

A Review of the Operation of a Large Scale, Demand Side, Energy Management System Based on a Valve Regulated Lead-Acid Battery Energy Storage System

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ABSTRACT

The installation of the Battery Energy Storage System (BESS) at GNB Technologies Recycling Division's Vernon, California, smelter had three objectives: 1) Prevent loss of power to the critical loads, 2) Reduction of electrical demand charges, and 3) Showcase BESS for demand side management. The BESS was commissioned in 1996 by GNB as a demonstration project under contract with Sandia National Laboratories. GNB partnered with GE Electrical Distribution and Control to build the largest known demand side energy management system of its kind.

The Vernon BESS can provide up to 5 MW of power at 4160 VAC to support the entire plant load. Since the critical loads are not isolated, it is necessary to carry the entire plant load (maximum of 5 MW) for a short period immediately following an incident until non-critical loads have been automatically shed. Plant loading typically peaks at 3.5 MW with critical loads of about 2.5 MW. The critical loads include all of the environmental systems and controls, security systems, and utility lighting. The recycling plant has the potential to release lead dust to the atmosphere if there is a failure in the environmental controls. The plant is located only 8 km from downtown Los Angeles, California. With the very strict air quality regulations in the region and the nature of lead dust, an atmospheric release is not acceptable. The installation costs of the BESS are based on the perceived cost savings due to mitigating the environmental risks.

The BESS also provides the recycling plant with customer-side-of-the-meter energy management options to reduce its energy demand during peak periods of the day. The BESS has provided a reduction in monthly electric bills through daily peak-shaving. By design, the BESS can provide up to 2.5 MWh of energy and still retain 2.5 MWh of capacity in reserve to handle the possibility of a power outage in protecting the critical loads for up to 1 hour. By storing energy from the utility during off-peak hours of the night when the cost is low (US\$4.4¢ per kWh), the BESS can then discharge this energy during high demand periods of the day (US\$10.30 per kWh). For example, by reducing the peak demand by 300kW, the recycling plant can save over US\$3000 per month in electric bills. This cost savings will not offset the installation costs of the BESS, but does reduce the operational costs. The BESS is also able to improve the plant's power factor, thus dropping the monthly electric bills even lower.

The BESS has proven its functionality in both testing and operational situations. When a utility failure occurs, the BESS senses and takes over powering the plant. It locks out the utility and sends a signal to the load shedding system. If the utility does not return, the plant shuts down operations, relying on the BESS for power until all processes are safely shut down. If the utility problem disappears, the BESS will sense that the utility is ready. The BESS then automatically synchronizes with the utility so that it can safely make the transition back to utility power. All of this can be done without operator intervention.

The Vernon BESS has provided a great deal of information about the operation of a large demand side energy management system and has proven the technology for other applications. It can improve power management and reduce operational costs. However, for a BESS to be cost effective, it must mitigate larger environmental, health, or safety issues that could conceivably incur great expenses. The BESS at Vernon has performed properly under utility loss situations and has kept the environmental systems running until they could be shut down properly or the utility came back on-line.

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1. Introduction

Electrical power interruptions and voltage depressions represent difficult and important power quality and delivery problems facing many industrial manufacturing plants, processing facilities, and commercial users. There is a definite need to have a dependable, efficient and controllable source of real and reactive power that is available instantly to support large electrical loads even if the incoming utility AC connection is lost. When power is interrupted or lost, the results can be extremely disruptive for critical processes resulting in lost production, costly downtime and loss of customer good will, and in certain industries, can lead to environmental damage through the release of toxic emissions into the air. Seven years ago, this challenge was faced by GNB Technologies at its lead reclaiming and smelting facility located in Vernon, California. Vernon is located about ten miles from downtown Los Angeles.[1]

The lead smelting process at the GNB recycling center (Fig. 1) creates lead dust that is recovered through the use of several large exhaust control fans and large containers to collect dust particles. In 1999, the plant produced over 120,000 tons of reclaimed lead from automotive and industrial batteries. When the plant loses its incoming utility power, these control fans, amounting to thousands of horsepower, must continue to run to avoid an environmental incident. That is, lead-dust can escape into the air if the fans stop running and can potentially cause an environmental problem.



