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Standby battery requirements for telecommunications power

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Abstract

The requirements for standby power for telecommunications are changing as the network moves from conventional systems to Internet Protocol (IP) telephony. These new systems require higher power levels closer to the user but the level of availability and reliability cannot be compromised if the network is to provide service in the event of a failure of the public utility. Many parts of these new networks are ac rather than dc powered with UPS systems for back-up power. These generally have lower levels of reliability than dc systems and the network needs to be designed such that overall reliability is not reduced through appropriate levels of redundancy. Mobile networks have different power requirements. Where there is a high density of nodes, continuity of service can be reasonably assured with short autonomy times. Furthermore, there is generally no requirement that these networks are the provider of last resort and therefore, specifications for continuity of power are directed towards revenue protection and overall reliability targets. As a result of these changes, battery requirements for reserve power are evolving. Shorter autonomy times are specified for parts of the network although a large part will continue to need support for hours rather minutes. Operational temperatures are increasing and battery solutions that provide longer life in extreme conditions are becoming important. Different battery technologies will be discussed in the context of these requirements. Conventional large flooded lead/acid cells both with pasted and tubular plates are used in larger central office applications but the majority of requirements are met with valve-regulated lead/acid (VRLA) batteries. The different types of VRLA battery will be described and their suitability for various applications outlined. New developments in battery construction and battery materials have improved both performance and reliability in recent years. Alternative technologies are also being proposed for telecommunications power, either different battery chemistries including lithium batteries, flywheel energy storage or the use of fuel cells. These will be evaluated and the position of lead/acid batteries in the medium term for this important market will be assessed.

Keywords: Lead–acid; Valve-regulated; Telecommunications power systems; Standby batteries

1. Introduction

The telephone network has changed in a few years from fixed lines to a mixture of fixed and mobile subscribers and further changes are now taking place as more and more fixed line subscribers migrate to broadband connections. For the present, this is a mixed system but telecommunications operators are now moving to full Internet Protocol (IP) telephony systems. In developed countries the number of fixed line subscribers is stable, market penetration for cellular telephones is close to saturation but the uptake of broadband connections is a rapidly growing market. Transition to a full IP system will enable the benefits of high bandwidth to be fully exploited. Uptake of mobile networks with higher bandwidth is proving to be slow relative to fixed networks but there are other options such as wireless hotspots which enable mobile computing. Table 1 summarises the main features of conventional fixed line networks and IP networks. Telephone networks generally have a statutory requirement to maintain service when the public utility is interrupted but IP networks do not have the same requirement unless they are also providing a telephone service through a principal fixed line carrier. Telephone networks are generally powered by 48 V dc systems, fully backed up by batteries and generators whereas IP networks are generally ac powered at line voltage with limited battery back-up. IP networks carrying voice traffic provided by the main carriers will, however, need to have the same level of reliability as conventional networks. Mobile networks require standby power to maintain adequate reliability and for revenue protection but autonomy times are generally shorter than for fixed line networks.

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Table 1
Principal features of fixed line telephone and Internet Protocol networks in terms of power provisioning

Network type	Telephone	Internet Protocol
Reliability	Guaranteed	Best effort
Bandwidth	Narrowband	Broadband
Information transfer	Voice/fax/slow data	Voice/fax/fast data/video
Cost/unit of data transmitted	High	Low
Power supply	dc 48 V	ac 240 V or higher

Conventional voice-based networks consist of dedicated subscriber equipment, repeaters and switches possibly using other carriers for bulk traffic. IP networks consist of routers and servers connected by a variety of broadband services. This has been developed for business to business communication, for internet access and for e-mail communication, all through computer-based access. The use of IP based systems for voice traffic without requiring the subscriber to use a computer locally changes the powering requirements. DC power systems with a simple arrangement of a rectifier and a battery permanently connected to the load can achieve reliability levels of 99.99995% with parallel operation of both rectifiers and batteries coupled with a strong maintenance policy. This equates to non-availability of 15 s per year.

AC power supported by an Uninterruptible Power Supply (UPS) is more complex and although the system is supported by batteries, no power can be supplied to the load if either the inverter or static switch fails. As a result, non-availability is higher at 120 s per year or a reliability of 99.9996% even with an equivalent level of redundancy and maintenance for the batteries [1].

