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LEAD/ACID BATTERIES FOR LOAD-LEVELLING APPLICATIONS

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Introduction

Load levelling in electric power supply systems has a long history. For example, it was back in the 1920s that the founder of HAGEN Batterie AG secured his first large orders from major municipalities in Germany for such applications. In those days, the electric power supply was a d.c system and the batteries were of the Planté type Voltage control was not considered to be the most important factor, rather, the continuous supply of power was paramount.

The load-levelling application was lost to the battery producers when the electric power supply was switched over to a.c , and all the self-reliant utilities were combined in a more self-stabilizing network It was not until semiconductor-based inverters entered the market that attention was again directed towards the concept of load levelling with batteries.

Definition of load levelling

There are three aspects of load levelling that must be distinguished·

(i) Real *load levelling* means that the batteries are charged with excess power during low-demand periods (mostly at night) and discharged when the power demand is on peak level (before noon and early evening). Therefore, the operation is also called *peak shaving* Discharge periods are 1 - 3 h. The savings are in the high specific cost for the peak-power demand and the low cost for the base load.

(ii) *Load frequency control* operates over a time frame of only a few minutes. The response of the power-supply system to demand fluctuations is found primarily in the frequency Increase of power demand means decrease of frequency, and vice versa The extent of this problem increases with decrease in the size of isolated supply systems Batteries (and inverters), operated at around 70% state-of-charge, absorb the fluctuations by undergoing short-term (high rate) charge/discharge cycles, and the power generating facilities (*i e*, gas turbines and (coal) power stations) follow the trend.

(iii) When a power station fails and others cannot take over the load immediately, a few minutes can elapse before the control can follow

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the new specific demand The traditional solution to this problem of *instantaneous reserve* is a spinning reserve, *i e* , the power station runs idle and consumes but does not deliver energy Batteries with inverters can fulfil this role without wasting energy

With these different aspects in mind, the term "peak shaving" should be used for the first application only, and the term "load levelling" to cover all three

Requirements of load-levelling batteries

Many different electrochemical systems have been examined, either in the laboratory or at the pilot-plant stage, for load-levelling applications To date, none of these alternative batteries has proved superior to the lead/acid system Even with the latter, further developments are necessary

The required properties for load-levelling batteries are (i) high round-trip efficiency, (ii) long service life, (iii) high cycling capability, (iv) zero or low maintenance, (v) easy assembly and replacement, (vi) no acid spillage

A high efficiency is important not only because of energy costs, but also because of the secondary costs involved with cooling, the loss of water from the cells, and the danger of sulphuric acid fumes To fulfil the necessary requirements, the ampere-hour efficiency must be close to 100% and the battery impedance must be low

Long service life and high cycling capability are more or less coupled features The number of cycles usually required for peak shaving is around 2000 (80% DOD) For a realistic operation of 200 full cycles per year, this means a service life of 10 years When compared with the 200 cycles within one year demanded from an automotive battery, or the 150 cycles and 10 years' life of an ordinary stationary battery, it is clear that the starting point for the design of a load-levelling battery should be the most sophisticated of the available traction (*i e* , cycling) types

The requirements of low maintenance, easy assembly and replacement, and negligible acid spillage can be taken together The battery units must have sealed covers, some kind of handling grips, and a weight not exceeding the capability of a light fork-lift truck Topping-up with water, if unavoidable, should be carried out via an automatic watering device A computerized monitoring system should automatically detect any system defects at a very early stage

The Hagen load-levelling battery

In the late 1970s, a load-levelling battery concept based on copper-stretch-metal (CSM) technology [1] was developed with partial sponsorship from the West German government The main goal was a minimum round-trip efficiency of 80% at the 0 5 - 2 h rate Investigations showed that the use of CSM negative grids was not in itself sufficient the following additional features were necessary

(i) The installation of a separate acid circulating system for avoiding stratification effects without having to resort to a gassing charge. This approach raises the ampere-hour efficiency to close to 100%.

(ii) Module design, as opposed to single cells, for reducing ohmic losses by replacing individual post connections with through-the-partition welds.

(iii) Copper inserts in the terminals to allow easy assembly via screwed-on intermodule connectors Unlike lead terminals, these connections require no maintenance

(iv) Internal water cooling to provide good thermal management. Note, battery service life is more affected by differences in temperature than by the absolute value.