Figure 1: GNB Technologies, Recycling Center
Vernon, California USA

To prevent an environmental incident, GNB considered installing diesel generators as backup or several large UPS systems. However, considering the overall requirements, operational performance of the various technologies,

capital cost, maintenance and operating benefits long term, GNB elected to install a Battery Energy Storage System (BESS).

On May 13, 1996, GNB commissioned a new BESS facility housing a 5-megawatt system. After five years of operation, the BESS has performed quite well and the plant has not been affected by power outages and is benefiting by having the ability to peak-shave its electrical demand.

2. Plant Electrical Demand

The Vernon facility operates 24 hours per day, seven days a week and 365 days a year. It never shuts down except for scheduled maintenance of its processing furnaces and equipment.

The main utility substation at the Vernon smelter is rated at 5.0 MVA. The incoming utility line is 4160 VAC. During a typical production day, the average plant loading is about 3.5 MW. Demand spikes can and do push the overall loading up to greater than 4.0 MW. When adding up all of the critical loads that must be protected, the plant critical loads are about 2.5 MW.

3. Power Interruption and Protection

When the plant loses utility power (which typically happens two or three times a year, more so recently with rolling blackouts effecting southern California, the BESS will provide up to 5-megawatts of power at 4160 VAC in support of all the plant loads. Since the critical loads are not isolated, it is necessary to carry the entire plant loading (maximum of 5 MW) for a short period of time immediately following an interruption until non-critical loads have been automatically shed.

This year, the threat of power outages has greatly increased. As the states go through deregulation of their utilities, system reliability is being brought under question by Electric Power Research Institute (EPRI), of Palo Alto, California. EPRI's Reliability Initiative is a two-year study of the root causes of recent power outages and the identification of ways to reduce the risk of further problems. The reliability problems are intensified by the small gap between generating capacity and peak demand.[2] In order to reduce the risk of citywide brownouts and blackouts, The City of Vernon had to create 10 MW blocks of consumers to drop during rolling blackouts required by the Independent Operating System. The Independent Operating System monitors power generation and demand and tells utilities when they need to shed some load. To both the consumer and the utility, this comes without warning.

4. Energy Management

The Battery Energy Storage System also provides the manufacturing plant with customer-side of the meter energy management options to reduce its peak energy demand during peak periods of the day. The BESS has provided a reduction in monthly electric bills through daily peak shaving. By design, the stationary ABSOLUTE IIP VRLA battery system can provide up to 2.5 MWh of energy for peak-shaving and still retain 2.5 MWh of capacity in reserve to handle the possibility of a power outage in protecting the peak critical loads for up to one hour. By purchasing and storing electrical energy from the utility at night when the utility cost of energy is low, 4.0¢ per kWh, the plant can then discharge energy on demand during peak hours of the day when the utility charges 4.7¢ per kWh. However, the big savings is with demand charge. The energy stored at night is used to offset a \$10.30 per kW demand charge during peak periods of the day. For example, by reducing the peak demand for power by 300 kW, the plant can save over \$3,000 per month in its electric bills.

5. Operating the BESS

The BESS is an unmanned facility that operates basically automatically. The system controls are preprogrammed to react during various power interruptions. The system is also preprogrammed to operate as an energy management tool in providing peak shaving and load leveling during high demand periods. The BESS is designed to handle up to 5.0 MW for a maximum of 15 seconds and followed by a continuous 3.5 MW output having automatically shed the non-critical loads. At the continuous rate of 3.5 MW, the system can provide backup power for a minimum of one hour. In addition to the emergency backup power, the battery was sized with an additional 2.5 MWh in reserve capacity for conducting daily energy management functions referred to as peak shaving or load leveling.

