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Battery energy-storage systems – an emerging market for lead/acid batteries

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Abstract

Although the concept of using batteries for lead levelling and peak shaving has been known for decades, only recently have these systems become commercially viable. Changes in the structure of the electric power supply industry have required these companies to seek more cost-effective ways of meeting the needs of their customers. Through experience gained, primarily in the USA, batteries have been shown to provide multiple benefits to electric utilities. Also, lower maintenance batteries, more reliable electrical systems, and the availability of methods to predict costs and benefits have made battery energy-storage systems more attractive. Technology-transfer efforts in the USA have resulted in a willingness of electric utilities to install a number of these systems for a variety of tasks, including load levelling, peak shaving, frequency regulation and spinning reserve. Additional systems are being planned for several additional locations for similar applications, plus transmission and distribution deferral and enhanced power quality. In the absence of US champions such as the US Department of Energy and the Electric Power Research Institute, ILZRO is attempting to mount a technology-transfer programme to bring the benefits of battery energy-storage to European power suppliers. As a result of these efforts, a study group on battery energy-storage systems has been established with membership primarily in Germany and Austria. Also, a two-day workshop, prepared by the Electric Power Research Institute was held in Dublin. Participants included representatives of several European power suppliers. As a result, ESB National Grid of Ireland has embarked upon a detailed analysis of the costs and benefits of a battery energy-storage system in their network. Plans for the future include continuation of this technology-transfer effort, assistance in the Irish effort, and a possible approach to the European Commission for funding.

Keywords: Battery energy-storage systems; Market; Lead/acid batteries

1. The changing world of electric power suppliers

Electric power suppliers have, quite properly, been regarded as large, monolithic, organizational and bureaucratic in structure, and largely refractory to change. That electric power suppliers became that way is not surprising since, in nearly all cases, they have been either publicly or privately owned utilities with monopoly status and protected markets. During the past decade, however, there have been enormous changes in the way these organizations must do business. Many government-owned utilities have been privatized and, whether privately owned or not, most have been required to face competition from other utilities and from co-generators.

This change in structure has caused power companies to begin to think like other businesses. No longer can they just 'sell electrons' at rates set by government authorities. Now, they must offer what their customers demand – or else they may lose markets. Their customers often require premium quality power and customized service. And the consumers require that power suppliers be cost-competitive, efficient, and environmentally clean.

Although the concepts of load levelling and peak shaving through the use of batteries has been around for several decades, it is only now becoming recognized that batteries, especially if they can be low-maintenance or maintenance-free, can serve as a valuable multi-faceted tool in helping utilities achieve the requirements of customer service and profitability.

2. History of ILZRO's involvement in battery energy-storage systems

ILZRO's first project aimed at developing large stationary batteries for energy management dates back 20

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years. At that time, ILZRO teamed with the Electric Power Research Institute (EPRI) to commission a study, carried out by C&D Batteries, to investigate the viability of lead/acid battery technology for utility load levelling, and to design and estimate operating costs for load-levelling and peak-shaving batteries. Following on from this study, C&D built what, at the time, was the largest lead/acid battery in the world, rated at 625 kW/1800 kWh. This was assembled at a test facility – called the Battery Energy Storage Test (BEST) facility – in New Jersey, USA. Somewhat later, in 1983, GNB installed a 500 kW/500 kWh battery energy-storage system in this same BEST facility. Interestingly, the battery was subsequently sold to Crescent Electric Membership Cooperative in North Carolina where it was brought on line, in 1987, as a customer-side, peak-shaving application. It is still operating well.

The next major programme undertaken by ILZRO in this area was a cooperative venture with EPRI and Southern California Edison to set up and test a 10 MW/40 MWh battery in Chino, CA. Although predated by several systems, including the Crescent battery previously noted, the Chino battery was notable for its size. In fact, it is the largest battery in the world and a photograph of the battery appears in the *Guinness Book of World Records*. The Chino battery also became the focus for renewed interest in the potential of battery energy-storage for utilities.

Originally designed for load-levelling purposes, operating experience with the Chino battery clearly demonstrated that load levelling alone could not justify the large capital investment required for a battery the size of Chino. Operating experience also demonstrated the desirability of maintenance-free batteries for such applications. Traditional flooded cell batteries were specified for Chino to help ensure reliability. Difficulties with the automatic watering system, however, required much greater than anticipated labour costs.

