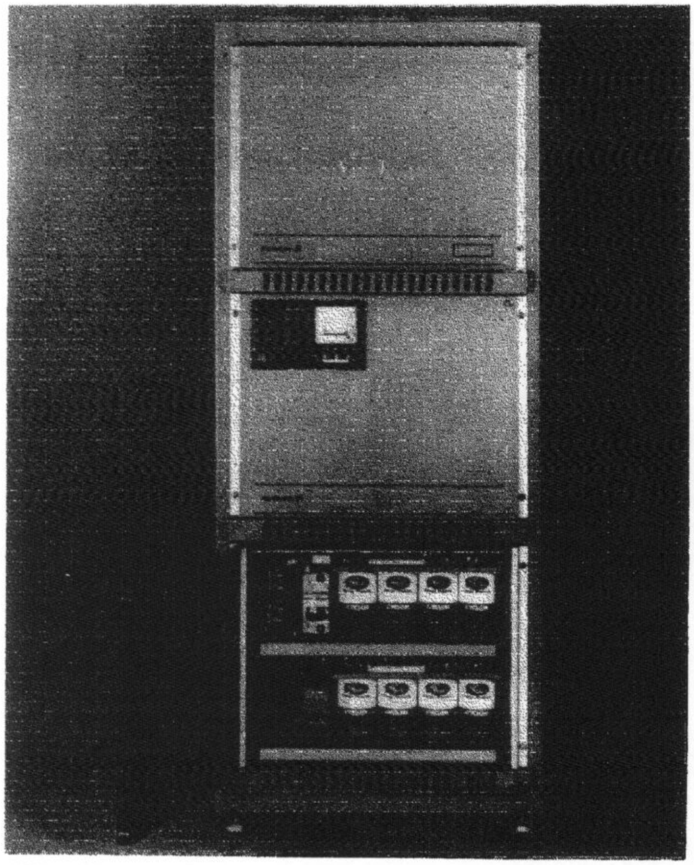
PROLONGED USEFUL LIFE AND REDUCED MAINTENANCE OF LEAD-ACID BATTERIES, BY MEANS OF INDIVIDUAL CELL VOLTAGE REGULATION

Sven Bergvik
ERICSSON POWER SYSTEMS
S-163 81
Stockholm, Sweden

Lars Bjorkstrom
ERICSSON COMMUNICATIONS
7465 Lampson Avenue
Garden Grove, CA 92641

During the last year we have seen an increasing number of applications within telecommunications for small power plants. Rural switching equipment has been with us for a long time, but cellular radio base stations and microwave repeaters in large quantities have not been on the scene that long. Totally new applications are the telecommunications part of the "new computerized office" and power units for individual racks or rack suites in switching systems not using a central power plant. The new type of power plants for these applications also calls for a new type of batteries and battery applications.



48V 25Ah battery unit mounted in a rack with rectifiers.

BATTERIES INVOLVE A LOT OF MONEY

Calculating the expected life-cycle cost for a power plant shows that a large portion of that cost is related to the batteries.

- Their purchase price is relatively high.
- They require more frequent maintenance than the rest of the power plant.
- Due to shorter life compared with the rest of the equipment, the batteries must normally be replaced at least once, maybe twice.
- They require, at least periodically, a higher voltage than what otherwise would have been sufficient, thereby increasing energy consumption.
- Batteries not carrying their full capacity, for whatever reason, are one of the major reasons for costly downtime in telecommunications equipment throughout the world.
- Almost all batteries emit gas, at least while they are being charged. Due to this the ventilation system of large switching centers is often designed in such a way that the air from the battery room is not recirculated. For small power plants, where a separate battery room probably isn't available, it is essential that the batteries emit as little gas as possible. If the batteries are installed in an office environment or integrated into a switching system, they should not emit any gas at all.

With these factors in mind, it is essential to find a battery which:

- Requires little or no maintenance.
- Has a long, useful life.
- Enables the telecommunications equipment to operate on an energy-saving voltage level.
- Will always carry its full capacity.
- Emits little, or for some applications, no gas at all.
- Meets all these requirements, while maintaining a reasonable purchase price.