The BESS at Vernon was primarily installed to protect the critical loads during a power outage. The plant was built during a time when the distribution feeders out of the substation did not isolated critical loads. Therefore, it was necessary to backup the entire plant versus just portions of the electrical distribution system. The BESS is fully automatic and operates in parallel with the existing plant loads. During the design phase of the Vernon BESS, tests at the plant revealed that, assuming an outage occurs, it is acceptable to transfer from parallel to series connection of the BESS within 12 cycles. A solid-state transfer switch (1/4 cycle transfer time) was not necessary in this industrial application. The types of critical loads are mainly large electric 3-phase induction and synchronous motors.

6. Protecting the Environment

To adequately describe the need for critical load backup, one first must understand the strong environmental history of the area surrounding the Vernon smelter. In 1947, California passed the Air Pollution Control Act, eight years before Congress passed the Federal Air Pollution Control Act of 1955. The first Air Pollution Control District was created in Los Angeles in 1947, the first of its kind in the nation. In 1967, California created the Air Resources Board which is still the governing agency for air quality standards in the state.[3] In 1997 the Air Resources Board identified inorganic lead as a toxic air contaminant. 38% of the inorganic lead emissions is due to aircraft fuel. The next largest contributor, at 2%, is from metal melting facilities.[4]

The Vernon BESS is the largest known installation of its kind in the world owned and operated by an industrial manufacturer to support critical manufacturing process equipment. One of the critical processes at the plant is the operation of emission control systems associated with handling lead dust. GNB's primary concern is to assure the continual operation of these systems during a power outage. To accomplish this, GNB, working with General Electric, designed and built the BESS to provide a source of uninterruptable power in the event of a loss of incoming utility power and thereby protects the critical processes from shutting down. Lead-acid battery recycling plants, like the one in Vernon operating within short distances of cities like Los Angeles, must operate under stringent state and federal regulations for air quality standards and environmental protection. The state-of-the-art manufacturing process equipment which GNB operates within the plant 24 hours per day, seven day a week, and year round to control its environmental emissions equipment must have an uninterrupted supply of power. No excuses are allowed.

7. System Design and Layout

7.1 System Rating

The Vernon BESS is designed to operate for up to 15 seconds at a maximum plant power demand of 5 MW immediately after a takeover following a loss of utility grid power. Presently, the plant peak demand is about 3.5 MW and generally ranges between 2.5 to 3.0 MW during a 24 hour period. The critical loads make up about 2.5 MW of the overall plant demand. Nominal ratings for the Vernon BESS are shown in Table1 below.

Table 1: Ratings for Vernon BESS

Base voltage at 1.0 pu	4160 Vrms L-L
Frequency	60 Hz
Continuous power rating	3000 kVA
Peak power rating (15 sec.)	5000 kVA
Nominal current rating	416 Arms
Nominal dc voltage rating	756Vdc
Number of series battery strings	2
Nominal battery capacity	5000 Ah @ the 1 hour discharge rate
Number of power converter pairs (PCP)	3
PCP power output rating	575 Vac
PCP dc voltage input range	600 - 900 Vdc

Upon sensing a loss of utility voltage, the BESS automatically controls the following functions:

- The incoming circuit breaker is opened.
- The existing plant control system sheds all but the critical loads (2.5 MW).
- The BESS will carry the plant load (up to 2.8 MW of which 2.5 MW are critical) for up to one hour, or, until such time that the utility power has been restored.
- Once the utility feeder voltage is present, the BESS can automatically reconnect (manual reconnect is also available) the isolated plant load with the utility.

7.2 Lead-Acid Battery System

At Vernon, the battery selected and being used is an advanced valve-regulated lead-acid (VRLA) Absolyte® IIP modular battery system manufactured by GNB Technologies.

For more than 100 years, lead-acid batteries have been used for many essential standby and portable power applications. In the past twenty years, advancements in lead-acid technology and battery construction have led to the production of large industrial-size, sealed, low-maintenance VRLA battery cells like the one being used in the Vernon BESS application.

The VRLA battery cell design is completely sealed and employs a pressure relief safety valve. This electrochemical device operates on the basis of oxygen recombination technology, uses starved electrolyte absorbed glass mat construction and has no free acid to spill. The cells store energy efficiently, economically and safely, do not require water addition, and during normal charge/discharge operation do not give off gasses as a traditional flooded vented lead-acid battery cell can.

