Energy Storage - Program 94

Program Overview

Program Description

Energy storage is expected to play a larger role in generation resource management, integration of variable resources, and peak management applications. Energy storage technologies are at a stage of maturity where they can be become feasible for such applications, making them ready for demonstrations. However, there are still significant knowledge gaps in understanding application requirements and how various storage technologies can meet them as well as analytics for developing the business case and performance data for assessing the deployment risk. This program addresses these gaps through technology assessment and defining application requirements for various storage applications in bulk storage, power delivery, and applications beyond the customer meter. This information is also necessary for the public and regulators to better understand the possible value energy storage can have in helping address renewables integration and shifting to lower greenhouse-gas-emitting resources.

While the main focus of this program is electric energy storage, it also monitors and assess selected emerging distributed generation technologies. The program is coordinated with other closely related research programs such as EPRI's IntelliGrid, Distribution Systems, Electric Transportation, and Renewable Integration programs.

Research Value

With the knowledge provided by this research program, members will have access to information that can help them:

- Support strategic and corporate planning in response to renewable portfolio standards and regulatory inquiries in the area of energy storage and distributed resources.
- Understand functional requirements for energy storage applications and the characteristics of the various storage technologies in meeting these requirements.
- Access technical characteristics and expected economic performance for various storage technologies in several utility applications. The economic information may include capital, operations and maintenance, as well as life expectancy of the technology.
- Inform the public, including regulators and policy makers, on the possible impact of storage solutions in various applications on the electric grid.
- Gain access to best practices for using bulk and distributed energy storage applications.

Approach

EPRI research in energy storage will yield a variety of information and knowledge that will be beneficial to members of the program. This information will come in a number of formats, and is expected to include:

- Strategic intelligence reports and specific technology assessments of energy storage and emerging distributed energy resource options
- Industry white papers to inform stakeholders on the role and value of energy storage
- Functional application requirements for renewable integration, capital deferral, and neighborhood energy storage systems for end-user peak load management and outage mitigation
- Online database for all energy storage and distributed energy resource (DER) options
- Monitoring and providing case summaries of all on-going energy storage demonstrations
- Test reports providing data on the operating envelope, performance, and durability of emerging energy storage systems.

Accomplishments

In the past, the Energy Storage program has delivered valuable information that has helped its members and the industry in numerous ways. Some examples include:

- Quarterly strategic intelligence reports, and reporting on trends and deployments of energy storage
- In-depth technology assessments of lithium-ion technology and other battery systems
- Valuation of energy storage systems along the electric utility value chain
- Identification of novel bulk energy storage cycles such as low-fuel-based third-generation compressed air energy storage (CAES) systems
- Best practice guidelines for using sodium-sulfur (NaS) energy storage for temporarily deferring investment in local grid infrastructure through peak management shifting and solutions
- Benchmarking the costs and greenhouse gas emissions of distributed generation options
- Updated and published and industry white paper on cost and performance of second-generation CAES systems.

Current Year Activities

In the coming year, this research program expects to accomplish these objectives:

- Strategic intelligence reports on trends in energy storage and distributed generation
- Functional application requirements for storage to allow for local peak shifting as well as participation in ancillary services markets in substations and along distribution feeders
- Updates on lifetime costs of various energy storage technologies
- Regional case study of the use of bulk energy storage systems together with renewable resources, and their impact on greenhouse gas emissions under various renewable penetration scenarios
- Conceptual design and definition of low-fuel advanced CAES systems
- Testing and evaluation of several distributed energy storage systems.

Estimated 2011 Program Funding

$4.0M

Program Manager

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Summary of Projects

Project Number	Project Title	Description
P94.001	Strategic Intelligence and Technology Assessments of Energy Storage and Distributed Generation	This project provides analysis and strategic information on energy storage and distributed energy resource systems through an online technology assessment database, annual technology assessments, and strategic intelligence reports. Analysis is undertaken to understand the impacts of energy storage systems, including their costs, benefits, potential value. It also includes assessments and evaluations of various technologies. Some of the information may be published in white papers to inform the public, including regulators and other stakeholders.
P94.002	Distributed Energy Storage Options for Power Delivery and End Use	This project provides information and guidelines for using distributed energy storage and distributed generation systems for power delivery and end-user applications such as infrastructure investment deferral and peak management, including shifting. To achieve this, the project conducts analyses, performs laboratory testing and field demonstrations, and prepares informative case studies of current and emerging battery energy storage systems.
P94.003	Bulk Power Energy Storage Solutions	This project provides information and guidelines for using bulk energy storage to shift low-cost, off-peak energy to high-value, on-peak energy and provide ancillary services including for integration of bulk variable generation. It includes R&D on technologies such as low-fuel CAES systems, pumped hydro, and emerging large flow battery systems.