Nevertheless, a series of tests carried out on the Chino battery during its demonstration phase showed that the benefits of battery energy-storage systems go well beyond the traditional load-levelling and peak-shaving applications. These benefits have justified the continuing operating of the Chino battery through to the present, with no plans to remove the battery from service.

3. Benefits of battery energy-storage systems

Batteries offer a wide variety of generation, transmission/distribution and environmental benefits, and also strategic benefits that allow utilities to serve their customers better.

3.1. Generation benefits

In terms of generation, batteries offer the advantages of supplying reliable power both quickly and efficiently. For example, batteries can provide black-start capability that allows utilities to start up after a blackout, like a large UPS. Typically, utilities use diesel generators for this purpose, but they cannot provide the instantaneous power of a battery. Batteries also provide both area regulation, which helps a utility to maintain overall power balance with neighbouring utilities, and frequency regulation, which is a particular problem in island-type systems. Batteries also provide spinning reserve. This is the ability to respond to generating equipment failures and forced outages by providing reserve capacity. The load-levelling benefit allows utilities to defer spending large amounts of funds on costly peak-load power plants. Through their dual ability to draw power when it is produced most efficiently and to discharge power when required, batteries can help utilities reduce production costs, provide ramp-rate constraint relief, enable flexible use of production equipment, allow for efficient load-following, and operate more efficient baseload plant at night during the period of lowest demand.

3.2. Transmission and distribution benefits

Modular battery systems permit utilities to defer the addition of new transmission lines and transformers during the time that demand is building, but expensive installations would be under-utilized. By reducing the load on transformers, batteries can extend transformer life and prevent the loss of power from heavily loaded transmission lines. Battery systems also offer a very fast, inexpensive way to improve voltage regulation and provide damping to reduce oscillations in the system. The ability of batteries to absorb and deliver power helps to maintain the operating frequency and phase angle (first-swing stability) of their generators immediately after a large system fault on a transmission line or generator. All these benefits lead to an overall better reliability of transmission and distribution.

3.3. Environmental benefits

Batteries can reduce air emissions by storing electrical energy from cleaner generating sources rather than depending upon local, more highly polluting combustion generators. Of course, the ability of batteries to reduce emissions depends on the turnaround efficiency of the battery and the ability of the utility to provide power from cleaner, more fuel-efficient plants. Also, concerns about the possible effects of electric and magnetic fields (EMF) can be reduced through deferral of the need for transmission lines.

3.4. Strategic benefits

Batteries allow utilities to store electricity that is generated using the cheapest available fuel. Batteries allow a greater degree of siting flexibility because they can provide an economical alternative to the construction of new lines and substations. Overall reliability of service is enhanced with batteries, as is the quality of power delivered. Finally, batteries can provide the means to reduce demand-side peak load from customers.

This adds up to an impressive array of benefits, all of which have real cost-saving potential for utilities. Of course, the level of benefits varies with dependence on a wide variety of factors that are unique to each utility and its particular location, load profile, and customer mix. There is no question, however, that many utilities can benefit from battery energy-storage systems. Fortunately, that message is starting to get out and interest is developing, particularly in the USA.

4. Technology transfer efforts

Credit must be given to EPRI for their early recognition of the benefits that battery energy-storage systems can bring to utilities in the USA. EPRI has sponsored demonstration projects, evaluations, and specialized workshops for utilities. They are co-funding a new programme with the US Department of Energy (DOE) to deploy and quantify the host utility benefits of a lead/acid transportable battery system. With the encouragement of EPRI and DOE, a Utility Battery Group has been formed by eight large utilities in the USA. This organization, formed in 1991, has as its purpose: 'to capture strategic and economic benefits from battery energy-storage'. This group has encouraged the installation of several battery energy-storage systems and has provided a forum for direct interaction between component manufacturers and utilities.

Several members of ILZRO, Yuasa Exide and Johnson Controls also participated in the technology-transfer effort through ILZRO's Energy Management Consortium. This group carried out a programme of advertising and public relations to help engender interest in utilities in battery energy-storage. This exercise resulted in the receipt of hundreds of inquiries for further information. These were passed on to potential vendors.