By using the VRLA battery at Vernon, the required floor space needed to house the two strings of battery cells was reduced by over 50% as compared to using a flooded battery. Since the VRLA cells are sealed, battery cells are arranged three to a module and stacked one-on-top of each other eight modules high. The battery assembly was designed and certified to meet a seismic zone 4 earthquake.

Low maintenance is especially important for utility companies and industrial users having a BESS. Since the Vernon BESS system is unmanned and operates automatically, servicing the system is kept to a minimum with the VRLA battery system and operating costs are lower [5].

7.3 Battery Layout

The battery system, as shown in Fig. 2 below, consists of two parallel strings, each having 378 GNB model 100A99 2-volt VRLA ABSOLYTE® IIP modules connected in series providing a nominal 756 volts dc. Each 100A99 module contains three model 100A33 cells connected in parallel. A metal housing for the 2-volt cells is used to assemble a single power module. The tray has three basic parts: a container to house the cells, restraint bars to hold the cells within the container, and a clear plastic protective cover to insulate the cell connectors.

The system contains 48 stacks of batteries per string arranged 46 stacks 8 high and two stacks 5 high. The total installed weight of the battery assembly is in the area of 612,000 pounds (305 short tons). At the end of each string is a dc disconnecting switch fused at 4000 amperes. Each of the battery stacks is monitored for voltage, temperature, and potential ground faults. Pilot cells, as well as string current and hydrogen sensors are also monitored [5].



Figure 2: Vernon BESS VRLA Battery Strings

7.4 Operator Interface

The BESS has an operator interface that is located in the BESS building. The interface is a personal computer that is tied into the station control PLC that runs the BESS. Each of the eight screens has a common header that displays the current status of the BESS. This includes the status of the utility, the state-of-charge of the battery, and the amount of time of backup power remaining. It also includes if the battery is currently charging or discharging and if the BESS is in automatic or manual modes.

There is an alarm panel screen and a screen that displays the one-line diagram of the system, which has a real-time display of power, voltage, and current flow. Real-time data for 24 pilot cells, the voltage of each of the 96 battery towers, and the ambient temperature and hydrogen sensors are displayed in a pictorial layout of the battery strings. All alarms and changes in modes are recorded and date stamped in the sequence of events recorder. The historical trending screen allows the operator to display each recorded value for any time period and can display the real-time trends.

The maintenance screen is one of two password-protected screens. From here, the operator can perform a capacity check on the battery or put the battery on an equalize charge. The other password-protected screen is for demand control. Here the operator can enter the plant demand trigger level in kW, any kW required above the trigger level will be supplied by the BESS. There is also a setting for the minimum allowable state-of-charge. This maintains a reserve requirement in case of loss of utility.

The last screen provides a method to translate the recorded data into a form easily analyzed with any spreadsheet software. This data is used to monitor the health of the battery, determine cost savings, and determine the best demand control setting.

The entire functionality of the operator interface is accessible remotely through a personal computer. Corporate engineering can analyze a situation on site and provide immediate feedback with this connection.

8. Uninterrupted Operation

There are two types of disturbances that the BESS protects against: power interruptions and short circuits. A power interruption is the loss of one or more of the 3-phase lines feeding the plant. Since the BESS acts as a voltage source in parallel with the loads, the plant load will not experience the interruption and will continue to operate normally. The BESS control system automatically opens the plant main breaker based upon a measured current unbalance or reverse power flow and isolates the plant from the incoming utility lines.

Short circuits can occur as phase-to-ground or phase-to-phase and will affect the entire plant. The strategy for dealing with short circuits is to isolate the plant from the fault and re-establish voltage to the loads as quickly as possible. Timing for this to occur is approximately 200 milliseconds. The BESS is designed to continue to operate through these short circuits. After the plant main incoming breaker is tripped, a signal is sent to the plant PLC to shed all non-critical loads and restart some critical loads if necessary.