CHOOSING BATTERY TYPE

Vented versus Sealed Batteries

Battery maintenance is expensive. It consists of regular checking of voltage and density, topping up with water, cleaning, greasing, etc. If the site is remote, the traveling costs will be high. Sealed (gas-tight), maintenance-free batteries would reduce the maintenance cost considerably. The saving often justifies the use of such batteries, in spite of their higher purchase price.

For applications where batteries are mounted together with electronic equipment, sealed batteries are the only alternative, as batteries that emit gas are unacceptable in such an environment.

Different Types Of Maintenance-free, Lead-acid Batteries

Maintenance-free, lead-acid batteries with totally sealed cells can be divided into three main types:

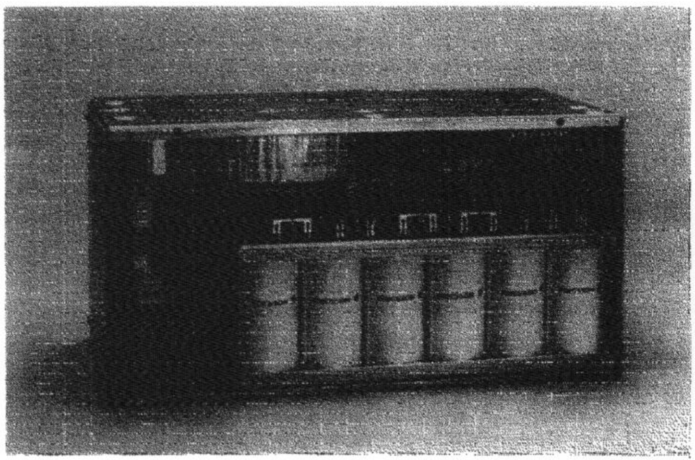
- Gel batteries, whose cells contain conventional upright plates with calcium alloy lead in the grids. The electrolyte

CH2073 - 5/84/0000 - 0063 $01.00

is gelatinized, with considerable surplus quantity. A safety valve opens at a pressure of 0.5 — 1kp. The batteries are usually supplied in blocks of 6V or 12V. The block containers consist of an ABS plastic which allows the diffusion of gas. This type of battery is also made with tubular positive plates for capacities of up to 1350Ah.

— Batteries with round cells, in which the generated gases are recombined into water. The plates are wound spirals and contain pure lead in the grids. The amount of electrolyte is small and is absorbed in the plates and separators. A safety valve opens at a pressure of approximately 4kp. The batteries are supplied as single cells or as blocks. The cell container consists of polypropylene, which prevents gas diffusion. A metal sheath surrounds the container.

— Batteries with rectangular cells, in which the generated gases are recombined into water. The plates contain calcium alloy lead in the grids. The amount of electrolyte is small and is absorbed in the plates and separators. A safety valve opens at a pressure of 0.5-1kp. The batteries are usually supplied as blocks of 6V or 12V, but single cells are also available. The cell containers are normally made of ABS plastics.



A complete power unit, 48V 4A, with a rectifier, distribution and a 12.5Ah battery.

OPERATING SEALED BATTERIES

Characteristics of Individual Battery Cells

If all cells in a battery were identical, they would all get exactly the same voltage by the trickle charging. However, there are differences between individual cells, caused by manufacturing tolerances, aging, etc. Certain cells can be kept fully charged by a fairly low current, whereas others require a considerably higher current. This shows up as a voltage discrepancy between the cells. The voltage of a battery cell falls if the cell does not receive sufficient current. If the voltage becomes too low, the plates become sulphated and the cell loses its capacity. This phenomenon is particularly marked in maintenance-free batteries with low self-discharge.

Methods for Equalizing the Cell Voltages in a Battery

Regular charging at raised voltage is usually recommended for equalizing voltage differences between cells in a battery. However, battery manufacturers do not recommend periodic equalizing charging for maintenance-free batteries. For these a relatively high floating voltage is recommended instead, varying between 2.30 and 2.38V per cell when the number of cells in the battery is 12 or more. The current will then be so high that even the worst cells receive sufficient current for full charging. In the case of batteries with 24 cells or more, the manufacturers suggest a division into groups of 6 or 12 cells, which are charged independently. [1] [2]

Disadvantages of High Cell Voltage

High cell voltage has the following disadvantages:

— The overall voltage is high. For example, with 23 cells and 2.38V per cell, the total voltage is 54.7V, which is too high for many applications. 2.25V per cell would give 51.8V, which is an ideal voltage for most applications.

