Cold storage

Battery energy storage system for Golden Valley Electric Association

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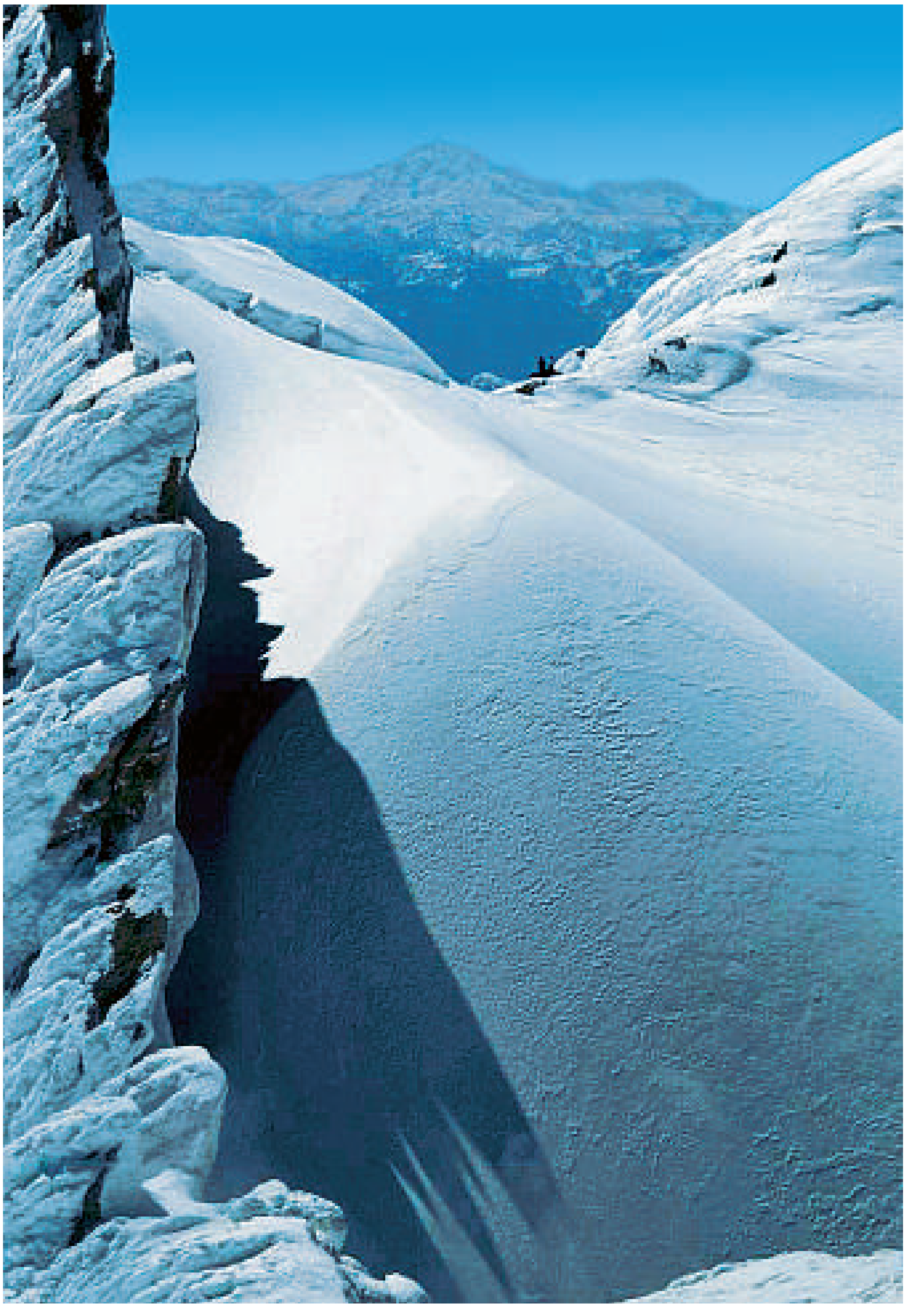
Alaskan winters are cold. Where temperatures can drop to minus 50 °C, power outages are very bad news indeed. A reliable supply of electricity is given a high priority when your water pipes can freeze solid within hours if the power goes down!

