Worlds Most Powerful BESS is Online and Working in Alaska

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ABOUT GVEA

Golden Valley Electric Association, Inc (GVEA) is headquartered in Fairbanks, Alaska and is a Rural Utility Systems (RUS) non-profit Co-op that was founded in 1946. GVEA provides its own generation, transmission and distribution facilities. GVEA maintains 2400 miles of distribution line, 442 miles of transmission line, a 25 MW coal fired generation facility and 200 MW of diesel and oil fired gas turbine generation. GVEA has a system peak of 182 MW during the winter months while serving 39,000 meters (90,000 residents) spread across 5700 square miles. GVEA's total MWh sales are over 1,000,000 annually.

ABOUT THE GVEA BESS

In late 2001 GVEA contracted with ABB (US) and their partners ABB (Switzerland) and SAFT to build a BESS capable of outputting 27 MW for 15 minutes. This BESS has to be capable of operating in a full power circle (+/- Watts and inductive/capacitive VARs) so that we can provide steady state voltage support during normal system operations and dynamic voltage support combined with the injection of real power into our system during dynamic system disturbances. This BESS uses liquid fill Ni-Cad batteries provided by SAFT from their factory in Oskershom, Sweden. The BESS as currently designed will have 4 strings of batteries with each string having 3,440 cells. As future conditions warrant the number of strings can easily be expanded to eight. With a DC bus voltage of +/- 2,500 Volts a power conversion system (PCS) from ABB Switzerland, using state of the art IGCT technology, was used to convert the 5kVDC to 5kVAC. The 5kV AC bus is connected to the GVEA grid via three single phase 5kV/138kV transformers. The PCS provides the AC/DC and DC/AC conversion as well as the harmonic filtering on the DC and AC sides. The PCS is water cooled using a SwedeWater ultra pure water system. Batteries are arranged in modules of ten cells (344 modules/string) and each module has a Sentry device, which is part of a battery monitoring system (BMS), monitoring voltage, electrolyte level, electrolyte temperature and the presence of liquid in the bottom of the module. Each module also has a self contained watering system to replenish the electrolyte level. The watering system and the BMS are supplied by Saft's subcontractor Philadelphia Scientific. To facilitate the installation and maintenance of the facility a Raymond, man up, fork truck is used to install/remove modules and to handle the 330 gallon deionized water pallet tank unit (PTU) used to refill the cells. The ultimate capability of the GVEA BESS is 46 MVA.

BESS UPDATE

It has been 16 months since the last update on the GVEA BESS. In that time we have completed the construction on the building and the installation of all BESS related equipment. The technicians and engineers have been trained and we have received the final documentation. We have installed three of the four strings of batteries (10,320 cells out of the 13,760 total) and have completed the commissioning and acceptance testing of the BESS.

We are extremely pleased to report that the 46 MVA BESS being built for GVEA is operating commercially and has already operated during a multi-contingency event in which two generator breakers and a transmission line opened. This BESS currently holds two world records, one; it is the highest voltage battery in the world (>5,200VDC) and two; it is the most powerful BESS in the world having surpassed 26 MW during commercial acceptance testing with two battery strings in operation. We are currently in the 18 month availability test period and anticipate testing the 40+ MW capabilities of the BESS when the installation of the fourth string is completed in December of 2003.

The BESS is incredible quiet from a broadband interference standpoint. EMI measurements from 500 kHz to 2.0 GHz revealed very little additional noise being added to the background noise level. This is good endorsement for the IGCT converter technology employed by ABB. (See appendix for more information on

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ABB's IGCT Converter) Harmonic measurements were taken to determine the background levels and then again at various output levels. The BESS met IEEE 519 for voltage and current harmonics.

We can also report that this project came in on budget and essentially on time. We had hoped to have the BESS commercially available in mid-July but due to a few issues we did not go commercial until mid-September.