— The power consumption is high. With 54.7V the consumption is 18% higher than with 51.8V.

— The difference between the working and discharge voltages is large and hence the number of cells in the battery has to be limited. This means that the cells cannot be discharged sufficiently to ensure full utilization of their capacity.

— The battery life is greatly reduced. With 2.40V per cell, its life is only half the life of a cell at 2.25V, see Fig. 1. (This applies to, for example, cylindrical cells from Gates Energy Products. [2])

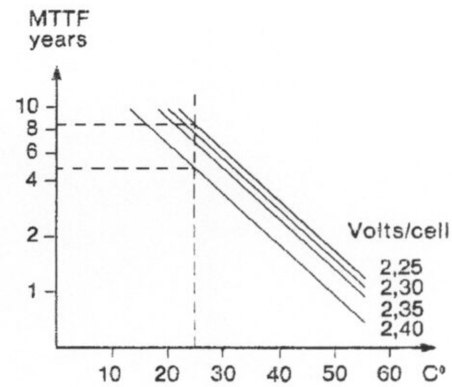


Fig. 1
Expected life (MTTF) for battery cells with trickle charging and without temperature compensation of the charging voltage

Regulator for Individual Control of the Voltage of Each Cell in a Battery

A radical solution to the problem of uneven voltages and high working voltage is to have a regulator for controlling the voltage of each individual cell in a battery. Ericsson has developed such a regulator, and its function is illustrated in Fig. 2. The regulator is placed directly over the cell and has no outgoing connections. Its function is thus entirely independent of the number of cells in the battery.

The regulator works as follows: Normally a current of approximately 150mA passes through a shunt consisting of a resistor and a transistor. For a cell that requires more current than a normal cell, the current through the shunt decreases correspondingly. For a cell that requires less current than a normal cell, the current through the shunt increases. Each cell thus takes exactly the amount of current it requires to stay fully charged. Extensive tests have shown that 2.25V is ideal and gives the maximum cell life.

At 2.25V a fully charged cell of 25Ah requires approximately 10mA, and since the shunt accepts current variations up to 150mA between the cells, it is clear that the system tolerates cells that are radically different.

The transistor in the shunt circuit is controlled by an individual control circuit, which senses the voltage across the cell. The power consumption in the shunt circuit is small compared with the power saved as a result of the reduction in voltage obtained when a regulator is used.

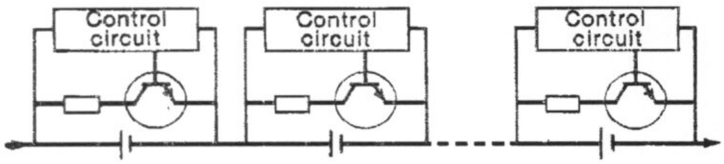


Fig. 2
Individual voltage regulators for each battery cell

BATTERY UNITS

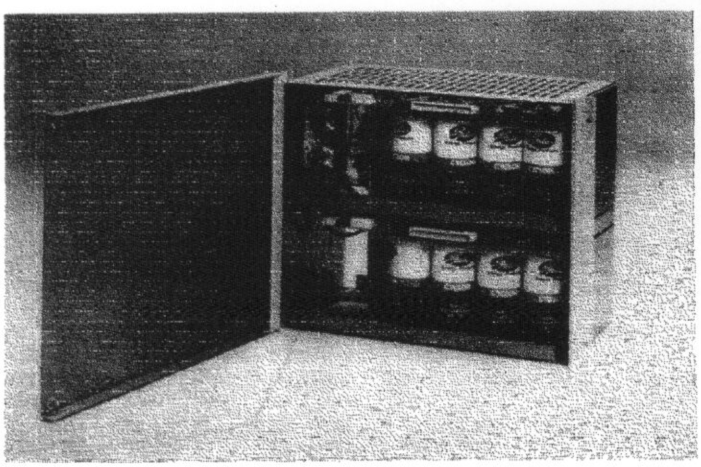
Based on what is described above, Ericsson has designed a concept for battery units, which for the time being, are available in two capacities, 12.5 and 25Ah.