These changes in telecommunication network architecture are in turn changing the power requirements including the battery types that are required and networks need to be designed such that overall reliability is not compromised. Mobile networks have different power requirements. Where there is a high density of nodes, continuity of service can be achieved with relatively short periods of back-up power. These changes are causing a shift towards shorter autonomy times although there remains a large part of the network that needs reserve power for hours rather than minutes. In addition, operational temperatures are increasing and battery solutions that provide longer life in extreme conditions are becoming important. In this paper, the nature of power provision for these networks will be discussed and standby batteries will be examined against various applications. Alternative technologies are also being proposed for telecommunications power. These will be considered and the position of lead/acid batteries for this important market will be assessed.

2. Power systems

Telecommunications power is derived through a rectifier from the public utility to supply a load at a nominal voltage of 48 V dc with a battery permanently connected across the rectifier output and in parallel with the load. There will also be a diesel generator to provide an ac supply in the event of an extended outage (Fig. 1).

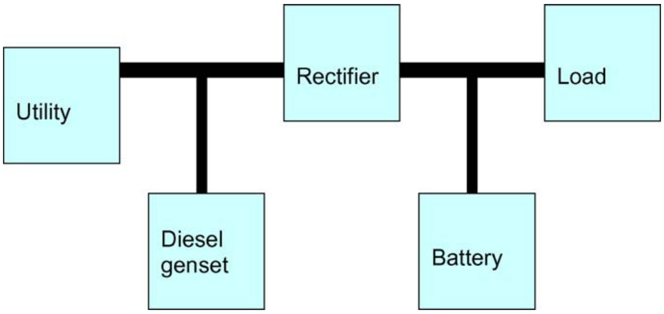

Fig. 1. Schematic arrangement for mains derived 48 V dc telecommunications power system.

UPS systems to support telecommunications systems will be on-line systems able to control all aspects of power quality including line noise, frequency variations, harmonics, over voltages, under voltages, spikes, sags, surges and transients as well as complete outages. The ac supply fed to the equipment is stable in every respect and offers the highest degree of protection. The normal configuration will be to rectify the incoming utility feed and the invert the dc output back to ac to feed the load. The rectifier output is connected across a standby battery. A static switch is used to change to a by-pass circuit if the rectifier or inverter fails and a diesel generator may provide an ac supply in the event of a utility outage (Fig. 2).

Less sensitive loads may be supported by parallel processing or line-interactive UPS systems. These provide protection from sags and surges and during an outage but do not protect against frequency variations, harmonics and electrical noise. Reliability is better because failure of the power converter will not prejudice operation while the utility continues to function normally. Energy efficiency is also better because double conversion is avoided but it cannot be used for large, critical systems that need the highest levels of power quality (Fig. 3).

The convergence of IP and telephone networks will result in different configurations and an example is shown in Fig. 4 where a parallel processing UPS system is adapted to feed the dc loads through a dc/dc converter. Alternatively the dc/dc converter may be replaced with a rectifier connected to the ac line but in each case both loads are supported by a single higher voltage battery. This offers the best compromise in terms of efficiency and

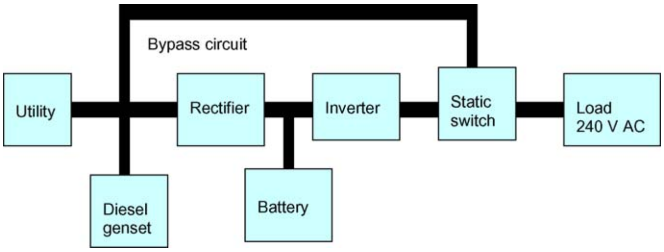

Fig. 2. Schematic arrangement for an on-line UPS system with double conversion and static bypass.