FUNDING THE GVEA BESS

Energy storage is not yet a true mainstream technology. It can be difficult to find funding or to convince a lending institute that your project has a real payback, that the technology is sound and that the risk is minimal. It is also logical to assume that you might have to pay a higher interest rate for the perceived risk associated with this type of project. What is interesting to note and what holds promise for the future is that GVEA did not find it difficult to fund this project and the interest rate we secured carried no additional points for risk. To fund this project GVEA, which is a Rural Utilities (RUS) co-op, used the traditional loan applications and funding mechanisms available to it through the Department of Agriculture. A $35,000,000 loan has been secured to pay for the land, building and the BESS. The interest rate that we secured is no different than GVEA would get if we were building a new substation or a generation facility.

CHALLENGES DURING CONSTRUCTION

With any project, problems will crop up and it is how the parties involved respond that determines the relative success or failure of a project. On this project everyone approached problems and issues from a perspective of a true partnership relationship. Our discussions were open, frank and we always tried to do what made sense for the project. Our approach was that if we don't do it correctly right now, we will just be back fixing it later on and that is always more expensive than doing it right the first time. An example of this approach was with the battery modules. A module consists of ten Saft SBH920 cells arranged in two groups of 5 cells each. Each group has a plastic liner holding the 5 cells. When the first modules started arriving from Saft's Oskarshamn battery manufacturing facility in Sweden it was pointed out that the top edges of some of the liners had small cracks. Being that the liner acts as a container for the electrolyte in the event of a leak and is also part of the electrical insulating system built into each module it was a little disconcerting to find these cracks, especially since you can only see about 5% of the liner as it sticks up above the module body. Once ABB and Saft were informed of the problem they immediately determined that there was a problem (this is always nice from the owner's perspective!) and went about determining how to fix it. An extensive study was conducted in Sweden that involved evaluating the plastic being used. The modules were put on a shaker table and then cooled to -40F. The reason the module was cooled to -40F was to simulate the temperatures a module might experience on its trip to Alaska. After shaking the modules it was determined that, yes indeed, the module liners cracked. The plastic material used was a polypropylene homopolymer that had less than optimal properties at the low temperatures experienced in shipping the modules to Alaska. Liners were then manufactured using high density polyethylene (HDPE) and a new module with the HDPE liners was put together and retested under the same conditions. These liners passed with flying colors. Saft and ABB then decided that it would change the liners in all modules. The problem was that there were already a total of 336 modules either on site or in transit. Saft stepped up and air freighted 210 new liners (enough for 105 modules) to Alaska, sent three people over from Sweden and three people up from Connecticut, put them up in hotels, rented a warehouse and proceeded to take two weeks to change out these liners. They did this not once, but twice because of the modules that were still in transit. We now have modules that everyone is comfortable will last beyond the life of the project. One additional positive out of the new liners is that they have an even higher dielectric strength which always nice when you are dealing with the highest voltage battery in the world!

In November of 2002 ABB informed us that they had discovered a couple of issues with the DC breakers that they were supplying to protect the four battery strings (16 total). When operated at currents above 15,000 amps the sound level emitted could be as high as 130dB! In addition pieces of metal may be ejected! Again, as any good partnership should do, the issue was discussed and ABB determined that it was in the best interest of the project that a fix be developed. After investigating the options available to them ABB determined that they needed to produce a housing for the DC breakers. Within five months a very high density fiberglass enclosure was developed, a retrofit frame designed to mount the enclosure to the DC breaker frame and the retrofit was completed.

From GVEA's point of view you could not ask for better partners than we have had on this project and these two examples are an excellent representation of how the entire project was approached.

HOW GVEA WILL USE THE BESS

We had a pretty good idea during the writing of the technical specification what the operating modes should be and how we would use the BESS within the parameters of those operating modes. The key for GVEA was to provide as much system operational flexibility for the operators of our system, the Dispatchers, while retaining enough flexibility in the design so that we can modify or adapt the BESS to changing needs. During daily system operations, the following BESS operating modes are available to the system dispatcher; VAR-support, automatic generation control (AGC), support of scheduled load increases, automatic scheduling, spinning reserve, power system stabilization and charging.

We also need the BESS to operate automatically, with out Dispatcher intervention, if system conditions warrant it. Because of this need the modes were prioritized in the following manner.