P94.001 Strategic Intelligence and Technology Assessments of Energy Storage and Distributed Generation (051547)

Key Research Question

Utilities need strategic and objective information on current and emerging energy storage and distributed energy resource technologies that could have an impact on utility operations and may reduce carbon emissions. Such information includes technical characteristics, performance and cost information, and trends in energy storage and distributed generation options. Analysis is needed to improve the understanding and assess the costs and benefits of energy storage and of distributed resources in a smart grid, including the associated impacts of greenhouse gas emissions as well as resource planning.

Approach

This project provides analysis and strategic planning information on distributed energy resources (both distributed generation and energy storage systems) through an online technology assessment database, annual in-depth technology assessments, and strategic intelligence reports. The project tracks, monitors and summarizes all on-going energy storage demonstrations. Analysis is undertaken to understand the operational value, costs and benefits, and impacts of energy storage systems. Specific technology evaluations and assessments are prioritized by members; technologies include novel distributed and bulk energy storage systems as well as novel flow battery systems.

The project will perform technology assessments of emerging energy storage systems, including zinc-chlorine, $NaSO_4$ chemistries, new lithium–ion battery chemistries, fuel cells, and advanced ultracapacitors. In addition, analysis will be conducted to assess the value proposition of energy storage and distributed generation (DG) systems in current and future smart grid configurations. Also, databases will be developed that maintain the latest cost, performance, trends, and greenhouse gas footprints of energy storage systems.

This project tracks and benchmarks all energy storage and advanced distributed generation technologies. It also monitors the status and development of all small to large energy storage options for transmission, generation, distribution, frequency regulation, and end-use peak load-shifting applications. The project provides summary information on all DOE and utility-sponsored national and international energy storage demonstrations.

Information on the value, role, and key markets for energy storage may also be transferred to external stakeholders via industry white papers, conferences, and collaboration with trade groups such as the Electricity Storage Association.

Impact

Participants in this project could be affected in a number of ways including:

- Having access to timely information on trends and developments in energy storage and distributed generation.
- Acquiring strategic intelligence on emerging technologies that can affect utility business operations.
- Gaining insight into the carbon reduction impacts of energy storage and distributed generation systems.
- Receiving objective information to support strategic corporate planning and answer regulatory inquiries.
- Having access to analysis and an online database, as well as assessments to support corporate strategy and decisions to invest in distributed generation and energy storage initiatives.
- Learning how to quantify the value of a distributed resource portfolio for utility business operations.
- Getting information to support win-win policies for deploying energy storage systems.

How to Apply Results

Research findings will be used by corporate and resource planners as part of their strategic planning function, and will help them anticipate technology trends and apply solutions to business issues. Distribution system designers of smart grids may incorporate research findings and results into future grid expansion assessments. Results could also be used by regulatory policy and regulatory affairs managers to respond to state public commission inquiries related to distributed generation and energy storage costs, benefits or market integration, as well as inquires related to greenhouse gas emissions and impacts of decentralized generation. Corporate strategic planners can use EPRI research findings and products to:

- Respond to senior management inquiries
- Evaluate the technology and investment risks of distributed generation and energy storage initiatives
- Inform senior management on technologies that could affect or improve business operations
- Inform policy makers.

2011 Products

Product Title & Description	Planned Completion Date	Product Type
Strategic Intelligence Reports: Strategic intelligence reports provide objective information on current and emerging distributed generation and energy storage technologies that could influence or support utility business operations and reduce carbon emissions. Up to six reports are produced, with a feature story and summaries of the latest information on the cost, performance, and trends of distributed generation and energy storage options that are available from credible sources in the literature.	12/30/11	Technical Resource