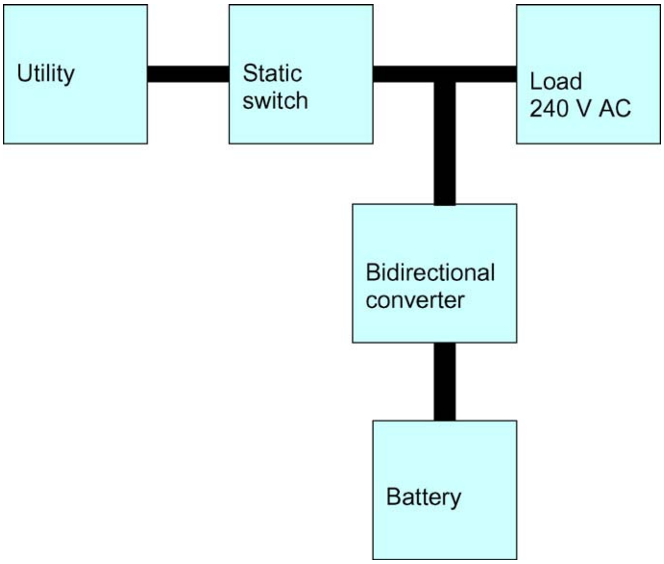

Fig. 3. Schematic diagram of line-interactive UPS system.

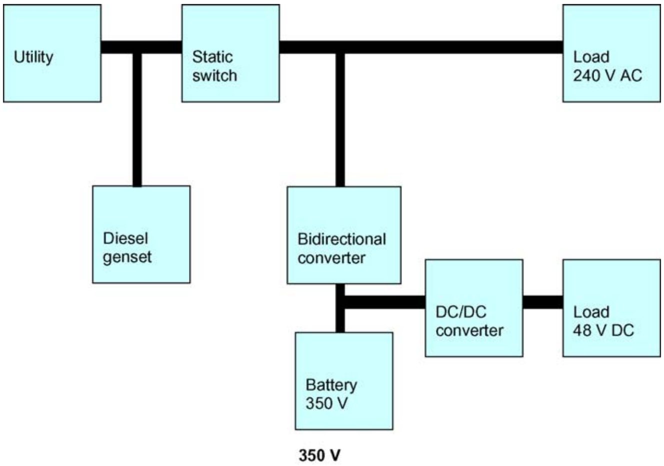

Fig. 4. dc/ac universal power supply system.

cost compared to systems with additional power conversion or separate standby batteries.

In addition to these changes to the overall power provisioning for telecommunications networks, other changes have taken place with fewer systems using large central batteries and both rectifiers and batteries being provided in a modular fashion with the equipment they are designed to protect. This has also lead to a change in battery layout to the use of 3 × 2 cells with front access terminals rather than the conventional six in-line layout.

3. Flooded lead/acid batteries

Flooded lead/acid batteries remain important for large central office applications for a number of major operators. Two technologies dominate the market; pasted plate lead/calcium batteries and tubular plate batteries, generally conforming to the OPzS specification, and some large round cells are still produced. The use of Plante cells is now very limited.

Pasted plate cells using Pb–Ca–Sn grids remain in use in large numbers in North America and in some other areas. The plates are substantial and will achieve a life of up to 25 years in a well-controlled environment. The grid thickness is sufficient to achieve the design life with moderate acid specific gravity. The positive plates are designed such that plate growth can occur in a benign manner with the plates suspended at the top of the container. The positive plates are wrapped in a glass retainer mat to ensure that shedding of active material cannot occur. Microporous plastic separators are used. Cell containers are moulded in transparent polyvinyl chloride (PVC) or styrene acrylonitrile (SAN) allowing visual inspection of the condition of the cells. Pillar seals are proprietary but generally designed to have a high degree of integrity and avoid stressing the seal over the life of the battery. Cell capacities range from 100 up to 4000 Ah. This type of cell has an established reputation for reliability and for central office applications, nuclear power, national security installations and for large critical UPS systems will continue to be specified.

Tubular plate cells for standby service follow the OPzS specification to DIN requirements. They are used for telecommunications for standby power in main switching centres for fixed line telephony but have been substantially displaced by sealed gelled electrolyte OPzV cells. The positive plates have die cast low antimony alloy spines and use a fabric gauntlet as a retainer for the active material. Some suppliers also offer positive plates with Pb–Ca–Sn grids as an alternative. The negative plates are a pasted plate type and generally microporous polyethylene separators are used. Cell containers are moulded in SAN so that electrolyte level and the visual condition of the cell can be readily seen. Pillar seals vary in complexity between suppliers but offer freedom from leakage and corrosion over the service life of the battery. The specific gravity of the electrolyte is higher than pasted plate cells. Sufficient excess of electrolyte above the group bar can be provided to permit a watering interval of up to 3 years and the overall service life is up to 15 years. Pb–Sb plates provide a good cyclic performance and for applications where the reliability of the public utility is poor or for supporting solar power installations, tubular cells provide good performance.