One way to prevent this happening is to have an emergency power source feed energy into the grid until back-up generation can be got back on-line. An economically and ecologically more viable alternative to 'spinning reserve' – gas turbines kept running in case of an emergency – is battery back-up. In August this year, the world's largest-ever battery energy storage system was inaugurated in Fairbanks, Alaska. In addition to stabilizing the local grid, it will reduce power outages in the area by 65 %. A consortium led by ABB supplied and installed the system.



Golden Valley Electric Association (GVEA) is a rural electric cooperative based in Fairbanks, Alaska, serving 90,000 residents spread over 2200 square miles. A reliable supply of electricity is essential to the local population since many residents live in remote areas and winter temperatures can fall as low as minus 50 °C. Back-up power therefore has to be available in the event of an outage.

Traditional solutions for providing reserve power require building and maintaining transmission and generation capacity well in excess of normal demand. GVEA's decision in favor of a battery energy storage system (BESS) reflects its commitment to installing a system that is a cost-effective and efficient alternative to these solutions.

15 important minutes

At the heart of the world's most powerful storage battery system are two core components: the converter, designed and supplied by ABB, and nickel-cadmium (Ni-Cd) batteries, developed by Saft. The converter changes the batteries' DC power into AC power, ready for transmission over the GVEA grid. The batteries constitute the energy storage medium. They can produce up to 27 MW of power for 15 minutes, giving the utility enough time to get back-up generation on line. While the BESS is capable of producing up to 46 MW for a short time, the client's primary need is for the system to cover the 15-minute period between sudden loss of generation and start-up of back-up generation.

Although the BESS is initially configured with four battery strings, it can readily be expanded to six strings to provide a full 40 MW for 15 minutes. The facility can ultimately accommodate up to eight battery strings, providing flexibility that will allow the client to boost output or prolong the useful life of the system beyond its planned 20 years.

System and project requirements

The final specification required that the vendor provide a turnkey solution and guarantee for twenty years that the BESS could supply 40 MW for 15 minutes, with a 4 MW/min ramp-down after the 15-minute mark. The system is required to be capable of operating in all four quadrants (ie, the full power circle) and to provide continuous, infinitely adjustable control of real and reactive power over the entire operating range. The specification also required that the BESS be able to operate in an automatic mode, as GVEA does not plan to man the facility.

Rated output had to be provided for the following power system characteristics:

- Nominal voltage of 138 kV (1.0 pu)
- Normal sustained voltage of 0.90 pu (min) and 1.1 pu (max)
- Normal frequency of 60 Hz, with normal deviation of +/- 0.1 Hz
- Sustained frequency range of 59.0 Hz (min) and 60.5 Hz (max)

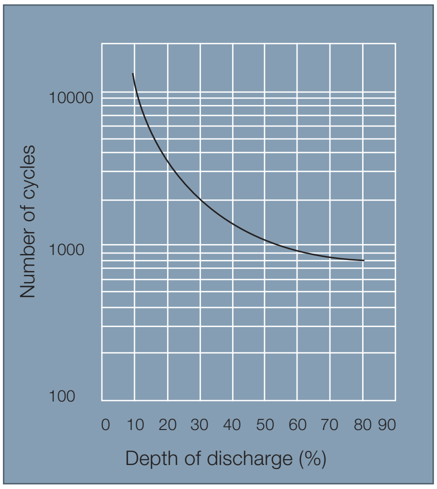
Seven operating modes

The BESS is able to operate in seven distinct modes:

- *Var support:* The BESS provides voltage support for the power system under steady-state and emergency operating conditions.
- *Spinning reserve:* In this mode, the BESS responds to remote generation trips in the Railbelt system. It is initiated at a system frequency of 59.8 Hz, with the BESS loading to full output at 59.4 Hz if system frequency continues to drop. Spinning reserve has the highest priority of all the modes and will interrupt any other mode the BESS is operating under.
- *Power system stabilizer*, included to damp power system oscillations.
- *Automatic scheduling*, used to provide instantaneous system support in the event of a breaker trip on either a transmission line or a local generator. The BESS has thirty independently triggered inputs, which will be tied remotely to the trip circuits of breakers.
- *Scheduled load increase:* This is initiated and terminated by SCADA and puts the BESS in a frequency and voltage regulation mode to allow it to respond to the addition of large motor loads.
- *Automatic generation control:* In this mode the BESS is capable of operating by AGC, similar to that of rotating machinery.