Product Title & Description	Planned Completion Date	Product Type
Cost and Technical Capabilities of Energy Storage Systems: The project will provide updated cost, performance and technical information on energy storage systems for applications in the electric enterprise. It will build on last year's work, which engaged vendors and system integrators to develop a 2010 baseline for technical and cost capabilities of energy storage systems. In 2011, this data will be further updated with an additional focus on uncertainty, risk, operation and maintenance costs, and estimation of cost per delivered kilowatt-hour over the project life. Technical data sheets, reference applications and current and forecasted cost estimates will be developed for a large set of storage solutions including: CAES, NaS, various flow batteries, lead acid, advanced lead acid, Li-ion ,and emerging technologies. EPRI will collaborate with DOE in updating the status and capabilities of energy storage systems. Results will be summarized in an updated *EPRI-DOE Energy Storage Handbook*.	12/30/11	Technical Update
Industry White Papers: This project will prepare one to two publically available industry white papers or industry technical briefs to better communicate the role, requirements and value of electric energy storage systems to the electric enterprise. Topics could include: Applications, Costs and Benefits of Energy Storage Systems; Roles and Requirements for Energy Storage in Renewable Integration; Energy Storage in the Smart Grid; and Neighborhood Energy Storage Systems and its Value.	12/30/11	Peer Literature
Analytics to assess the value and support the business case of energy storage and distributed resources: This project provides analysis and analytics to support business case evaluations of investments in energy storage and distributed energy resources. Activities will be prioritized by members based on needs. Activities will build on work conducted in 2009 and 2010 examining distributed energy storage investments. The total resource recovery cost (TRC) test and life-cycle analysis methodology will be organized and presented in a useful guideline. As a second activity, the project will apply methods developed in EPRI's Smart Grid Program to estimate the value, benefits, costs, and greenhouse-gas impacts of implementing a distributed energy resource portfolio within a utility planning framework. Analytics will focus on member needs to help internalize their business case evaluations of storage and DER options.	12/30/11	Technical Update
Monitoring and Reporting on Energy Storage Demonstrations: This project monitors and reports summary information for all energy storage demonstrations projects under way in the United States. Where possible, international projects also will be covered. In late 2009, the DOE invested more than $250 million in energy storage demonstrations. EPRI advisors in 2010 recommend EPRI provide a one-stop source of all energy storage demonstration activities. Summary information started in 2010 will be updated in 2011. EPRI will also follow and track all DOE ARPA-E awards for breakthrough R&D in stationary energy storage systems.	12/30/11	Technical Update

P94.002 Distributed Energy Storage Options for Power Delivery and End Use (065556)

Key Research Question

Aging grid infrastructure, the challenge of installing new lines, and requirements for higher reliability are prompting many utilities to consider energy storage and distributed generation options for capital deferral, grid support, distribution planning, and end-user energy management. To deploy and effectively utilize these assets in substations, along the feeder, and beyond the meter, utilities need empirical information on costs, performance, operational characteristics, reliability, risks, and durability. Research is required to better understand solution capabilities, including the cost, performance and reliability of these options and how the grid can accommodate the use of energy storage.

Approach

This project provides information and guidelines for using energy storage and distributed generation systems for temporarily deferring investments in local grid infrastructure by shifting the load from peak to off-peak. This application may be employed to mitigate peak load issues for urban load pockets, radial feeders, substation equipment, distribution networks, and communities. The project also assesses storage solutions for meeting end-user load management and peak load-shifting needs and compares the findings with other options.

The project defines application functional requirements for grid support and end use. It performs laboratory testing and field demonstrations of storage technologies to produce empirical data on performance, lessons learned, risks, and costs of these systems for use in utility and end-use environments. It also derives best practices from these demonstrations for asset managers and distribution planners interested in applying energy storage solutions for deferring infrastructure investments.

In a smart-grid environment, distributed storage may also play a significant role in integrating distributed renewable resources, and can be paired with photovoltaic resources to provide energy management solutions along the feeder or on the customer side of the meter. This project will cooperate with the EPRI's Program 174 to define the functional requirement for this application. In addition, it will augment the common requirements with storage technology capability investigations to determine how the various technologies would meet the requirements.

Impact

Participants may be affected in a number of ways including:

- Obtaining demonstrated capability to use distributed energy storage for grid support
- Procuring, installing, operating, or contracting for energy storage systems in a safe and reliable manner by employing guidelines and best practices
- Understanding risks based on validated test data for performance, costs, and operational issues related to energy storage and selective emerging distributed energy resource options
- Incorporating the use of distributed energy storage options into T&D planning
- Understanding options for deferring T&D capital investments by applying storage solutions for peak management
- Making more informed purchase and deployment decisions for energy storage systems.

How to Apply Results

Research findings may be used by distribution planners to develop grid operational solutions, and by engineers and planners when developing a smart grid implementation. Distribution system designers of smart grids can incorporate research findings and results into future grid expansion plans. Results from case studies and evaluations can be used to assess the risk and value of energy storage to utility business operations. Results can also be used to develop new energy management and demand-response solutions for end-use customers.