The round cells designed by AT&T Bell Laboratories have a number of features that provide for a life of 40 years or more [2,3]. These have a circular pure lead positive grid shaped as shallow cone and stacked horizontally with pure lead negative plates of a similar construction. The positives are welded together externally and the negatives welded to a central conductor core with an insulator at the outside edge. Microporous polyethylene separators are used with a glass retainer mat. The cell containers and lids are moulded in PVC. The positive active material is a mixture of chemically produced tetrabasic lead sulphate and red lead before formation. The use of pure lead reduces plate growth and corrosion. The special shape is designed to counter the effect of plate growth and ensure that the grid and the active material remain in good contact throughout the life of the battery. Grid growth is caused by formation of lead dioxide at the surface of the grid and distorting the grid but in this case the shape change causes no adverse effects. The conversion of grid material into lead dioxide causes a small but measurable capacity increase over time. The acid specific gravity is low and the float voltage is also low. This could cause a problem with recharge of the positive plate and this is resolved by adding a small amount of Pt as a depolarizer to the negative expander rather than by increasing the float voltage. The terminal design is also unique. A Pb–Sn alloy is used to prevent nodular corrosion and an epoxy sheath formed around the pillar which then has a rubber boot to seal to the cover. It is important for seal integrity that the area coated in epoxy is not below the electrolyte level [4]. Large numbers of these cells have been deployed in central office applications in the United States and some other territories and following revisions to the design, particularly for the pillar seal, are achieving very long service lives.

Plante cells were used extensively in Europe for telecommunications but although there is limited production for replacement, they are no longer specified. These cells use a pure lead positive grid with an extended surface such that the active material was formed directly by controlled corrosion of the grid material. The plates are hung from the top of the cell such that plate growth occurs harmlessly downwards. Pasted plates with Pb–Sb alloys are used for the negative plates and microporous plastic separators. Cell cases and lids are in SAN and pillar seals vary in design from simple rubber bushings to arrangements similar to the round Bell designed cells. This type of battery has a service life of up to 25 years.

4. Standards for VRLA batteries

The technical standards for valve-regulated lead/acid (VRLA) batteries have been recently updated and two new international standards, IEC 60896-21 Methods of Test and IEC 60896-21 Requirements have been published. The first part defines a variety of characteristics for safety, performance and durability (Table 2) and the second part calls up the requirements for different applications. For a number of the safety related, constructional and performance features, including high current tolerance, internal ignition from external sources, protection against ground shorts, battery marking, material identification, valve operation, charge retention in storage, recharge behaviour and the ability of the battery to withstand mechanical abuse during installation a definitive pass is called up. For a number of other features, including gas emission, internal resistance, short circuit behaviour, the flammability of the container and lid, intercell connector performance, susceptibility to thermal runaway and the stability of the container and lid at elevated temperature and pressure, data is requested and it is for the user to determine the requirement. The main differentiator between different types of battery comes with the main characteristics defining durability. These are:

(i) float service with daily discharges,
(ii) service life at an operating temperature of 40 °C,
(iii) impact of a stress temperature of 55 or 60 °C,
(iv) abusive over-discharge,
(v) low temperature sensitivity.

Regular cycling requires a cyclic life of >50 cycles for a reliable utility supply, >150 cycles for unreliable supplies and >300 cycles for very unreliable supplies. Service life at 40 °C calls up four levels of requirement: >500, >750, >1100 and >1700 days. The highest level would be equivalent to ~12–14 years of operation at 25 °C. Stressing the battery at 55 °C also leads to four levels of requirement: >150, >250, >350 and >500 days. The highest level here is equivalent to ~12 years of operation at 25 °C, similar to the 40 °C requirement when the battery is discharged at the 3 h rate but when the battery is discharged at the 15 m rate the durability requirements are halved as performance at these rates is critically dependant on the degree of corrosion that has occurred in the battery. The way in which the battery survives abusive over-discharge relates to utility quality and the low temperature sensitivity simply defines the capacity that the battery should have after freezing in addition to being free from mechanical damage.

These standards are not presented in a manner in which general compliance to the standard should be claimed. Instead a set of results may be presented against the prescribed tests which then need to be interpreted against the users requirements. The more rapid reduction in high rate performance should be noted especially in relation to shorter duty cycles for UPS and for support of cellular networks.

