives to discuss benefits, opportunities, and barriers for installing battery storage and to address issues that the executives are facing. At least four meetings are planned with utility senior management and a team of DOE, SNL, and support staff to present information on the DOE UBS Program, discuss problems facing the utility, and pursue opportunities for evaluating battery storage.

Expected Outcomes of Element 5.0 Industry Outreach

Heightened awareness and knowledge of battery storage applications by the utility industry

Implementation of the Battery Technology Assistance Center for dissemination of a wide range of battery systems information to potential users

5.2 Battery Technology Assistance Center

The purpose of this subelement is to create a clearinghouse for information on the use of BES in utility applications. The clearinghouse would start as a phone line and administrative support staff to answer inquiries and requests for information received from utilities and industry. The UBS Program currently attracts inquiries for information—from a wide range of sources—that are accommodated on an as-needed basis. Establishing the Battery Technology Assistance Center would ensure timely answers to such inquiries and formalized mechanisms to follow through with in-depth information that satisfies inquirers' needs. As the awareness of battery storage benefits grows, the Center would be especially useful in providing information about the technology to utilities that do not have access to EPRI or other industry-supported information resources.

Benefit evaluation software and information on existing and planned utility BES projects are examples of the type of information that would be disseminated by the Center. A similar center is operated by the photovoltaics group at SNL and has provided information related to PV technology to potential users. The Battery Technology Assistance Center would be patterned after the PV center and benefit from the lessons learned in establishing and operating it.

END

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