The client's primary need is for the BESS to produce up to 27 MW for 15 minutes – the time between sudden loss of power and start-up of back-up generation.

1 Cycling characteristics of the BESS battery. No. of charge/discharge cycles vs depth of discharge



World record

During commissioning tests, ABB's power conversion system and the Saft battery set an unofficial world record by achieving a peak discharge of 26.7 MW with just two strings in operation, making use of the short-time overload capability of the battery modules. This makes the Alaskan BESS more than 27 percent more powerful than the previous record holder – a 21-MW BESS commissioned by PREPA (Puerto Rico Electric Power Authority) at Sabana Llana, Puerto Rico in 1994.

- *Charging:* The SCADA dispatcher can control the MW rate at which the BESS will be charged and when charging is to start after a BESS discharge.

The battery

The Alaskan BESS battery comprises 13,760 Saft SBH 920 high-performance rechargeable nickel-cadmium cells, arranged in four parallel strings to provide a nominal DC link voltage of 5000 V and a storage capacity of 3680 Ah. The cells are built into 10-cell modules for mounting in a drive-in racking system. An aisle between the racks provides installation and service access for a swing-arm fork truck.

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The complete battery weighs some 1300 tons and the hall in which it is located measures 120 meters by 26 meters – about the size of a soccer field. The initial battery configuration has four individual strings operating in parallel, but can be expanded to accommodate eight strings. Each string has 3440 cells connected in series.

The battery features a pocket plate construction with thin, high-performance plates. This design allows the full 20–25 year life to be attained without any loss of the beneficial characteristics of Ni-Cd batteries. The type of cell used can deliver 80% of its rated capacity in 20 minutes.

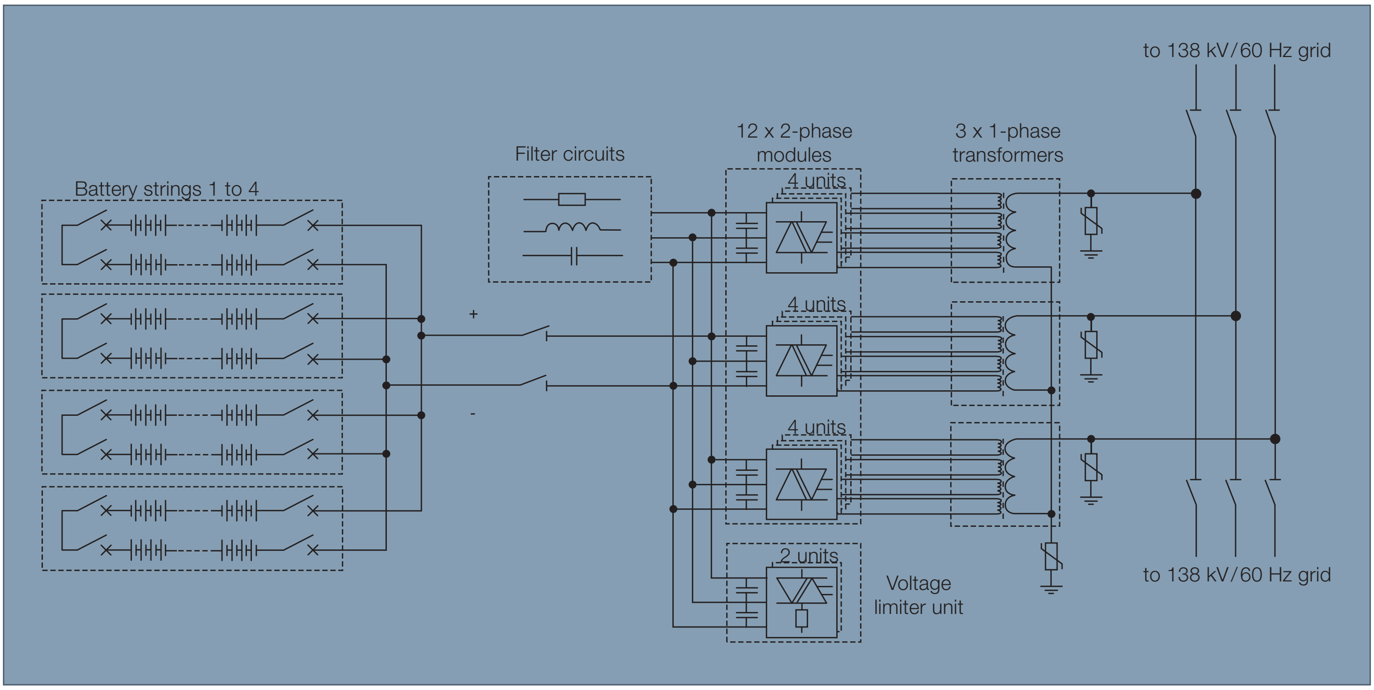
Ni-Cd pocket plate cells can withstand repeated deep discharges with little effect on battery life. The graph in 1 shows the cycling characteristics of the SBH battery.