Following a power interruption, the BESS is set to automatically re-synchronize and connect to the utility when power is restored. When first installed, the control function on resynchronization was set in the manual re-closure of the main breaker. Shortly after the first power outage back in July of 1996, it was decided to set the control function of resynchronization on automatic and not manual control. This action was taken because, following the first power outage event, the system performed exactly as designed and tripped the main incoming breaker. The utility outage lasted only about 90 seconds. However, the plant technicians forgot to transfer the power back to the utility and the BESS continued to carry the entire plant loading for almost two hours before the low voltage battery alarms alerted the plant personnel that they were still operating off the BESS. Without being in the operations control room at the smelter, one can not distinguish the difference between utility power or BESS battery backup unless visibly looking at the BESS monitoring control screen. The BESS is an unmanned facility and the audible alarm in the control room, which indicated the BESS was operational, was not heeded.

9. Utility Power Demand Peak Reduction

Besides providing backup power in the event the plant loses utility power, the BESS also provides for daily load shedding of power and energy to save money. In most countries like the United States, reducing the peak demand for power during peak periods of the day can lower an electrical bill if controlled properly. An electric utility company or supplier typically charges a different rate per kW on demand versus the rate for kWh energy consumed. The rates can vary greatly between suppliers, summer and winter seasons, or time-of-day usage. Peak demand periods are generally when utility companies charge small and large industrial or commercial users a fixed amount per kW.

A BESS like the one in Vernon can provide savings by reducing the monthly demand peak for power by conducting daily peak shaving. By pre-programming the BESS, it becomes an automatic process whereby the system is programmed to peak shave all power requirements over a set value. By storing energy into the batteries during off-peak hours (at night) when rates for energy are low, then, by discharging this energy on demand during the peak demand periods when rates are high, the overall electric bill can be lowered. For example, at the Vernon BESS facility, the cost of energy at night is 4.0¢ per kWh. During the peak demand period of a summer day, the utility company charges the customer at a rate of \$10.30 per kW. The local utility company monitors electric usage once every fifteen minutes. The highest kW demand during any fifteen-minute period sets the overall value for the month regardless if it is reached only once. Therefore, by reducing the demand by 1 kW, basically, the customer can lower its electric bill by \$10.30 for every kW it can peak shave. In other words, if the highest period for demand during the month was set at 3400 kW, the customer is billed a demand charge of \$35,020 ($\$10.30 \times 3400\text{kW}$) plus the energy it uses. If there was a power spike during the month that reached 4000 kW and it lasted only 30 seconds, and, assuming the utility recorded that value, the demand charge billed would have been \$41,200 plus the energy used. The BESS can automatically supply the additional power requirements for the 30 seconds, thereby, preventing the additional demand charge of 600 kW at \$10.30 per kW that would have cost the customer an additional \$6,180 in demand charges for the month.

10. Power Factor Correction Improvement

One additional cost benefit in operating the BESS at Vernon is a reduction in the monthly penalty charge for power factor. A given amount of electric power can be supplied in various ways from a given voltage source. A utility

company can supply a given number of watts with a relatively high current and low power factor or with a smaller current and a high power factor. The minimum current at any given voltage will be drawn when the power factor is at unity. Because the conductors, or other apparatus supplying a load, must be large enough to handle the current without overheating, a greater capital investment is required on the part of the energy supplier to supply a given number of watts at a low power factor than would be required at a higher power factor. Utility rates for large-scale energy users reflect this difference in capital investment cost by some form or other rate penalty for drawing power at a lower power factor. It is advantageous for the user to take action to raise the power factor of loads to save on the energy bill at the end of month. The capital investment of a BESS at the GNB Recycling Center in Vernon has benefited by improving the power factor demand. Having the necessary power conditioning system and harmonic filters (capacitor bank) the system has improved the overall plant power factor from a typical 0.87 to 0.94, current lagging. The benefit is a cost saving of about \$200 per month.