1. Discharge Test
2. Spinning Reserve
3. Automatic Scheduling
4. Support for Scheduled Load Increases
5. Automatic Generator Control (AGC)
6. VAR Support
7. Charging

Prioritization means that higher modes can interrupt lower modes. For example if the Dispatcher is operating the BESS in the AGC mode and a system disturbance happens that necessitates the need for a spinning reserve response from the BESS, the BESS will preempt the AGC mode and immediately respond with the spinning reserve mode. After the system disturbance is over the BESS automatically goes back to the AGC mode unless the Dispatcher has canceled the mode during the disturbance.

CHARGING

If we look at the lowest priority mode we find that the BESS can provide three different charge rates.

1. Float Charge, maintain cell voltage at 1.40 VDC (4,988 VDC on the bus)
2. High Rate Charge, charge at a cell voltage of 1.45 VDC (5,160 VDC on the bus)
3. Equalize Charge, charge at a cell voltage of 1.52 VDC (5,229 VDC on the bus)

The float charge is the charge rate that the battery is normally operating under. If the BESS is used to provide real power (MW) to the GVEA grid and the state of charge (SOC) of the battery drops below 95%, the BESS will use the high rate charge to bring the battery up to full charge at which point the BESS will automatically drop back into the float charge rate. The equalize charge will be used sparingly. If a battery string is down for a number of days or weeks the equalize charge can be used. Generally speaking we will not use the equalize charge very often. One important note is that the Dispatcher determines when the BESS will be recharged. System conditions are usually less than optimal after a significant system disturbance and if the BESS has been fully discharged there may not be generation resources available to charge the BESS right away. Because of this a charging schedule table was developed for the BESS HMI and within the GVEA SCADA master station to allow the Dispatcher to control the amount of power available to the BESS on an hourly basis. Maximum recharge rate is 1.5 MW per string or 6 MW total with four strings online. The Dispatchers charging schedule table allows him to set the MW rate and the time at which the battery will be recharged.

VAR SUPPORT

This will be the primary operating mode for 99% of the year. The VAR support mode was a given as the BESS was justified, partially, on the fact that we needed an SVC for the Northern Intertie Project. The sunk cost of providing an SVC helped justify the incremental cost of adding energy storage in the form of batteries. The VAR support capability is defined by the operating characteristics of the ABB supplied converter. The converter is not capable of providing a true, four quadrant power circle under all operating conditions. The reactive power and active power output of the converter is dependent on the grid voltage. A higher grid voltage limits the capacitive output of the BESS but increases the inductive limit. This is not as limiting as it first appears because the steady state voltage support needs are different than the dynamic voltage supports needs that we experience during a system disturbance. The BESS fits perfectly into a system disturbance scenario because as voltage starts to go down, the capacitive capability of the BESS increases from 24 MVAR at 1PU volts to 46 MVAR at 0.9 PU volts. We are currently running the BESS around 7-9 MVAR capacitive at a slope (3%) that is similar to the other SVC's in the system. The BESS will be a huge asset during a disturbance as the SVC's that we currently operate in our system were designed with steady state conditions in mind and have little room to respond to the dynamic situations that occur during a system disturbance. The new Northern Intertie parallels an existing transmission line between Healy and Fairbanks which will lower the reactive losses and further reduce the need for voltage support provided by the existing SVC in Fairbanks. This, coupled with the BESS capabilities, should give us enough dynamic response to prevent some of the voltage collapse situations we have experienced in the past.

AUTOMATIC GENERATOR CONTROL (AGC)

The ability to run the BESS as a generator using AGC was an area that was debated pretty heavily within GVEA. Generally speaking we would never need this mode, but during the summer when we have a number of generating units down for maintenance we might be able to use the BESS to squeeze through a short morning peak load requirement. The trade offs between using up a portion of the battery warranty verses not having to start a generator (wear & tear, fuel, emissions) are not easy to evaluate. In the end we decided to keep this mode in the specification primarily because when you are operating an islanded utility in the middle of Alaska you want as much flexibility as possible and the future is not always as clear as you wish it would be.

