Pre-Conceptual Design Of The Boulder City Battery Energy Storage Demonstration Unit

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INTRODUCTION

Black & Veatch Corporation has developed a pre-conceptual design for a 2.5 MW, 10 MWh Battery Energy Storage System (BESS) demonstration unit at Boulder City, Nevada [1]. The project was funded by the United States Department of Energy through a contract administered by Sandia National Laboratories. The concept of a battery energy storage demonstration unit at Boulder City has been sponsored by NEVAREST Research, a non-profit organization located in Boulder City. A significant portion of the project, the evaluation of advanced battery storage technologies in the context of this project, was performed by Gridwise Engineering Company of Danville, California, under subcontract to Black & Veatch.

BOULDER CITY PROJECT CHARACTERISTICS

Boulder City ("the City"), a community with a population of about 15,000, is located just west of Hoover Dam and about 20 miles southeast of Las Vegas. Originally the City was built to house workers building Hoover Dam. The City is now the residence of many federal workers employed by the United States Bureau of Reclamation and the National Park Service, as well as many residents who commute to jobs in the Las Vegas area. The electrical load for the City is primarily residential with some light commercial.

The City owns and operates a municipal electric utility, which, as a Public Power entity, has a preference status with the U.S. government. It receives allocations of hydroelectric power from the Hoover and Glen Canyon Dams on the Colorado River. These relatively low-cost resources are provided by the Western Area Power Administration (WAPA) and the Salt Lake City Area Integrated Projects (SLCA/IP), which comes through the Colorado River Commission (CRC). Because power (capacity) and energy from hydroelectric sources is limited, the City must also purchase capacity and energy from other, more expensive sources, including Nevada Power Corporation (NPC). Purchases from non-utility capacity owned by Reliant are also possible if scheduled in advance.

The City's ability to receive its full hydroelectric allocation is dependent on water flow, and thus rainfall and snowfall each year. The City's full load was met by hydroelectric resources for seven months in 1999 and for four months in 2000. To meet the remainder of the months required some purchases of power from NPC. Purchases from NPC occurred in June through October of 1999 and in May through December of 2000.

The City purchases power from NPC through either "Amendment 1" or "Schedule D" contracts. Amendment 1 purchases include a capacity charge and an energy charge. Purchases from NPC through Amendment 1 result in relatively low energy costs. However, there is a capacity charge element that can result in high incremental costs.

Schedule D purchases are on an as-needed basis, and are priced at the NPC marginal cost. The costs can be substantially higher than the City's other resources because the rate for Schedule D energy is market-based. It is anticipated that the BESS demonstration unit will primarily displace the Schedule D purchases.

Proposed Site for the Boulder City BESS Demonstration

The Boulder City BESS Demonstration would be located adjacent to the Hemenway Substation on property owned by the City. This substation converts incoming power from 69 kV to 12.47 kV for distribution to local loads. The proposed 150 ft by 300 ft site has been cleared of vegetation and is relatively level. An empty bay

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Funded by the United States Department of Energy, through a contract administered by Sandia National Laboratories.

for future expansion will facilitate interconnection of the BESS to the substation. The site has ready access from US Highway 93.

EVALUATION OF BATTERY ENERGY STORAGE TECHNOLOGIES

Gridwise Engineering Company performed an evaluation of Advanced Battery Energy Storage technologies as part of this project. Four advanced BESS technologies were considered for the demonstration project.

- Sodium Sulfur
- Vanadium Redox
- Zinc Bromine
- Regenesys®

Gridwise developed a questionnaire, which was sent to a number of advanced battery developers requesting information on various topics, including a request for specific information on costs for a 2.5 MW, 10 MWh demonstration plant. The appropriateness of the technology to the application, the storage sizing requirements, the physical site limitations, potential safety issues, and relative acquisition and operating costs were considered for each technology.. Gridwise contacted the following vendors concerning their battery technology.

