

Update on the Golden Valley Electric Association BESS

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Introduction

Golden Valley Electric Association (GVEA) is proposing to install a 40 MW, 14 MWh Battery Energy Storage System (BESS) as part of a project to add a second transmission line from Healy to Fairbanks, Alaska. The following is an update of the process GVEA has undertaken to award a contract for the work.

First, here is a little background. The GVEA system is part of a network that makes up the Alaska Railbelt System. The Railbelt is a portion of Alaska that is connected by railroad and highway systems. Its power system is comprised of three main areas that will be referred to as the southern, central and northern areas. Each of these areas is geographically separate and contains its own load center and local generation. The southern area includes the Kenai Peninsula communities of Kenai, Soldotna, Homer and Seward. The central area contains the largest generation and loads in Alaska, and includes the state's largest city, Anchorage. The northern area, which includes the communities of Fairbanks, Healy and North Pole, is the area served by GVEA.

The three areas are connected through single radial transmission lines that are constrained by stability criteria. The stability criteria is set by the Alaska Systems Coordinating Council (ASCC). The southern and central areas are connected via a 110-mile 115kV transmission line. The central and northern areas are connected by a 186-mile 138kV transmission line to Healy, where two mine mouth coal-fired power plants are located. Another 105-mile 138kV transmission line connects Healy to Fairbanks.

The Railbelt system is not interconnected with any other power grids. It is relatively small and has low inertia. It is, therefore, susceptible to large changes in frequency and voltage for relatively minor disturbances. The loss of the single largest generator on the Railbelt system causes frequency to decay at about 0.8 Hz/second. Loss of generation in the northern system overloads the radial transmission line between the central and northern areas and causes an out-of-step condition that shows up as a voltage collapse to about 48 percent of normal voltage before tripping of the line occurs. In one example recorded by a dynamic system monitor, the trip of a 25 MW generator at Healy caused voltage collapse to 0.43 puV in about 70 cycles. The depressed voltage caused the transmission line to trip.

In addition to the coal-fired generation at Healy, GVEA operates fuel oil fired combustion turbines as the primary generation source in the northern area. The generation in the central area is primarily natural gas fired combustion turbine and combined-cycle generation, which is more economical. GVEA can purchase power from the central area for less than it can generate it. Therefore, for economic reasons, GVEA prefers to operate the transmission line near its maximum stable operating limit. If the transmission line trips under this loading condition, frequency can decay at up to 7.0 Hz/second.

All utilities connected to the Railbelt system provide a share of the spinning reserve requirements for the loss of the largest operating generator on the system. However, for transmission line trips or disturbances causing out-of-step conditions that separate the northern and central systems, GVEA must take additional steps to keep its system from blacking out. The cost of operating combustion turbines for spinning reserve is prohibitive. Even if the turbines were operated for spinning reserve, the large block of load required to be picked up by the turbines would most likely cause them to trip on under-frequency.

In response to this problem, GVEA has developed load shedding schemes including a Shedding In Lieu Of Spin (SILOS) system. This complex SCADA-based system monitors the deficiency in spinning reserve, loads on various feeders and number of outages on that feeder to determine the amount of load to be shed at any time. Only the margin between the active spinning reserve and the required spinning reserve to remain stable is shed for an event. The scheme rotates the feeders that are selected for shedding so the outages are spread among the customers.

The Project

GVEA plans to add a second transmission line from Healy to Fairbanks, partially due to the addition of another coal-fired power plant in Healy. As part of the project, Golden Valley is installing a 40 MW, 14 MWh Battery Energy Storage System (BESS) adjacent to the new Wilson Substation in an existing building in Fairbanks. The BESS will increase the stable operating limit of the transmission system and allow greater transfers of less expensive power from the central area. It will also solve or greatly improve the stability of the system from the loss of generation or transmission lines, and will minimize load shedding. GVEA plans to leave the SILOS system in place as a backup to the BESS. Figure 1 illustrates the required ratings of the BESS.