SUPPORT FOR SCHEDULED LOAD INCREASES

The GVEA system is electrically soft. Large motors starting on our system have always impacted us. In the early eighties we required the owner of an electric dragline used to mine coal to come up with a solution to the voltage swings caused when they were swinging the bucket and digging under load. Their solution was to install a 5MVA flywheel to absorb the fluctuations. Since that time we have had a number of relatively large motors (4-8,000HP) added to our system. All of these motors have some form of soft starting but in designing the BESS we thought it would be prudent to have the ability to help our customers (and the system) in the event the soft start capability was not available due to equipment failure.

AUTOMATIC SCHEDULING

This is a very exciting new tool that will be used by GVEA for problems within our own area of control. The loss of a generator within our system typically means that frequency will decay at < 1.5Hz/second. The loss of a critical transmission line means that frequency can decay at rates up 7.0 Hz/second. The ability to inject real power into the GVEA grid, as a breaker is going open, will have huge dividends. The basic hardware and software pieces are as follows.

1. GVEA's SCADA system continuously monitors the power flows through GVEA generators and selected transmission line breakers and updates a SCADA table.
2. A unique algorithm for each breaker takes the power flow information from the SCADA table and determines what the BESS response will be for each of these breakers if they open.
3. The required BESS response for each breaker is updated continuously and sent from GVEA's SCADA to the automatic scheduling table in the BESS HMI.
4. The trip circuits of the breakers are monitored continuously. When a breaker starts to open the signal is sent to the BESS PSR controller via microwave/fiber optic.

With thirty inputs available, a flexible algorithm on the software side we should have enough flexibility built into the system to handle any contingency.

Timing tests have shown that we can detect the trip current going to the trip coil of a breaker and get the signal to the input of the BESS controller (PSR) from one hundred miles away fast enough to actually start injecting power into the grid before the breaker goes open if we want to. Time and operational experience will tell how much delay we need for optimal system response. Schweitzer relays at both ends of the communication path play an important role here as well as we can use them to provide time delay in the signal if we need to.

SPINNING RESERVES

The spinning reserve mode has the highest priority of all BESS operating modes and for good reason. This mode has to deal with problems that are external to the GVEA system. GVEA buys non-firm energy from the Anchorage utilities and imports it over the Intertie between the Anchorage grid and the GVEA grid. Because we buy non-firm energy we are responsible for our share of the spinning reserves (spin) in the event that a Anchorage generator goes offline. Historically we keep track of our spin obligation using the AGC and Load Shed applications on the SCADA master station. These applications constantly track the amount of real spin we have on our local generation, what our current spin obligation is and determines which substation feeders to shed to make up for any deficit in our spin obligation. If the amount of load connected exceeds the generation available the system frequency will decay and trigger the load shedding of substation feeders. When the system frequency gets to 59.7 Hz we shed 25% of our spin obligation, if system frequency gets to 59.4 Hz we shed another 25% of our spin obligation and if system frequency continues to drop and gets to 59.1 Hz we shed the final 50% of our spin obligation. If after meeting our spin obligation system frequency continues to drop we have hardwired underfrequency relays in our distribution substations that will continue to shed load until the system either recovers or we go in the dark.

The spinning reserve mode tracks system frequency and initiate the first stage of our spin obligation when the system frequency gets to 59.8 Hz. The amount of real power injected into the grid will be dependent on our spin obligation at that time and is constantly updated by the GVEA SCADA master station. The real power points for the three stages of spin obligation ($P_{spin\text{-}stage\ 1}$,$P_{spin\text{-}stage\ 2}$, $P_{spin\text{-}stage\ 3}$) are updated and the frequency set points ($f_{spin\text{-}stage1\text{-}3}$, $f_{spin\text{-}emerg1}$, $f_{spin\text{-}emerg2}$) are fixed, although if future system conditions warrant it we can easily change them. The $P_{spin\text{-}max}$ point can be used to limit the MW output of the BESS in an emergency condition.