Table 2
Tests specified by IEC 60896-21

Test number	Characteristics defined
Safety	
4.1	Gas emission
4.2	High current tolerance
4.3	Short circuit current and dc internal resistance
4.4	Protection against internal ignition from external sources
4.5	Protection from ground shorting
4.6	Markings
4.7	Material identification
4.8	Valve operation
4.9	Flammability rating of container and lid
4.10	Intercell connector performance
Performance	
4.11	Discharge capacity
4.12	Charge retention during storage
4.13	Float service with daily discharges
4.14	Recharge behaviour
Durability	
4.15	Service life at an operating temperature of 40 °C
4.16	Impact of a stress temperature of 55 or 60 °C
4.17	Abusive over-discharge
4.18	Thermal runaway sensitivity
4.19	Low temperature sensitivity
4.20	Dimensional stability at elevated internal pressure and temperature
4.21	Resistance to mechanical abuse during installation

5. VRLA batteries

There are three main types of VRLA battery: tubular gel cells, pasted plate cells with Pb–Ca–Sn grids, and pasted plate cells with pure lead or pure lead–tin grids. These differ in construction and performance but all are sealed and recombining such that no maintenance watering is required.

5.1. *Tubular gel cells*

Tubular gel cells generally follow the OPzV specification and dimensions and are available in sizes from 200 to 3000 Ah. The positive plates have a tubular construction with spines in Pb–Ca–Sn alloys. Tin levels tend to be higher and calcium levels lower in recent years to improve the corrosion life of the cell and also cyclic behaviour. Negative plates use flat cast grids and are pasted conventionally. The separator system uses a microporous plastic separator with pores in the larger range of available materials and the electrolyte is gelled with finely divided silica. The gel allows oxygen transport from the positive to the negative plate through microscopic fissures in the gel. Cell cases and lids are moulded in flame retardant acryolonitrile butadiene styrene (ABS). Pillar seals are proprietary and pressure relief valves are normally of a Bunsen valve type. The life in floating service is ∼12 years and this type of cell has a reasonably good cyclic performance. The rate capability is modest.

5.2. *VRLA batteries with Pb–Ca–Sn grids*

The majority of VRLA batteries produced, either as cells or monoblocs, use pasted plates with Pb–Ca–Sn grids and absorptive glass mat (AGM) separators (Fig. 5). Sizes range from 12 V, 1 Ah monoblocs to single cells with a capacity of 4000 Ah. Cell cases may be polypropylene, ABS, polycarbonate (PC)/ABS or PVC but the majority of types specified for telecommunications applications use flame retardant ABS. The positive grid alloys have evolved from moderately high levels of calcium (0.07%) to lower levels (0.04/0.05%) with a corresponding increase in the tin level from 0.7/0.8% to ∼1.2% to improve the corrosion behaviour. One manufacturer has used Pb–Sb–Cd alloys but this has not been followed elsewhere in the industry. Grid thickness is an important parameter for the life of a cell float and for a life of 10–12 years at 20–25 °C, thicknesses of 4–6 mm are required. The details of the electrochemical design of cells, separator specification and compression and acid filling are all important in achieving reliable performance over life. For higher performance with shorter discharge times, thinner plates are used but at the expense of life. Pillar seals use a variety of rubber sealing rings, mechanical compression and thermosetting resins. Valves may be simple Bunsen valves or more complex arrangements and normally have a flame filter to prevent any external ignition of hydrogen from penetrating the cell.

Fig. 5. VRLA telecommunications battery with front access terminals.

Table 3
Comparison of energy densities at low and high rates for conventional VRLA batteries with cast Pb–Ca–Sn grids with thin-plate pure lead batteries

	Energy density (Wh kg^{-1})	Energy density (Wh l^{-1})
Conventional VRLA ∼4 mm thick plates		
15 m rate	11	26
8 h rate	26	64
Thin plate pure lead ∼1 mm thick plates		
15 m rate	18	44
8 h rate	39	99

5.3. *VRLA cells with pure lead grids*

Instead of using cast Pb–Ca–Sn grids, cells may be built with pure lead or pure lead–tin grids. These are fabricated from continuously cast or wrought strip by punching the grid pattern into the strip. The strip is then pasted continuously and the plates are then processed as for VRLA cells with Pb–Ca–Sn grids. The grids are typically 1.0–1.2 mm thick. Active material utilisation is much better than cells with thicker plates and the use of pure lead grids reduces the corrosion rate such that the life is equivalent to cells with Pb–Ca–Sn grids with much thicker plates. Alloying with a small amount of tin (0.4/0.6%) improves the cyclability but will slighty reduce the corrosion resistance. Other details of construction are similar to normal types of VRLA cell.