- NGK Insulators, Ltd: Sodium Sulfur
- Powercell Corporation: Zinc Bromine
- Sumitomo Electric Industries, Ltd.: Vanadium Redox
- Vanteck (VRB) Technology Corporation: Vanadium Redox
- ZBB Energy Corporation: Zinc Bromine

Gridwise also contacted Innogy Technology Ventures, Ltd., the vendor for the Regenesys® technology. Innogy declined to participate in the evaluation because the 2.5 MW, 10 MWh demonstration unit size is below their minimum capacity. Innogy indicated that their focus is on larger plants, such as their two 120 MWh plants under construction in the United Kingdom and the United States. The Regenesys® technology was therefore not included in this evaluation.

BESS Technology Characteristics

A summary of BESS technology characteristics, as provided by vendor responses in June of 2001, is given in Table 1. The sodium sulfur technology appears to be the most developed in terms of size and number of commercial installations, annual production capacity, and in terms of UL listing. However, the vanadium redox and zinc bromine technologies have installations of appreciable capacities, with annual production capabilities which could support the Boulder City BESS demonstration project.

A key technology consideration was whether the demonstration unit based on the technology would fit in the available land area and adhere to height restrictions. Table 1 provides key information on the physical configuration and footprint of the BESS for each of the technologies. The sodium sulfur battery would come in self-enclosed packages. The other technologies would require building enclosures. All of the technologies would fit within the site boundaries.

Table 1 also lists life and performance projections based on 100 cycles per year. There is a wide spread of life projections. Charge/discharge efficiency (AC to AC) varies from 65 percent to 80 percent.

Capital and O&M Cost Estimates

Vendors' estimates of engineering, procurement, and construction (EPC, sometimes referred to as "turnkey") costs for the 2.5 MW, 10 MWh battery energy package are listed in Table 2. The survey provided a clear listing of costs to be included, including all batteries, controls, enclosures, engineering, and construction of the BESS unit. Estimates do not include BESS interconnection with the substation or other site improvements.

Vendors' estimates of operations and maintenance (O&M) costs are presented in Table 2. Each technology vendor indicated that no operators would be required on site. Maintenance requirements differ with the

technology, with regular inspections recommended. Vendors' estimates of O&M costs varied considerably, from about $30,000 per year to $150,000 per year.

Table 1. Battery Technology Characteristics

	Sodium Sulfur	Vanadium Redox	Zinc Bromine
Field Experience	Over 30 projects ranging from 25 kW to 6 MW. Largest commercial installation is 48 MWh.	Several projects, ranging from 100 kW to 3 MW (pulse power rating). Largest commercial installation is 1.5 MWh.	Several projects, from 50 kW to 250 kW. Largest commercial installation is 400 kWh.
Annual Production Capacity	160 MWh	30 MWh	40 to 70 MWh
Actual Production, Last 12 Months	50 MWh	10 MWh	4.5 MWh
UL Listing	Expected to have UL report by early 2002. Electronics would be UL listed.	Electronics only	Electronics and possibly battery
Structure	Outdoor rated battery enclosures and PCS enclosures.	Building enclosure.	Building enclosure.
Footprint	About 5,000 ft^2	12,000 to 17,000 ft^2	5,000 to 7,000 ft^2
Life	15 years	7 to 15 years	10 to 20 years
Efficiency (AC to AC)	72 percent	70 to 80 percent	65 to 70 percent

Table 2. O&M and Capital Costs

	Sodium Sulfur	Vanadium Redox	Zinc Bromine
Operators On Site	None	None	None
Required Maintenance	Remote monitoring. Three-year inspections include retorquing terminals, collecting/analyzing OCV data, sensor calibration, system testing.	Quarterly or annual maintenance. Periodic parts replacement (pumps and fans every 5 to 10 years).	Remote monitoring, annual inspections. Specific maintenance items still to be developed.
O&M Cost	$32.5k per year	$50k per year	$30-150k per year
EPC Cost	$12 Million	$10.9 to $11 Million	$5.8 to 8 Million

PRE-CONCEPTUAL DESIGN OF BESS DEMONSTRATION UNIT

Pre-conceptual designs were developed using each of the technologies using the information provided by the vendors as an EPC building block. The following items were included in the design and cost estimate.