As a result of these activities, a number of battery energy-storage systems have been installed in the USA, and several more are in the planning stage. Table 1 lists all current and planned battery energy-storage systems. Of the systems currently in the planning stage, all but one are in the USA. This reflects the technology-transfer efforts that have occurred in the USA.

4.1. Activities in Europe

ILZRO is concerned that the technology-transfer efforts that are being carried out in the USA are not being mirrored elsewhere. Europe should have a large potential market for battery energy-storage systems. Unfortunately, however, there is no similar organization to EPRI to help assure that the information on battery energy-storage systems is brought to the attention of electric utilities and power authorities in Europe. Therefore, with minimal funding thus far, ILZRO has taken the following steps.

- Supported a UK-based consultant to maintain contact with interested utilities and suppliers in order to effect the flow of relevant information.
- Encouraged the formation of a European group interested in 'Large Batteries for Electrical Networks'. A small group based primarily in Austria and Germany was formed in late 1993. This group has held two meetings, most recently at the Institute for Electrical Installations and Energy in Aachen in June, 1994. Membership includes representatives of battery companies, power equipment suppliers, utilities and academic researchers.
- Sponsored and helped organize a two-day workshop 'Evaluating Battery Storage' utilizing EPRI-prepared materials and EPRI's specialized software (BaSES) to allow the costs and benefits of battery energy storage to be calculated. The workshop was hosted by ESB National Grid in Dublin on June 9–10, 1994.

The purpose of the Dublin workshop was to take the first step toward serious consideration of a modern installation in Europe. In addition to representatives from the Lead Development Association, ILZRO and Britannia Refined Metals, the following companies and organizations were represented.

Utilities

ESB National Grid	Ireland
Electricité de France	France
BEWAG	Germany
National Power	UK
Southern Electric	UK
Northern Ireland Electricity	UK
ENEL	Italy

Battery companies

GNB	USA
Tudor (Hagen)	Spain
AB Power Systems (Hawker)	Ireland
Delco Remy (ACG France)	France

Power electronics companies

GE Drive Systems	USA
ASEA Brown Boveri	Switzerland
Wavedriver	UK

Table 1
Installed and planned battery energy-storage systems

Company/location	Size	Operation application	Date
Southern California Edison Chino, CA, USA	10 MW/40 MWh	utility energy storage demonstration	1988
Crescent Electric Member Cooperative Statesville, NC, USA	500 kW/500 kWh	peak shaving	1987
Delco Remy, General Motors Muncie, IN, USA	300 kW/600 kWh	peak shaving	1987
BEWAG AG Berlin, Germany	17 MW/14 MWh	frequency regulation/spinning reserve	1986
Kansai Electric Power Company Tatsumi, Japan	1 MW/4 MWh	multi-purpose demonstration	1986
Elektrzitatswerk Hammermuhle Selters, Germany	400 kW/400 kWh	load levelling	1980
Hagen Batterie AG Soest, Germany	500 kW/7 MWh	load levelling	1986
San Diego Gas and Electric San Diego, CA, USA	200 kW/400 kWh	transit peak shaving	1992
Puerto Rico Electric Power Authority San Juan, PR, USA	20 MW/14 MWh	frequency regulation	1994
Pacific Gas and Electric San Ramon, CA, USA	250 kW/167 kWh	distributed peak shaving	1993
Pacific Gas and Electric Various sites in CA, USA	500 kW/1 MWh (up to 4 units)	distributed peak shaving T&D deferral	1994
Hawaii Electric Light Company Island of Hawaii (Big Island), HI, USA	10 MW/15 MWh	frequency regulation spinning reserve	1994
Chugach Electric Association Anchorage, AK, USA	20 MW/10 MWh	frequency regulation spinning reserve	1995
Golden Valley Electric Association Fairbanks, AK, USA	70 MW/17 MWh	frequency regulation spinning reserve	1995
Oglethorpe Power Corporation Atlanta, GA, USA	2 MW/10 s	power quality	1995

Also present were representatives of EA Technology, which is the privatized UK Electricity Council, and the Research and the Engineering Departments of Stuttgart and Dortmund Universities. The EEC Commission was represented by FORBAIRT, which is a member of OPET (Organization for Promotion of Energy Technologies).