Battery

The battery cells are round lead batteries with spirally wound plates. They work on the principle of recombining oxygen and hydrogen into water. The cells are gas-tight with a safety valve. The self-discharge is low. The nominal capacity is 25Ah or 12.5Ah.

The cells have very low internal resistance, permitting a relatively high drain capacity even with a high discharge current.

The choice of battery is a result of extensive testing and evaluation in our laboratories.



Battery with 48V 25Ah for 19" racks.

Structure

The battery units are built to fit into standard 19" racks. They can therefore be installed in the same racks as the rest of the power plant, as well as the equipment being supplied with power, thereby making a very compact, floor-saving installation. To install a battery unit, and put it into service, is merely a question of connecting the plus and minus cables from a rectifier and cabling for any outgoing alarms.

A printed board assembly placed on top of the cells contains all voltage regulators (one per cell), cell connections and alarm circuits. In this way loose wiring is avoided..

The unit also includes an automatic fuse and undervoltage guards for both alarm and disconnection of the unit (to avoid damaging the cells).

Voltage Levels, Charging Times

During operation the voltage should be 2.25V per cell, which gives the following overall voltages:

with 12 cells 12 x 2.25V = 27.0V
with 23 cells 23 x 2.25V = 51.8V
with 24 cells 24 x 2.25V = 54.0V

Raised voltage should not be used. With 2.25V full charge is reached within 24 hours. 80-90% charging is reached in one or a few hours depending on the available rectifier capacity.

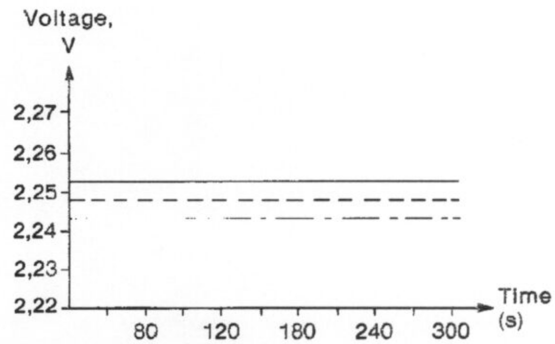


Fig. 5
Cell voltages measured on batteries with 23 cells for 25 Ah which have been in service for a considerable period. The uniformity of the cell voltages is a feature of the system

——— Highest cell voltage
- - - - Average voltage
—·—·- Lowest cell voltage

Service, Tests

The battery unit with its sealed cells requires no maintenance. However, in plants of vital importance it may be necessary to check that the battery retains its capacity. The most reliable method would be to carry out discharge tests, but such tests are expensive and can interfere with the operation.

A good idea of the condition of the cells can be obtained from the cell voltages. The battery unit is equipped with an easily accessible jack for reading off all cell voltages. The unit is thus prepared for output to a measurement processor.

If all cell voltages lie in the range 2.24-2.26V, the cells can be considered as new. If a cell shows a voltage as low as 2.20-2.21V, this means that it draws abnormally high current (10-15 times the usual value). Tests have proven that such a cell still has full capacity, but the cell should be changed on the first suitable occasion, since there is a risk of further deterioration.

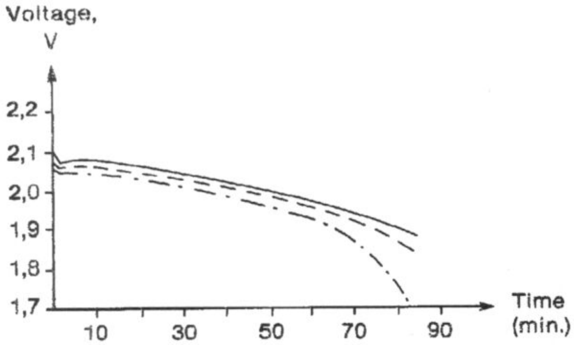


Fig. 6
The cell voltage as a function of time, with a discharge current of 12.5 A for a battery of 23 cells, of 25 Ah capacity

——— Highest cell voltage
- - - - Average voltage
- · - · - Lowest cell voltage

When a new cell is inserted in a battery unit, it does not necessarily have to be fully charged. The cell will be fully charged after awhile in the battery unit.