Table 3 shows a comparison of the volumetric and gravimetric energy density for a typical thin-plate VRLA monobloc against a thicker plate Pb–Ca–Sn monobloc on a constant power discharge at the 15 m and the 8 h rate to the same end voltage. The difference in energy density is striking, especially at the 15 m rate. As the pattern of use for telecommunications shifts towards higher rates, this approach to battery design may become more important.

Thicker plate VRLA cells with pure lead plates are also manufactured. Here the corrosion life is extended but the rate performance is unaltered. Service lives in excess of 25 years at 25 °C and up to 10 years at 40 °C are claimed.

6. Nickel/cadmium cells

Nickel/cadmium cells are used for telecommunications applications where environmental conditions, especially temperature, are particularly harsh. Cells with sintered positive electrodes and plastic bonded negatives are used. The separator consists of one layer of a non-woven felt and a membrane and the cells are designed not to recombine oxygen. As a result, watering is required but the maintenance interval is up to 5 years and lives of 10 years or more are projected at 40 °C. Batteries of this type have been in service for a number of years in remote cabinets in North America as an alternative to VRLA batteries where the life is limited because of the environment [5].

7. Lithium batteries

7.1. Lithium-ion

Lithium-ion batteries have been developed for telecommunications back-up where the autonomy times are very short by exploiting good capabilities at higher rates to offset the higher costs of this battery chemistry. The energy density at the 15 m rate for commercial products is shown as 32 Wh kg^{-1} or 45 Wh l^{-1} which is better than thin-plate lead/acid batteries but volumetrically, the improvement is small. Lithium-ion cells use cobalt or mixed cobalt/nickel oxide cathodes, liquid organic electrolytes with microporous plastic separators, and carbon/graphite anodes. Lithium is reversibly intercalated into the cathode and the anode. This technology is universally deployed for mobile telephones and portable computers but does not lend itself to float operation. A resistive but ionically conductive layer forms at the anode/electrolyte interface on float which limits the life of the battery. Capacity loss on float [6] has been reported to be 70% after 10 years at 25 °C and commercial product offers indicate a life of 10 years at 30 °C and 5 years at 40 °C. Lithium-ion is likely to find application where space is very limited and the duty cycle is only a few minutes.

Lithium-ion batteries with phosphate based cathode materials are also offered for telecommunications. The energy density is 82 Wh kg^{-1} or 173 Wh l^{-1} at moderate discharge rates and this system is capable of supporting systems both at low and high rates. A high cycle life is indicated but the life on float is restricted by temperature and shown as 20 years to 60% capacity retention at 20 °C. In common with other lithium battery offers commercial battery offers have extensive batttery management, safety and diagnostic features integrated with the battery.

7.2. Lithium metal polymer batteries

Lithium metal polymer (LMP) [7] batteries differ from lithium-ion batteries in that the anode is metallic lithium and the electrolyte is a solid lithium-ion conducting polymer (Fig. 6). They operate between 40 and 60 °C and can provide long service life at ambient temperatures of up to 60 °C. The anode is a thin foil of pure metallic lithium and serves both as a lithium-ion source and a current collector. The cathode is vanadium oxide which acts as an intercalation compound in the same way as the cathode in lithium-ion cells. It is formulated with lithium salt, carbon and polymeric electrolyte and laminated to an aluminium foil current collector. The solid electrolyte is based on a polyether copolymer with a lithium salt (lithium perfluorosulphonimide) dissolved in the material. The conductivity of the electrolyte is limited at room temperature and the battery is operated at 40–60 °C to achieve satisfactory performance. LMP cells are able to use metallic lithium for the anode because the use of a polymeric electrolyte with a controlled pressure on the cell stack and a moderate rate of charge allows lithium to be plated to the anode on recharge in cohesive rather than in a dendritic form. It is for this reason that lithium-ion batteries use a lithium/carbon intercalation anode. LMP cells have a solid electrolyte interface (SEI) conductive to lithium ions similar to liquid electrolyte cells but it does not limit life on float in the same way as lithium-ion cells.