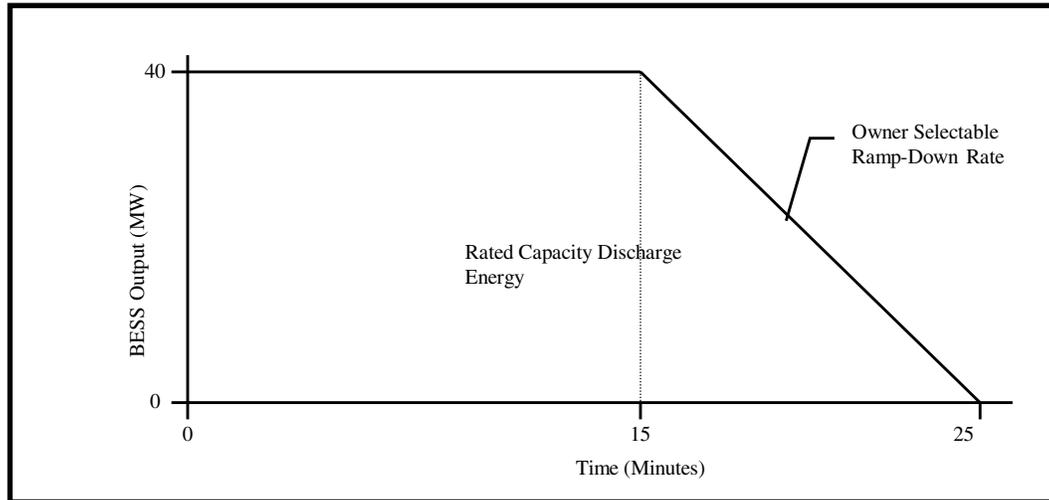


Figure 1: BESS Ratings at End of Life

The Specification

GVEA hired POWER Engineers Inc. to prepare a turnkey specification for procurement of the BESS. The specification is primarily performance-based with much attention given to operating descriptions and performance guarantees. The preliminary specification was sent to recognized industry experts and potential vendors for review and comment. The comments received were used to refine and clarify the specification.

The preliminary specification was issued with a request for budgetary prices. The responses were compared to in-house estimates, and a benefits study that was used to justify the project. Results indicated that the project should move forward with formal bidding. A later version of the specification was issued with a request for un-priced technical proposals. This process was used to determine how well vendors understood the requirements of the specification and to assess the level of interest in the project. Responses to the request for technical proposals were used as part of a short-list process before issuing the formal request for proposals.

The primary focus of the specification is performance of the BESS and how that performance will be monitored and guaranteed. Battery capacity was based on the spinning reserve requirements alone. Although there are other functions, some of which require absorbing power, no added battery capacity was requested for those functions. It is anticipated that a discharge will precede any expected operation where the battery is required to absorb power. In addition, the batteries have the ability to absorb a limited amount of power even at full charge.

The types of operation specified are listed below in the approximate order of importance to Golden Valley. These illustrate the expected uses of the BESS.

- **Spinning Reserve:** This has the highest priority of all operating modes. This mode is initiated when system frequency declines to 59.8 Hz and requires the BESS to load to full output by the time system frequency reaches 59.4 Hz. These requirements are designed to prevent load-shed operation, which begins at 59.0 Hz. Once the frequency decay is arrested, the BESS will reduce output to zero as the system returns to 60 Hz. This operation is illustrated by Figure 1 below.

- Automatic Scheduling: The GVEA SCADA system will monitor the load on selected critical generators and transmission lines, and transmit this information to the BESS control. If the circuit breaker for one of these critical components opens, the BESS will automatically load to the output of the generator or load on the transmission line just prior to the trip. This is essentially a spinning reserve operation, but the BESS will respond without waiting for the frequency to decay. Operation in this mode is illustrated by Figure 2.