2	Battery module, comprising 10 cells, on the move

The chosen design has several advantages:

- Compact arrangement: More rack depth can be utilized, minimizing the space taken up by aisles 2.
- Easy installation: 90% of the connections are made in the factory; only the inter-module connections are made on site.

3 Basic diagram of the electrical system



- Quick change-out: If there is a problem with an individual cell, the module containing that cell can be replaced by another complete module in less than 30 minutes.
- Minimum power losses: 99 % of the inter-cell connections are made with solid copper bars; power losses caused by flexible cable connections are therefore minimized.

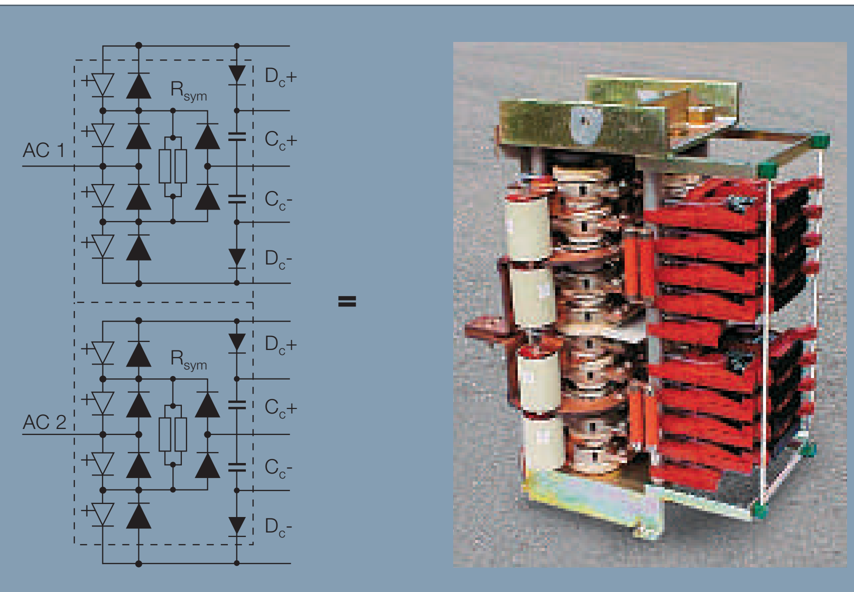
A PE liner on the inside of the module case (between the battery cells and metal tray) provides the necessary insulation. Each module is fitted with a self-contained, single-point filling system, allowing all 10 cells to be topped up in a single operation without removing the module from the rack.

Battery monitoring system with multiple features

The battery monitoring system was supplied by Philadelphia Scientific Inc. It measures, records and reports the module voltage, string current, cell electrolyte level (one cell per module) and cell internal temperature (also one cell per module).

Data collection and transfer are organized hierarchically. The lowest-level device in the hierarchy is the sentry unit. There is one for each 10-cell module, and its task is to measure the module voltage, cell electrolyte level and cell internal temperature. Each sentry unit reports its collected data to a

4 Building block. A double-stack water-cooled PEBB in NPC connection, forming one H–bridge



sergeant module. Every string has its own sergeant module, which also measures the string float current. In turn, the sergeant module reports its collected data to the supervisory computer, which analyzes and displays the data. This computer is also responsible for forwarding summary data to the HMI and is the main terminal for BESS personnel who need to access the monitoring system.