11. Peak Shaving Energy

When automatically set to provide peak shaving of energy usage, the BESS will provide all the power and energy requirements over and above the maximum level established. The maximum level set at Vernon may vary monthly and was established via researching and analyzing the data showing the electric usage over the past 24 months. The term peak shaving is associated with the amount of energy (kWh) that is used, whereas the demand peak is associated with the amount of power (kW) required in supporting the plant loads. By purchasing and storing off-peak energy at night, the plant at Vernon pays 4.0¢ per kWh. That same energy costs the plant 4.7¢ per kWh during peak hours of the day. Peak shaving energy is, but not necessarily, an additional cost saving benefit in addition to the reduction in demand charges. The driving factor is the difference in the time-of-day rate cost of energy being charged by the utility. Savings are offset when taking into consideration the cost associated with recharging the battery following a daily discharge.

12. Operational Experience at Vernon

It should be noted here that justification of installing a BESS at Vernon solely on the basis and merits of providing peak-demand reduction, peak-shaving of energy and improvements in overall power factor demand, are not favorable. The BESS would never pay for itself. However, that point is secondary since the primary justification for installing the BESS at Vernon is to provide emergency power backup to the critical environmental controls, filters, and fan motors controlling lead dust. Any savings derived from the BESS via daily energy management are considered as added benefits. As of this date, the BESS system has successfully supported three power outages preventing the plant from shutting down and, therefore, has prevented environmental incidents that are generally accompanied by heavy fines or possible law suits.[6]

Figure 3 shows the results of a 45 minute long utility outage test. During a partial plant shutdown, the system received a loss of utility signal. Immediately, the BESS began to power the smelter. The BESS supported a 2.4MW load continuously for approximately 45 minutes. During that time period, the battery state-of-charge dropped from 98% to 67%. At the end of the test, the system received a signal indicating that utility was back and it was safe to return to the utility. The BESS automatically synchronized with the utility and began to recharge. The figure also shows the ramp up of recharge current going to the BESS.