2011 Products

Product Title & Description	Planned Completion Date	Product Type
MW scale Energy Storage Systems for Substation and Grid Support: This project will continue efforts in 2010, which developed functional application requirements for megawatt-scale storage systems for grid support, and assessed technology and vendor capabilities. A single integrated deliverable is planned, which will address functional requirements, technology capabilities and status, test results where applicable, and information to enable members to support the business case for this application. Activities in 2011 will be prioritized by funders but may include: • Preparation of requests for information from vendors to meet the application requirements • Summary reviews and case studies of on-going storage demonstrations involving this application (e.g. Zn/Br flow battery, NaS, and other battery systems) • Tests, evaluation and demonstration of candidate storage systems, based on readiness and member guidance. Examples include: Extreme Power, Ecoult, GS Yuasa advanced lead-acid batteries, NaNiCl (ZEBRA), and Li-ion systems. • Subscale tests of emerging systems to gain a better understanding of viability and readiness for this application.	12/30/11	Technical Update
Energy Storage systems for Pad Mounted transformer and advanced IUT applications.: This project will build on work started in 2009 and 2010 which defined the functional application requirements, and conducted preliminary technology screen and capability assessments, for energy storage systems that can be used for grid support, outage mitigation, and shifting end-user peak loads. The work will be prioritized by funders but may include: Activities to accelerate technical and functional capabilities and early deployment with program members: • Field demonstration of a 6-kW, 20-kWh residential energy storage system • Lab test of a 25- to 50-kW, 2- to 4-hour system for commercial end users • Lab test of a 25- to 100-kW, 2- to 4-hour system for pad-mounted transformer support or commercial and industrial (C&I) energy management. In either of these projects, EPRI will also conduct work to ensure that these systems have inter-operability functionality with the grid and utility energy management systems. Testing and vendor capability assessments performed in 2010 will be advanced to include further lab evaluations and tests of deployed units with members. The project will also integrate and assemble lessons learned from ongoing distributed energy storage system demonstrations. Finally, work to advance the integration of storage with pad-mounted transformers (both conventional and IUT) will be continued.	12/30/11	Technical Update

Product Title & Description	Planned Completion Date	Product Type
Tests and evaluation of Emerging Energy Storage and Distributed Generation Systems: This project will test and evaluate emerging energy storage and distributed energy resource options, and characterize their performance and operating envelope and readiness for utility applications. Options will be recommended by EPRI staff and advisors and selected by funders. Activities may include tests of advanced batteries, fuel cell systems, and advanced distributed generation systems. EPRI will seek testing opportunities that leverage awards provided from the DOE Smart Grid Demonstrations Recovery Act and ARPA-E funding. The strategic intelligence activities and technology assessments conducted in the program will help identify promising options for possible evaluation. Examples may include: • Zinc-air rechargeable battery systems • Advanced lead acid battery • Zn/Cl flow battery • Solid oxide fuel cells: Bloom Energy, VersaPower, Ceramics Fuel Cell Limited • Other novel systems that offer cost and performance breakthrough characteristics.	12/30/11	Technical Update
Photovoltaic- Energy Storage Solutions and Capabilities: This project prepares and updates functional requirements for energy storage to support distributed photovoltaic (PV) installations smaller than 1 MW and typically on commercial end-use buildings or at residential locations. The project identifies energy storage technologies, assesses energy storage capabilities, and tests and evaluates storage with PV installations in collaboration with members or at the EPRI Knoxville facility. Activities initiated in 2010, including small 5-kW PV integration projects, will be monitored and reported. The project will be coordinated with EPRI Program 174: Renewable Integration on Distribution Systems.	12/30/11	Technical Update

P94.003 Bulk Power Energy Storage Solutions (065557)

Key Research Question

The electric enterprise needs cost-effective and reliable bulk energy storage to help balance and optimize supply and demand of bulk power resources, including nuclear, fossil, and renewable resources. This may include shifting low-cost, off-peak generated energy to provide on-peak, high-value energy.

In addition, state renewable portfolio standards (RPS) are causing a high penetration rate of variable renewable resources. Bulk power storage may be one option to help utilities manage the variability of renewable resources. This project examines the functional requirements and storage technology capabilities for mitigating the effects of variability of bulk, transmission connects of renewable generation. It also analysis possible impact of bulk energy storage on long term planning.

Presently, several technologies are at a maturity level that may help meet the requirements, including CAES and pumped hydro. Pumped hydro needs to be re-examined and assessed for its ability to provide cost-effective bulk storage. Selected battery technologies may also be approaching a maturity level such that they could be considered for these types of applications. New trends and developments in large flow-battery systems may require reconsideration of vanadium, Zn/Br, and Zn/Cl redox cycle technologies for use in large bulk storage applications.