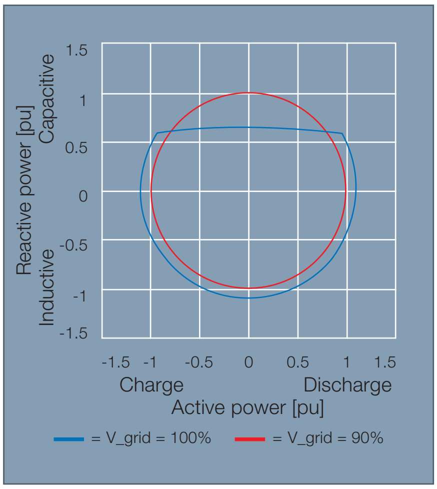
> The converter and transformers have been designed and built to handle the total power should the battery be extended from four to eight strings later.

Optical couplers carry the data from the sentry units to the data bus, which is insulated to withstand a minimum of 5000 V. 5560 readings are taken every 30 seconds – a total of 5.8 billion readings per year. These numbers can be doubled if required.

The electrical system

Four battery strings are currently installed 3. All preparations have been made for extension at a later stage, with up to eight battery strings possible. Every string (and sub–string) can be switched off and completely isolated from the rest of the system by DC switches. In addition, two disconnectors allow separation of the battery

5	Operating range of BESS P/Q diagram 1 pu corresponds to 40 MVA



and the DC link of the converter when maintenance work has to be carried out on the batteries. The converter can then remain in operation and provide reactive power to the grid for voltage control. Filter circuits in the DC link eliminate the risk of resonances at higher frequencies should any harmonics be generated in the grid by non-linear loads. The voltage source converter at the heart of the electrical system comprises standardized PEBBs (Power Electronic Building Blocks). One double-stack PEBB in NPC (Neutral Point Clamped) connection forms a single-phase H-bridge 4. Four H-bridges are installed per phase, for a total of twelve single bridges. The stacks are cooled by deionized water in a closed-loop circuit.

Each bridge is connected to its dedicated transformer winding. The voltage contributed by the bridges is added in the transformer by series-connecting the line-side partial windings, resulting in a voltage wave shape similar to the quality that could be expected from rotating machines. Voltage limiters prevent any overvoltages due to sudden load rejections or possible disturbances in the electric grid from damaging the DC link.

The converter and transformers have been designed and built to handle the total power should the battery be extended from four to eight strings at a later stage.

The active switching devices used in the converter are integrated gate commutated thyristors (IGCTs), an advanced type of gate turn off thyristor (GTO). Compared with other devices that can be turned off, IGCTs have the advantage of lower conduction and switching losses, plus superior switch-off characteristics that allow a snubberless converter design.

ABB wins 2003 Global Energy Award – Alaskan BESS 'Energy Engineering Project of the Year'

It was announced in December that ABB has won the Platts 2003 Global Energy Award for its part in developing the world's most powerful battery energy storage system. The battery was energized in August 2003.

Peter Smits, head of the ABB Power Technologies division commented: "We are pleased to receive this kind of recognition for this high-end power transmission component. The BESS will stabilize the local grid and reduce the number of outages for Golden Valley's customers by 65 percent."

Now in its fifth year, the Platts Global Energy Awards have become the most prestigious awards program in the industry. The Energy Engineering Project of the Year Award recognizes innovation, practicality and commitment to safety and the environment.

Advantages of this converter design include:

- The three-level medium-voltage modules are proven, highly reliable products. Low FIT values are obtained when these modules are used.
- Use of double-stack modules shortens the distances between the power semiconductors, keeping stray inductances low, and reduces the space required for the complete converter.
- Since the clamp diodes and capacitors are integrated in the semiconductor stack, the stray inductance in the clamp circuit is also minimized, allowing use of higher IGCT switch-off currents.
- Using a single clamp for two phases reduces the need for bulky and costly clamp inductors and resistors.
- Ease of serviceability was a primary consideration during the mechanical design. All power semiconductors in the stack are readily accessible, allowing easy replacement.