Fig. 6. Lithium metal polymer battery.

Batteries are constructed as 48 V modules from 18 cells in a stack with integral heaters, an insulated container and a charge and discharge management unit which also monitors and records battery operation. The battery is maintenance-free and the internal diagnostics will monitor the state-of-health of the battery. The operational temperature range is −40 to +65 °C and within this range, life is projected to be 20 years. The discharge rate is limited to intermediate rates and the battery is optimised for longer autonomy times. The energy density at the 8 h rate is 106 Wh kg^{-1} or 137 Wh l^{-1} providing significant benefits in battery accommodation. The LMP battery offers longer service life than any other type of battery at extreme temperatures and is likely to become the system of choice for applications where long life in remote high or low temperature environments is required.

8. Other battery chemistries

Very few other battery chemistries are suitable for standby power. Attempts to use reserve batteries such as aluminium/air to extend the autonomy time of systems where lead/acid batteries are used for the larger number of shorter outages were made some years ago but were not successful. Nickel/metal hydride batteries have no real advantages for standby power and are not used. Sodium/nickel chloride (Zebra) batteries are technically suitable for back-up power and offer higher energy density as well as good cycle life and rate capability but the need to keep the battery installation at 300 °C limits the scope of application.

9. Flywheel energy storage

Flywheel energy storage is suitable for providing high power levels for very short periods of time as an adjunct to a UPS system which will still in any event need to have a battery for longer back-up periods and in addition a flywheel system may not have sufficient autonomy time without a battery to enable a diesel generator to be brought on line securely. The technology is simple; a heavy rotor is spun at high speed in a vacuum and may be operated as a motor to charge and as a generator for discharge. A typical system can provide high power levels of up to 500 kW for 10 s but the energy density is very low. Cycle life is essentially unlimited and ambient temperatures up to 40 °C have no impact on service life which is up to 20 years subject to bearing maintenance. This type of device has application where power quality is critical or where the local network is likely to suffer from exceptional transients.

10. Fuel cell systems

The use of fuel cells for reserve power is limited by the cost of available systems and by considerations regarding fuel infrastructure. For reserve power a proton exchange membrane fuel cell (PEMFC) is favoured which may be fuelled by using hydrogen directly or by using hydrogen derived from a fuel gas by reformation. The fuel cell will be an electricity generator and as such is substitutional for a diesel generator. Furthermore, it will not start instantly as it will need several minutes to reach operating temperature and so a battery will be required not only to support the load but also to bring the fuel cell to the correct operating condition. A PEMFC is not suitable for continuous operation over a period of years as the life will be limited to several thousand hours. Fuel cells for reserve power are an alternative to a diesel generator and would be favoured where the lack of noise is a benefit or on general environmental grounds. The use of high temperature fuel cells as part of co-generation systems where the heat can be utilised for central plant is possible but the considerations are economic and environmental and not principally concerned with the security of the power supply.

11. Conclusions

Changes in the telecommunications network have shifted battery requirements from large batteries installed in central office requirements to a mixture of larger systems and distributed power in smaller switching centres. As the system evolves to the increased use of broadband connections and to a full IP telephony network the power requirements will shift again as there will be a requirement to power data processing equipment and access equipment. For fixed line access, the requirements for integrity and reliability should not be compromised. For mobile networks, there are different considerations for network reliability and autonomy times are generally shorter.

Battery requirements have changed from larger flooded central office applications to modular power in equipment racks and smaller switching centres and base stations. Shorter autonomy times favour lead/acid batteries optimised for this type application and the relative life expectation at higher rates of discharge needs to be considered. Under extreme conditions the life of lead/acid batteries is reduced considerably. Improvements to VRLA batteries are possible to extend service life. Nickel/cadmium batteries have been used for higher temperature service but LMP batteries offer the possibility of extended life in the most extreme environments. Lithium-ion batteries are restricted in operating temperature range in floating service but offer compact power solutions for high rate applications. Other methods of providing reserve power such as flywheel energy storage of fuel cells are not an effective substitute for batteries. Lead/acid batteries and in particular VRLA batteries will continue to dominate telecommunications power but need to be adapted to the requirements of new networks. Lithium-based systems with advantages in power and energy density can secure a market share and, in particular, LMP batteries offer an effective solution where the life of VRLA batteries is limited.

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