(v) The arrangement of batteries in several parallel strings to allow equalizing charges to be conducted without having to take the facilities out of service. For satisfactory design, the unit size must be limited and, of course, must not exceed the unit weight corresponding to easy assembly.

(vi) An automatic device to provide topping up This was taken from traction battery technology

(vii) Temperature and acid level probes in pilot cells to allow remote monitoring The module voltages and the string currents were also recorded. As a result of these developments, a 5-cell module (10 V) was developed with a capacity of either 1000 or 1250 A h at the 5 h rate.

Battery for load frequency control

About the same time as the battery development discussed above, the utilities in West Berlin (BEWAG) commenced an investigation into load frequency control by batteries [3 - 5]. As knowledge and experience in this area was scant, test facilities were installed under sponsorship by the West German government These tests used cells within the module configuration described above

The typical load profile and the corresponding battery operation are shown in Fig 1. Integration of the discharge peaks results in a discharge of 2 5 *C* per day. Since the inverters, the control system and, most importantly, the batteries have demonstrated satisfactory performance for more than five years, a full-size facility has been ordered and will be commissioned by the end of 1986.

The BEWAG battery is arguably the largest installed in the world to date. It consists of 12 parallel strings with 118 modules per string. Each module has a voltage of 10 V, a capacity of 1000 A h (5 h rate), and a weight of 380 kg. The technical data of the plant are given in Table 1. The service life of the battery is expected to be 8 years and will correspond to a discharge of 6000 times the nominal capacity This extremely high performance is achievable only in load frequency control applications. In peak shaving service, a battery life of 2000 cycles is expected.

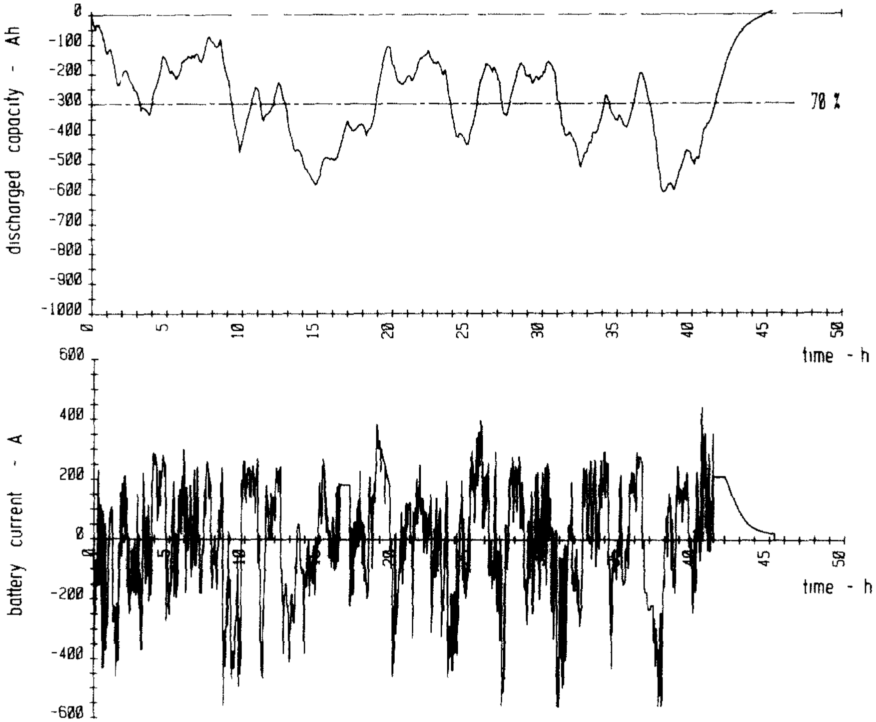

Fig 1 Load profile and frequency control at BEWAG [5]

TABLE 1

Design features of BEWAG battery for load-frequency control

Parameter	Value
Nominal control power (MW)	± 8 5
Control power gradient (MW s^{-1})	17
Instantaneous reserve (MW)	17
Nominal energy (MW h)	14 4
Minimum instantaneous reserve energy (MW h)	4 3
Maximum current at frequency control (A)	7200
Maximum current at instantaneous reserve (A)	14 400

References

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