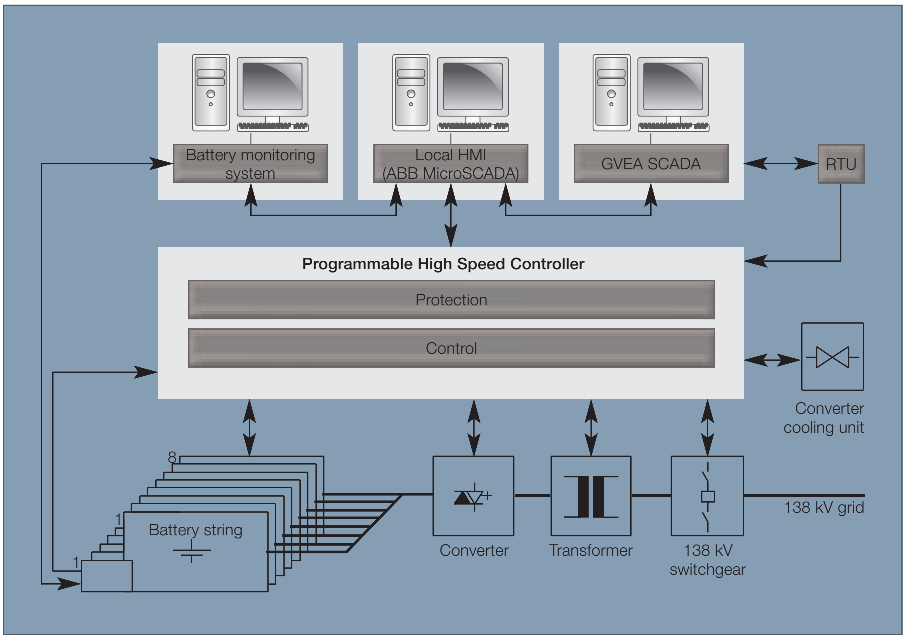
Power and reactive power performance

The system is designed for four-quadrant operation. It can charge as well as discharge the battery and it can absorb reactive power from or supply reactive power to the grid. Each of these modes is possible with the DC link voltage varying as the battery's charging condition changes.

In addition to reducing power outages in the Fairbanks area, the BESS has specific benefits in the areas of transmission and distribution, generation and strategic planning.

The operating range of the system in terms of active and reactive power for 90% and 100% of the nominal grid voltage is shown in 5.

6 Overview of control and protection system



The control system

Local system control is provided by an ABB SPIDER MicroSCADA human machine interface (HMI) based on the Microsoft Windows operating system 6. The system is operated via pictures, windows and function keys using a mouse and a keyboard. Sequence and closed-loop control as well as overall protection are provided by ABB's programmable high-speed controller (PHSC), which can be programmed using the graphic function plan program FUPLA. The PHSC is well proven and its reliability has been shown to be suitable for both system control and protection in numerous applications.

The converter control incorporates the following functionality:

- Sequence control
- Control of the main breakers
- Signal conditioning
- Processing of measurement signals
- Fast current control for ride-through in the event of external faults
- Power and reactive power control
- Load management
- Interlocking of local control and SCADA/RTU control
- Redundant protection functions

BESS – a stabilizing factor

While fulfilling its overall mission of reducing power outages in the Fairbanks area, the Alaskan BESS has specific benefits in the areas of transmission and distribution, generation and strategic planning:

Transmission and distribution benefits include voltage regulation, first swing stability and loss reduction.

In the *generation area* the BESS offers spinning reserve, ramp-rate constraint relief, load following, black starts, load leveling, and a reduction in deferred turbine starts.

Strategic benefits include improved power quality, reduced demand peaks, and enhanced service reliability through reduced power supply generated outages.

The principal benefit, however, is the ability of the BESS to instantly contribute to system stability following the loss of a major transmission line or generator. The spinning reserve it provides has the potential to allow generation units to be run at lower levels or be shut down entirely, resulting in significant savings. Almost instantaneous active power is available. This is important in cases where the BESS has to ramp up before the impact of a generator loss becomes noticeable at the point of common coupling.

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