Of particular interest in this workshop was a presentation by the General Electric Company (GE) and the GNB Industrial Battery Company that introduced their alliance as a worldwide supplier of turnkey energy-storage systems. GE/GNB have claimed that their alliance will offer customers the benefits of: a standardized, modular system; the advantage of working with a single supplier, instead of assembling a system from a variety of component suppliers; lower cost; shorter lead times. GE/GNB estimate the price for the system at $925 to 1200/kW with $325/kW for each additional hour of storage. They also claim that, in their systems, batteries represent about 30–35% of the cost, with the power-condition system and transformers at about 18–20% of the total installed cost. These figures are somewhat higher than EPRI's projected costs for a mature system. Nonetheless, they are particularly useful for utilities now contemplating the installation of a battery energy-storage system.

Subsequent to the Dublin Workshop, it was ascertained that ESB National Grid had determined at the workshop that there could be a benefit of installing a battery system primarily to defer the installation of a 220 kV transmission line. ESB has now produced the Terms of Reference for an economic screening study with completion targeted within 1994.

4.2. Planned activities

From the standpoints of the lead, lead/acid battery and power electronics industries, battery energy-storage systems represent an emerging and potentially large new market. Experience has shown, however, that elec-

tric utilities are slow to take up this new tool, which, to them, is a new and unproven technology. It is incumbent, then, that in the absence of a champion such as EPRI and DOE in the USA, those with a vested interest in the success of the technology – namely the lead producers, battery manufacturers, and power electronics companies – must assure that effective technology-transfer takes place. ILZRO has taken initial steps to put in place necessary elements of a technology-transfer mechanism for the near term. These include continuation and expansion of work in the following regions.

(i) *Ireland*

Continue to work closely with ESB National Grid and also Northern Ireland Electricity (NIE) towards encouraging installation of a battery energy-storage system in Ireland. Because of their island location and the fact that they are not tied to the European grid, Ireland and Northern Ireland probably have the most acute need for battery energy-storage systems. The installation of such a facility would serve as a focal point for the formation of a utility study group, analogous to the Utility Battery Group in the USA.

(ii) *Germany/Austria*

Continue to encourage the German/Austrian group in their activities and provide them with information from other parts of the world.

(iii) *European Union*

The commission of the European Union (CEU) is committed to research and development in the energy sector and substantial funds are available for this work. The Third Framework for this work concludes in 1994, but a Fourth Framework will soon be announced. Under the Third Framework, to promote the rational use of energy, the Thermie programme gave grants for the establishment of demonstration plants and for the dissemination of technology (150 million ECU). This program is supported by OPET (Organization for the Promotion of Energy Technology) which has a fundamental role in the implementation and exploitation of new energy technology. Joule II is another program for research in the energy area (138 million ECU). Every opportunity will be examined for the possible use of CEU funds to assist in the development of demonstration projects and the dissemination of information on battery energy-storage systems, and research – where appropriate.

(iv) *General technology transfer*

The lack of knowledge of battery energy-storage systems by utilities is the key area that must be tackled if progress is to be made in the development of this market. An information package on the principal uses of such systems, including some key economic data, should be prepared and forwarded to the government energy departments of the principal European countries. Where interest is aroused, further consultation would be carried out by correspondence or by visits in appropriate cases.

Finally, it may be necessary to provide some subsidy for a battery energy demonstration, probably in Ireland. While the ESB and NIE have expressed serious interest in battery energy-storage systems, they have yet to determine the best first application of the systems in their networks. It is anticipated that this determination will be made by the end of 1994. The application to be chosen will naturally show a projected economic benefit. Because of the capital costs associated with the installation of a battery facility, however, it would be desirable to provide assistance to ESB and/or NIE in the form of in-kind, cash, or loaned lead to reduce their risk and to encourage the installation.

5. Conclusions

Battery energy-storage systems represent a major new potential market for lead/acid batteries. Improved valve-regulated batteries and more reliable electrical systems are now available. Also, the ability now exists to determine, in advance, the costs and benefits of energy management systems for specific applications.

These improvements, together with effective technology-transfer efforts, have resulted in a growing market for these systems in the USA. Similar opportunities exist in other parts of the world. Nevertheless, this market won't create itself. Concerted efforts to build on the USA experience and the fledgling technology-transfer efforts in Europe are required to bring this exciting potential new market into reality.