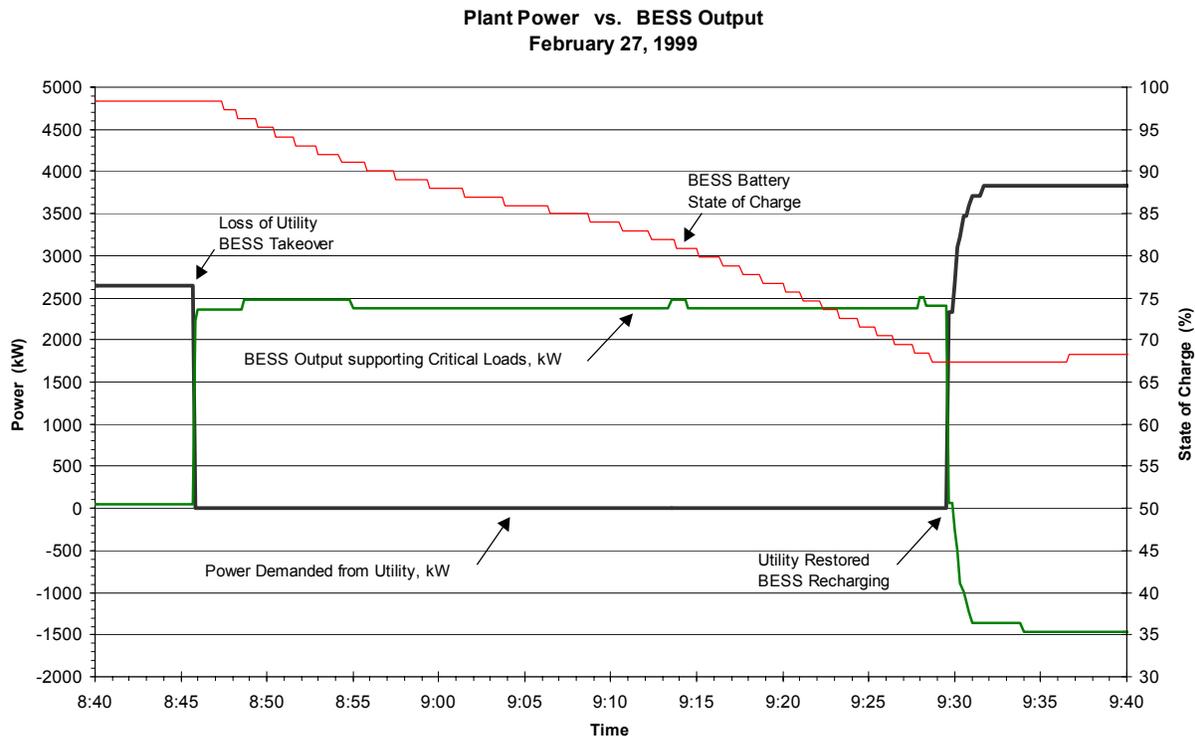


Figure 3: Utility Outage Test

During daily demand peak reduction and on-peak energy management usage, the BESS is programmed to discharge and deplete up to 50% of the battery capacity while retaining 50% for emergency backup power to support the critical environmental loads, if required.

In July 1997, an active demand reduction and peak-shaving program was initiated. During the first few months, the level at which the BESS was set to activate was quite high with regard to the average demand for power. In the months of July through August 1997, the BESS was programmed to supply demand for power and energy at levels above 3400 kW. This setting permitted GNB to observe the operation of the BESS and to better understand how the system responded to power demands while barely exercising the battery. Recordings show the battery easily handled peak demands reaching as high as 3900 kW. However, these peak demands only lasted for a few minutes. Typically, the plant demand will range between 2900 kW and 3400 kW depending upon the plant loading, time-of-day, and month. The idea is to set the output level of BESS at a point that will offer the highest dividends in lowering the overall plant demand and, at the same time, not discharge the battery beyond the 50% capacity set aside for emergency reserve purposes. The peak hours for summer demand in Vernon are between 1:00 p.m. and 7:00 p.m. PST Monday through Friday. The BESS is set to engage one half-hour before and disengage one half-hour after the on-peak demand period. This timing ensures that we are in demand control mode during the entire on-peak demand period.

Since the plant loads do not always run at a constant rate, the power demand fluctuates up and down. Assuming the BESS peak shaving set point is 3050 kW and the plant demand is running at 3500 kW (+/- 150 kW) the BESS will automatically control the amount of power being supplied by the utility. The utility provides the 3050 kW and the BESS supplies the additional demand, averaging 450 kW, from the valve regulated lead-acid (VRLA) storage battery. At that rate, the battery, over the seven hours of demand period, provides a total of 3150 kWh. At 450 kW, we actually discharge the battery at the 7-hour discharge rate. The reserve capacity was sized at the 1-hour rate. At the 1-hour discharge rate, the battery has a capacity of 2.5 MWh, however, at the 7-hour discharge rate, i.e. about 600 amperes, the battery can deliver 4.2 MWhs. Figure 4 shows how the BESS can reduce the plant demand for power (kW) from the utility as compared to the total plant demand.