It is through the use of the auto scheduling and spinning reserve modes that GVEA hopes to reduce power supply types of outages (generation and transmission line) by 65-75%. GVEA will have to balance the desire to reduce outages with the total number of cycle equivalents left on the battery and the warranty we are working under. Since the warranty is based on a total number of cycle equivalents, we could choose to use them all up quickly, or to hold on to them in a miserly fashion while waiting for “the big one” to occur.

PSS (Power System Stabilizer)

The BESS can be used to provide damping of power system oscillations through the use of the PSS sub- mode. Power system oscillations caused by system disturbances, primarily transmission line faults or the sudden addition or loss of large loads or generation will cause frequency deviations that are detected by the BESS PSR. The ability of the BESS to respond is somewhat limited by the state of charge of the battery and the limited ability of the battery to accept real power when it is fully charged. Since we have a weak electrical system GVEA has enabled the PSS even though the response may be somewhat limited.

So What Happens Now?

We have just entered the 18 month availability period during which ABB/Saft must prove that the BESS will be available 98% of the time. This means that the BESS has to be down for less than 11 days during the next 18 months in order for GVEA to accept the system. Learning how to integrate the BESS into our system, becoming familiar with the maintenance requirements, learning to sift through all the data from the battery monitoring system and the PSR and educating our membership will keep us very busy for the foreseeable future. These are exciting times for GVEA and for the future of energy storage.

APPENDIX

Information in this appendix is provided by Niklaus Umbricht with ABB Switzerland. Nik can be reached in Switzerland at +41 58 /589 38 07 or by email: niklaus.umbricht@ch.abb.com

IGCT-Converter Introduction

The two primary subsystems of the BESS are the IGCT converter and the Ni-Cd battery. The converter interfaces between the DC voltage from the battery and the 60 Hz AC GVEA system voltage. The converter is capable of operating in all four quadrants of the power diagram. The converter transformers match the converter output to the 138 kV system voltage.

The active switching elements used in the converter are Integrated Gate Commutated Thyristors (IGCTs). A kind of advanced Gate Turn Off Thyristor (GTO). Compared to other elements with switch-off capability, IGCTs have the advantage of lower conduction and switching losses, and in addition to that allow a snubber-less converter design because of their superior switch-off characteristics.

The converter is liquid cooled with a closed-loop water cooling system. This design has two water loops; de-ionized water cools the converter. A raw-water/glycol solution circulates in a secondary loop removes the waste heat via outdoor radiators.

Design of the BESS Converter

Regarding the requested power P_{Grid} = 40 MW (cos φ = 1.0) with minimized harmonic distortion, a 3 level converter design was chosen. On the AC line side the power converter consists of four paralleled twin connected three-phase units (total of 24 converter phases). The converter is connected to the medium voltage grid via three single phase transformers. The converter consists of the DC link (low inductance DC bar and capacitors) and the 2-phase modules mounted on a rack. With regards to the power and the high number of phases, the converter is built out of two similar converter frames (half converters). Each frame consists of 6 2-phase modules. One half converter frame houses also a VLU (Voltage Limiter Unit). On site, these two half converters are connected together to form a single unit.

The base unit for the PCS (Power Conversion System) is a ABB standard medium voltage three level 2-phase module. This module has undergone an intensive design review process so that it is optimized for mechanical, electrical, and maintenance considerations. The standard module provides obvious benefits in terms of overall cost reduction and long term maintenance and support.

This converter design offers the following advantages:

- Development is greatly reduced by implementing well known techniques.
- The three level medium voltage modules have proven to be highly reliable products. Its application leads to low FIT values.
- The use of the 2-phase modules allows short distances between the power semiconductors, which offer low stray inductances, and reduces the space requirement for the total current converter.
- The clamp diodes and capacitors are integrated in the semiconductor stack. In this way the stray inductance in the clamp circuit are also minimized, allowing use of higher GCT switch-off currents.
- One single clamp for two phases, reduces the need for bulky and costly clamp inductors and resistors.
- Ease of serviceability is a primary consideration during mechanical design of the converter. To guarantee an individual semiconductor replacement, all power semiconductors in the stack are directly accessible.