- The BESS building block
- Electrical and control interconnections with the substation
- A Visitor Center
- Parking lot for the Visitor Center
- Indirect capital costs

BESS Building Blocks

The BESS building block in each case is assumed to be a complete package. In the conceptual design, the only difference between the technologies is the capital and O&M cost estimate based on the vendor's EPC cost

estimates. Two artist's renditions were prepared: a rendition with the self-enclosed BESS, which is characteristic of the self-enclosed sodium sulfur system, and a building-enclosed BESS, which is characteristic of the vanadium redox and zinc bromine systems.

Electrical and Control Interconnections
The BESS demonstration unit would be located at the City's 12.47 kV Hemenway Substation. The substation has two 69 kV to 12.47 kV transformers fed by two separate 69 kV transmission lines. At the time of construction of the substation, the City reserved a spare vacuum recloser bay for future expansion. The spare bay will be equipped to provide the necessary substation electrical interconnections with the BESS. Controls for the relaying equipment will be housed within an existing control building.

Visitor Center and Parking Lot
The demonstration project design includes a 2,500 square foot Visitor Center as well as a 20-vehicle parking lot. The demonstration units location along U.S. Highway 93, a major thoroughfare for tourists visiting the Hoover Dam, would allow public education on battery energy storage system technology and benefits, as well as other energy programs supported by the U.S. Department of Energy, such as renewable energy. It is estimated that 15 million tourists per year drive by the site. The Visitor Center would include office space for attendants and rest room facilities for visitors.

Figures 1 and 2 are artist's renditions for the demonstration project including the self-enclosed and building-enclosed BESS demonstration units, respectively. The Visitor Center is at the right of the rendition; the BESS is in the middle; the substation (surrounded by a brick wall) is at the left. The rendition for the building-enclosed BESS is based on the largest footprint identified by a vendor. The actual size could be smaller, as indicated in Table 1.

BESS Demonstration Unit Cost Estimates
A summary of capital cost estimates for the BESS Demonstration Unit for each of the technologies considered is given in Table 3. The category "Engineering" included in this estimate is for design of the electrical interconnections, Visitor Center, and parking lot only. BESS engineering is considered to be included in the EPC estimate. Contingency for the battery systems is also considered to be included in the EPC estimates. Additional project contingency is assumed to be 5 percent for all technologies.

Table 3. BESS Demonstration Unit Capital Costs (Thousands of Year 2001 US$)

	Sodium Sulfur	Vanadium Redox	Zinc Bromine
EPC Battery System Cost	12,000	11,000	5,000 to 8,000
Electrical Upgrade	65	65	65
Facilities	396	396	396
Engineering and Construction Management	450	450	450
Contingency	632	612	323 to 432
Total	13,543	12,523	7,034 to 9,343

Figure 1. Stand-Alone BESS.

Figure 2. BESS Enclosed in Building.

CONCLUSIONS

The following conclusions have been drawn concerning a Boulder City BESS Demonstration Unit using advanced battery system technologies.

- Each of the advanced battery system technologies (sodium sulfur, vanadium redox, and zinc bromine) remains a viable candidate.
- The site is appropriate for such a demonstration unit.
- Rough capital cost estimates for BESS demonstration units range from about $7 million to about $13.5 million.
- Vendor estimates of annual O&M cost estimates range from about $30,000 to about $150,000. We believe the $150,000 per year estimate to be high. Four of the five estimates were in the $30,000 to $50,000 per year range.

ACKNOWLEDGEMENTS

The authors acknowledge the support of Dr. Imre Gyuk of the United States Department of Energy and Mr. Garth Corey of Sandia National Laboratories. Mr. Benjamin Norris of Gridwise Engineering Company performed a significant part of the project under a subcontract to Black & Veatch. We also acknowledge the assistance and guidance of Mr. Kawana Pohe of NEVAREST Research and Mr. Ned Shamo of the City of Boulder City.

Figures and Tables included in this paper are adapted from Reference 1.

REFERENCE

[1] Garth P. Corey, Larry E. Stoddard, and Ryan M. Kerschen, "*Boulder City Battery Energy Storage Feasibility Study*," SAND2002-0751, Sandia National Laboratories, March 2002.