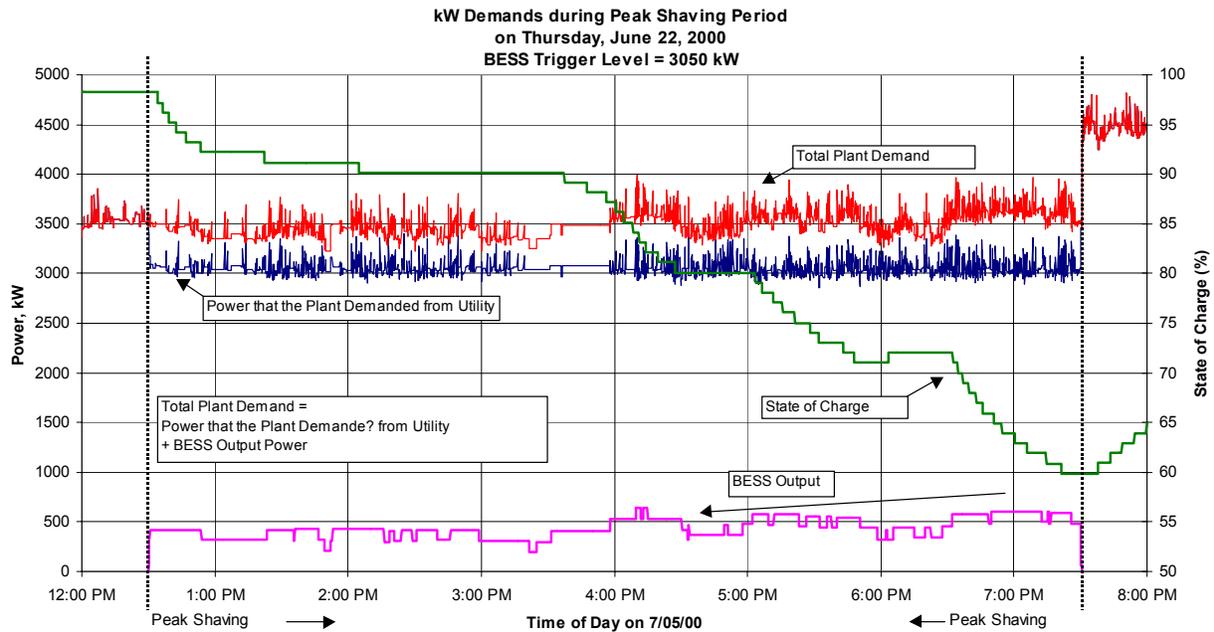


Figure 4: Demand Trends

Setting the level of peak-shaving operation has been a balancing act between past experience, current plant loading, production forecasts, and working up to a point where the battery is being discharged to about 40% DOD (depth of discharge) daily. GNB has determined that the plant's day to day power demand is increasing. Initially, it was believed the plant loads were flat. Data is showing that the production levels push the demand for power up-and-down creating voltage spikes that are anything but flat. The peak demand has been increasing and now adversely affects the setting of the trigger level. In order to insure that the BESS will have the required 2.5MW backup power to support critical loads, and, to ensure that the capacity level for energy management (2.5MW) will operate over the entire peak shaving time period, the trigger level had to be raised, see Table 2.

Table 2: Maximum and Average On-Peak Plant Demands and BESS Output by Month for 2000

2000	Max. Plant Demand	Avg. Plant Demand	BESS Trigger Level	BESS Max. Output	BESS Avg. Output	Estimated Savings
Jan.	4136 kW	3637 kW	3050 kW	1086 kW	587 kW	\$2,925
Feb.	3624 kW	3624 kW	3050 kW	574 kW	574 kW	\$3,632
Mar.	3947 kW	3340 kW	3050 kW	897 kW	290 kW	\$3,739
Apr.	5024 kW	3529 kW	3050 kW	1974 kW	479 kW	\$4,233
May	4346 kW	3559 kW	3050 kW	1296 kW	509 kW	\$10,424
Jun.	4042 kW	3578 kW	3050 kW	992 kW	528 kW	\$2,899
Jul.	4666 kW	3646 kW	3225 kW	1441 kW	421 kW	\$2,749
Aug.	3788 kW	3518 kW	3125 kW	663 kW	393 kW	\$6,486

Data from the Vernon, California BESS has been accumulated and analyzed to determine the monthly cost savings brought about by demand peak shaving. During the period from July 1997 through July 2000, records and utility bills show that the overall actual savings has averaged about \$3,800 per month. Over this 36-month period, the savings have been approximately \$144,000 plus the avoidance costs/savings; i.e., value placed on interruptions, value placed on voltage dips. At this time, it is difficult to assess the value of avoidance costs since in some cases the voltage spikes exceed 1 MW, but only for a few seconds. We are unsure whether the utility company would or

would not have recorded the events and actually billed the customer. At best, we believe the BESS can save the customer about \$75,000 per year. At the present time, the Vernon plant spends an average of more than \$100,000 per month for electric power and energy consumption.

Acknowledgements

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