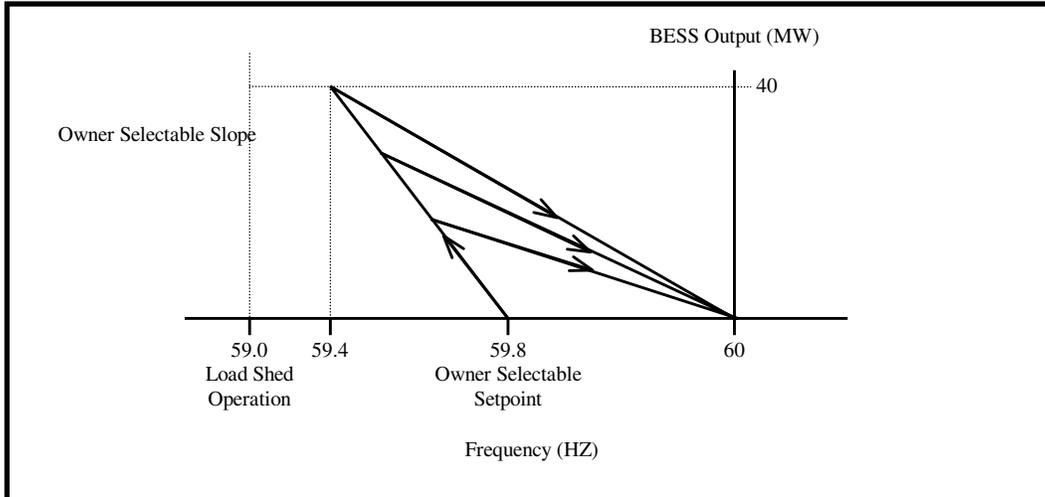


Figure 1: Spinning Reserve Operation

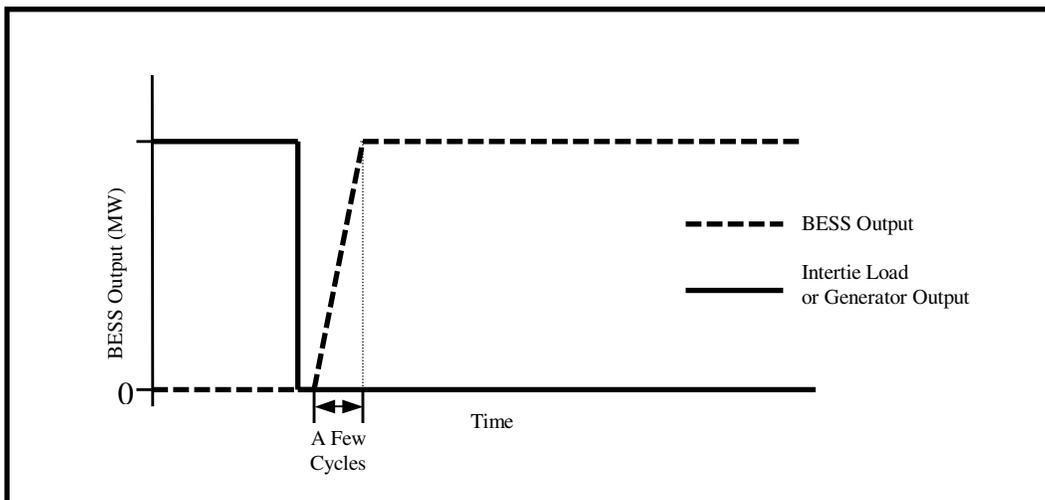


Figure 2: Automatic Scheduling Operation

- Support for Scheduled Load Increases: Since the GVEA system is relatively weak, the sudden addition of large loads will cause frequency and/or voltage variations on the system. For example, a gold mine on the GVEA system has large motors that can cause significant voltage dips when they are started. Distribution feeders lose diversity following an extended outage and picking cold load can also affect the system. For this application, the BESS would be put into a frequency and voltage regulation mode prior to the known addition of large loads. This should minimize the disturbance to the GVEA system.
- Automatic Generation Control: The Railbelt system has implemented an Automatic Generation Control (AGC) system for coordinated dispatch of the various generation resources in all three areas. The BESS will be added to the AGC system to allow operators to schedule power or vars into or out of the BESS if needed. In this mode, the BESS will operate on droop settings in the same manner as a generator.

- **Black Start:** The BESS will be required to energize a portion of the transmission system to existing generation locations and provide black start power for the generators.
- **Power System Stabilizer:** The control for the BESS will include a power system stabilizer to effectively damp power system oscillations. As described above, certain faults on the Railbelt system can cause out-of-step conditions. The power system stabilizer will be able to detect and mitigate such conditions.
- **VAR Support:** The BESS will be used to provide steady state voltage support for the power system and to assist the existing Static VAR Compensators (SVC) in responding to contingencies. The specification allowed the use of switched capacitors if needed to provide full capacitive output for the system operating parameters specified. No switched capacitors were proposed.
- **Charging:** The maximum recharge time for the BESS is specified at 12 hours. The maximum demand from the GVEA system during charging is owner selectable.