Approach

This project provides information and specific solutions based on low-fuel advanced CAES, pumped hydro, and large battery storage systems to improve the value of large-scale variable renewable generation. Research may include:

- Advanced, low-fuel CAES system R&D
- A technical update on pumped hydro storage: costs, resource potential, sizing, siting, permitting, and historical operating experiences, including an update on trends in new pumped hydro technologies
- Updates and cost assessments for large (50 to 100-MW) flow battery systems
- Regional analysis of energy storage for renewable energy integration under upcoming state RPS requirements
- Energy storage for ancillary services, including frequency regulation and other ancillary services.

Impact

Participants may be affected by this project in a number of ways including:

- Increasing the market penetration of variable wind power
- Improving cost-effectiveness and reducing the industry's greenhouse gas emissions profile
- Learning about assessments and timelines for advanced bulk energy storage systems
- Improving their utilization and operation of transmission assets
- Improving their understanding of the system-wide benefits of CAES and bulk energy storage
- Improving their use of fossil assets and lowering greenhouse gas emissions when using storage for ancillary services.

How to Apply Results

Research findings could be used by corporate strategic planners, resource planners, and system planners as well as utility design engineering staff. Planners and operators of bulk power generators may use the results to plan new projects as well as increase the utilization of existing baseload or intermediate-duty generation assets. Independent system operators (ISOs) can incorporate project findings into their planning and market development activities.

2011 Products

Product Title & Description	Planned Completion Date	Product Type
Energy Storage Role in Supporting Renewable Generation: This project defines the functional and application requirements for energy storage to support high penetration of wind and PV renewable generation. It continues efforts started in 2010 in which regional analysis, stakeholder discussions, and input across EPRI sector R&D provided insights into the technical and cost requirements for storage systems. In 2010, additional analysis, stakeholder discussions and workshops are being conducted to sharpen the blueprint and road map for storage solutions for supporting high renewable penetration. EPRI's storage program coordinates R&D on storage solutions with other EPRI programs' R&D, including that of Programs 84, 173, and 174.	12/30/11	Technical Update
Wind - Storage Demonstration: This project provides co-funding to a battery-wind demonstration project awarded by DOE under the American Recovery and Reinvestment Act (ARRA) in 2009. Activities in 2010 include battery selection, benefit analysis and benchmarking. A battery system of approximately 20 MW will be installed, integrated and dispatched with a 100-MW wind power facility in Texas. EPRI's role is to provide support in technology selection, benefit and value analysis, and monitoring the performance of the system, which is anticipated to be operational in 2012.	12/30/11	Technical Update

Product Title & Description	Planned Completion Date	Product Type
Low Fuel Advanced Compressed Air Energy Storage: This project will continue to advance the development of a low-fuel advanced compressed air energy storage (A-CAES) system, with the goal of enabling a demonstration by 2013. In 2009, a concept design of an A-CAES system was developed, including trade-offs of thermal storage media/options. In 2010, the designs were further optimized, refined and updated, with the focus on plant functional and operational requirements for wind and renewable integration as well as investigation of the thermal energy storage subsystem. In 2010, EPRI will seek DOE ARPA-E funding to advance R&D. Efforts in 2011 will depend on this award, and could include continued R&D of the thermal storage system and testing of the most optimal thermal media materials to develop scale-up information. Modeling of the cycle will provide design information for transient operation inherent with thermal storage systems. The development plan and demonstration plan will be updated. A Project Task Force will guide efforts to conform with industry needs and requirements. The goal at the end of 2011 will be to have the design basis to proceed with more preliminary engineering and planning for technology demonstration and the value proposition for wind integration.	12/30/11	Technical Update
Bulk Battery Storage System Costs and Performance: This project will build off the R&D work done in 2010 examining bulk storage options for improving wind and PV integration. In 2010, conceptual designs for several bulk battery options are being defined and developed, including cost, performance and functional characteristics. Options considered in the 2010 work included: NaS, Zn/Br, aboveground CAES, advanced lead acid, and several other flow battery chemistries. Based on the findings in 2010, the 2011 work will continue R&D for the most promising option(s) in the near-term (3 to 5 years). The project will also review the DOE ARPA-E awards for bulk storage in 2010 and develop appropriate EPRI R&D projects and leveraging opportunities based on member input and guidance.	12/30/11	Technical Update