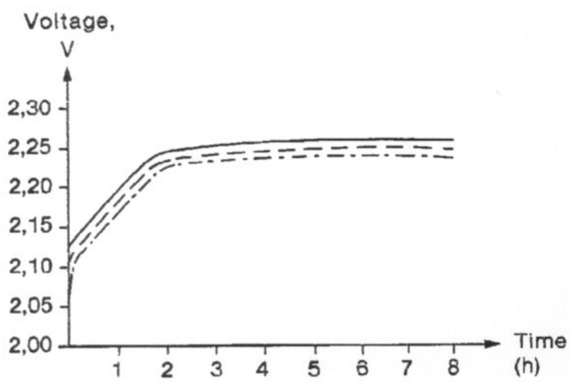


Fig. 7
The cell voltage as a function of time when charging a battery with 23 cells of 25 Ah with the current limited to 5 A

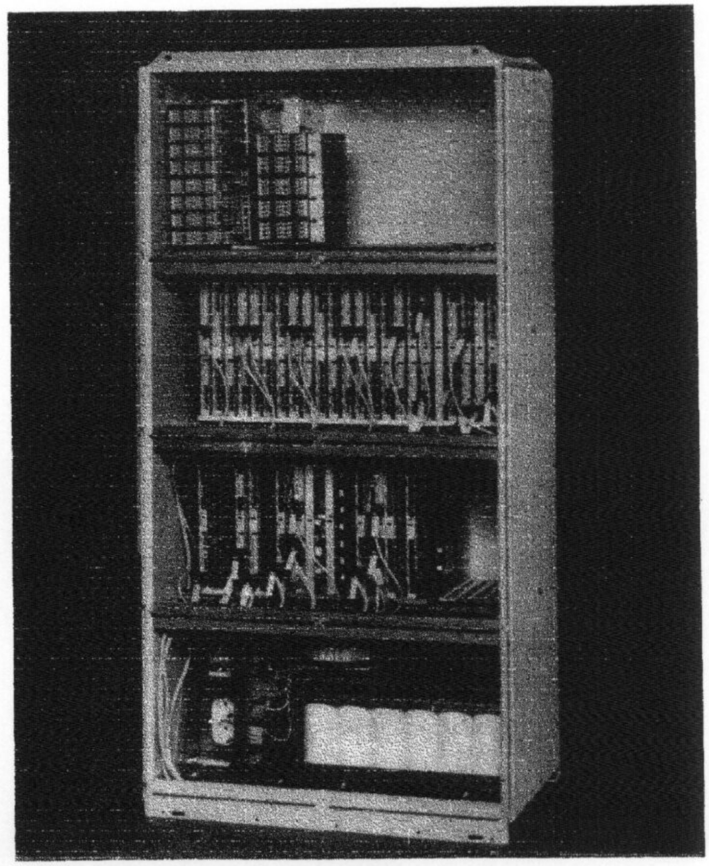
——— Highest cell voltage
- - - - Average voltage
- · - · - Lowest cell voltage

Applications

Voltage equalization gives the battery unit remarkably high operational reliability. The battery can work at temperatures down to −40°C, and can withstand occasional temperatures up to 40-45°C without noticeable shortening of its life. The battery life is estimated to be 8-10 years at 20-25°C, and approximately 4 years at 35°C continuously.

Two or more battery units can be connected in parallel. The installation is easy, the unit being mounted in the same rack as the electronic equipment, Fig. 8. The battery cells are classified by IATA (International Air Transportation Association) as "dry", which means that they can be sent by air without restriction.

These characteristics give the battery unit a wide field of application, and it is particularly suitable for small rural exchanges, repeaters on long-distance cables, radio relay link, PBXs, military applications, etc.



A 4A power unit with a 12.5Ah battery, integrated with transmission equipment.

REFERENCES

[1] Accumulatorenfabrik Sonnenschein GmbH, Prospekt Nr. 7023, p. 10.

[2] Harrison, M.R., Gates Energy Products, Denver, Colorado, USA: Considerations in the Application of Sealed, Recombining Recharge Lead-acid Batteries to Remote Installations and UPS Systems on Telecommunications Networks. International Telecommunications Energy Conference, Oct. 3, 4, 5, 6, 1982,
Washington, DC, USA, pp. 424-428.