One of the most difficult aspects of a performance-based specification is how to enforce the requirements of the specification. Since specific designs and types of components are not specified, vendors are given a large degree of freedom to design a system they feel best meets the Owner's requirements. There are significant differences in approach to the design. Measurement of compliance with the specification must then be based on how the system performs once it is constructed and in operation. This can be much more subjective than other types of specifications. It is critical to define what constitutes acceptable performance and how that performance will be measured.

Much of the performance criteria will be provided by the vendor and will be negotiated prior to signing a contract. This information was required in the specification and submitted with the proposals. For example, the vendor was required to guarantee battery life for the operating scenarios specified based on historical outage data contained in the specification. Data was also required to predict battery life as the number of discharges or total energy delivered varies. The vendors also specified the conditions on which the guarantee was based, such as environmental conditions or maintenance. Annual capacity tests will be performed to determine compliance with the data.

A sequence-of-events recorder and dynamic system monitor will be installed to record actual operating data for various events. This data will be used to verify BESS performance for the types of operation specified. To the extent possible, the modes of operation will be tested prior to putting the BESS online. However, it may not be possible to test all aspects of operation. Actual operating data for a specified period of time will be used as an extension of the function tests.

The specification contained several types of warranties and guarantees. These were included to enforce the performance requirements of the specification. The biggest unknown is battery life, and this is also one of the most difficult areas for which to provide guarantees. Other considerations include availability and equipment failures. Guarantees were implemented in four main areas.

- **Construction Warranty:** A standard 12-month construction warranty was required that covers quality of workmanship issues. It helps ensure that the facility is constructed in accordance with the specification and local requirements. This warranty also covers modifications to the existing building used to house the BESS.
- **Equipment Warranty:** The manufacturer's standard equipment warranty for defects in material and workmanship of the individual components used in the BESS.
- **Availability Guarantee:** Since the BESS is critical to the stable and economic operation of the GVEA system, it must be available for use to the maximum extent possible. An 18-month availability guarantee period was implemented, where the ownership and operation transfer to GVEA but the maintenance responsibility stays with the vendor. If the BESS fails to meet the required 98 percent availability, the 18-month period is extended until 18 consecutive months at the required availability is achieved. The availability guarantee period will be used to cover startup problems, work bugs out of the control system and allow system burn-in. Experience has shown that the majority of problems with a facility of this type will occur in the first 18 months to two years. Also, as noted above, the performance of the BESS will be monitored as an extension of the function tests. Retention of 10 percent of the total project cost until all

documentation and training is complete and the requirements of the specification have been met will be used to enforce this requirement.

- **Capacity Guarantee:** The BESS was evaluated over a 20-year life span. The specification contained a requirement for a 20-year warranty. For the purposes of the evaluation, it was necessary to determine how many, if any, complete change-outs of the battery would be required in the 20-year period. The vendors were required to provide battery life information based on the operating descriptions and outage data contained in the specification as discussed above. The 20-year warranty was to include any battery replacements required to meet the 20-year life. A performance bond in the amount of 75 percent of the total battery replacement cost was required. As an alternative to the 20-year warranty, the vendor could propose to maintain the facility for the 20-year period. The vendor would be responsible for replacement of all failed components and battery replacements for the 20-year period.

A life-cycle evaluation is part of the vendor selection process. The vendors provided costs for installing, maintaining and operating the BESS. These costs were compared to the value of benefits to determine the feasibility of the BESS and to compare the total ownership costs of the proposed systems. This life-cycle evaluation process allowed GVEA to compare low first cost, high maintenance systems with high first cost, low maintenance systems. The life-cycle evaluation also provided a tool to evaluate the effect of battery replacement. For example, it may be more economical to purchase a lower first-cost system and replace the batteries at some point during the life of the system than to purchase a system that will last for the full 20 years.

The factors used in the life-cycle evaluation to compare bids and determine total ownership cost for comparison to benefits included the following:

- **Reduced Capacity Time:** A cost was assigned to any amount of time that the BESS will be out of service or below rated capacity due to failures or scheduled maintenance. A graduated scale was used to penalize complete outages more than slightly reduced capacity. If the BESS is online at reduced capacity, there is still some benefit to the GVEA system.
- **Charging Efficiency:** This is the net difference between energy delivered to the GVEA system and the energy required from the GVEA system to fully recharge the battery. For uniformity in the evaluation, specific discharges from varying states of charge were specified. The point of measurement is the high voltage side of the main step-up transformer and therefore includes all battery system, PCS system and transformer losses. A \$/kWh value was assigned to these losses.
- **Maintenance Costs:** This included the total annual costs to perform scheduled maintenance on the BESS. This could take two forms. The vendor could provide the estimated man-hours for GVEA crews to perform maintenance. A \$/man-hour figure was given in the specification for this purpose. The second option was for the vendor to provide a cost to maintain the BESS under an annual contract.
- **Battery Replacement:** The evaluation included the total cost to replace batteries during the life of the project. This included labor and materials for failed individual cells or modules as well as complete replacement of battery strings due to loss of capacity.
- **Self-discharge Losses:** An evaluation to include losses incurred while the BESS is in stand-by mode including battery self-discharge losses and transformer no-load losses. A \$/kWh value was assigned to these losses.
- **Auxiliary losses:** This category included all electrical losses not accounted for in the other categories such as BESS auxiliary systems and building HVAC. A \$/kWh value was assigned to these losses.
- **Efficient use of Building Space:** A credit was given for any useable space for GVEA use left after the BESS is installed. A definition of useable space and a \$/sqft value were given in the specification.

The factors used in the life-cycle evaluation to determine the value of benefits included:

- **Transmission Capital Deferral:** There is a value to the Railbelt system for deferral of new transmission line construction to improve stability and increase power transfers between the areas. These benefits were estimated and included in the evaluation.

- **Generation Capital Deferral:** Additional generation to meet spinning reserve requirements can be deferred if the BESS is installed. These benefits were estimated and included in the evaluation.
- **Production Expense Savings:** Many times generation must be operated at less than maximum efficiency to provide spinning reserve. Other times, generation must be started and put online for spinning reserve even if it is not needed for load. The BESS will allow more efficient use of the generation resulting in lower operating costs and reduced maintenance costs. These benefits were estimated and included in the evaluation.
- **Increased Transfer Capacity:** As noted previously, GVEA can purchase power from the central area less expensively than they can generate. The BESS will increase the stable transfer limit of the existing transmission system and allow greater purchases from the central area. These benefits were estimated and included in the evaluation.
- **Reduced Emissions:** Operating generation at its most efficient point and not running generators for spinning reserve when not needed for load will result in lower emissions. This results in a savings to GVEA for permitting and mitigation. These benefits were estimated and included in the evaluation.
- **Improved Reliability:** The BESS will improve reliability, which will result in more energy sold. Load shedding for power system problems should be drastically reduced. There are also other more intangible benefits such as customer satisfaction and less damage to consumer-owned equipment. These benefits were estimated and included in the evaluation.

Alternate proposals for both technical alternatives and financing options were solicited. Technical alternatives must show a performance or cost benefit to GVEA and must be priced before they will be considered. Alternate proposals received included alternate configurations that would reduce cost but had higher risk. Others proposed maintenance options that would guarantee performance and availability for the life of the project. Financing options were proposed, but further discussions with the vendors would be required to gather enough information to evaluate them. Although the specification allowed proposals for alternate technologies, none were proposed.

Current Status

The specification was issued for commercial bids in November 1999 with bids received in February 2000. The preliminary life-cycle evaluation indicated that costs exceeded the value of benefits. The vendors were then asked to identify the cost-driven elements within their proposals and determine how these costs could be reduced.

One of the main areas identified through discussion with the vendors included the amount of risk the vendor must assume versus the amount of risk that could be assumed by GVEA. The 20-year warranty is a primary example of this. The costs in some of the proposals to provide a system with a 20-year life or provide a guarantee were significant. Systems were significantly oversized and had considerable redundancy to meet the requirement of the 98 percent availability for the 20-year life.

Other technical issues were discussed, but cannot be published until negotiations with the vendors are complete.

As a result of these discussions, vendors were requested to revise their proposals. The preliminary life-cycle evaluation indicates that this process has been successful. Benefits will exceed cost at a point that is acceptable to GVEA. Evaluation of the proposals is still in process. As part of the evaluation process, GVEA is scheduling meetings with selected vendors for further discussions. The objective of these discussions will be for the potential vendor to fully understand the intent of the specification and for GVEA to fully understand what has been proposed. These discussions with the vendors are scheduled for October 2000. Following the discussions, a decision will be made as to whether or not additional submittals from the vendors are required. Award is expected this fall, with the BESS online 12 to 18 months following award of the contract.