ELSEVIER

Journal of Power Sources 53 (1995) 149–152

JOURNAL OF POWER SOURCES

Reducing the cost of maintaining valve-regulated lead/acid batteries in telecommunications applications

M.W. Kniveton [1]

British Telecommunications Plc, Wales and West Networks Division, 3rd Floor Bristol CTE, Marsh Street, Bristol BS1 4BH, UK

Received 21 August 1994; accepted 1 September 1994

Abstract

British Telecommunications has utilized valve-regulated lead/acid (VRLA) technology for 10 years and has considerable experience of varying product performance. A discussion is given of battery applications in telecommunications and includes experiences of typical failure modes such as group-bar corrosion and premature capacity loss, together with the detrimental effects of high temperature on service life. Specific maintenance requirements are also reviewed with particular attention to costs and reliability. Data are presented on the effectiveness of new methods of testing large numbers of VRLA batteries and, in particular, the reliability of conductance testing. An explanation is given of the role of conductance measurements, discharge testing and manufacturers' laboratory analysis in contributing to an effective maintenance programme. Specific requirements for the management of a battery-replacement programme are also included. Finally, BT user experience is described and solutions are provided to reduce the cost of VRLA maintenance while improving reliability.

Keywords: Application; Failure analysis; Conductance testing; Maintenance; Costs; Reliability

1. Introduction

Since 1984, British Telecommunications (BT) has utilized valve-regulated lead/acid (VRLA) battery technology in all new telecommunications power equipment. The projected life, maintenance-free service and inherently safer and more user-friendly design has promised improved system reliability at a lower cost. Indeed, the new components of modern power systems, switch-mode rectifiers and VRLA batteries, has enabled power systems to keep pace with the digital modernization programme.

The expected life of the VRLA product was anticipated to be 10 years. Costs with a 10-year turn-around were favourable in comparison with more traditional flooded-electrolyte designs. Much earlier than anticipated, however, some VRLA designs seemed to be flawed by poor quality manufacturing techniques. These caused a sudden and total loss of battery capacity and, thereby, resulted in expensive system downtime and a lack of confidence in the VRLA product. The occurrence of these failures and the lack of any proven method of detection prior to failure, exasperated and delayed traditional maintenance programmes. This posed a threat to BT's objective of providing a superior high-quality network. Urgent investigations into the cause of the battery failures detected corrosion of the internal group bar as the primary cause in products from one particular supplier. Clearly, improvements in manufacturing quality were urgently required and BT has worked with manufacturers to enable a better understanding of the telecommunications application. This cooperation has been beneficial in enabling manufacturers to introduce major improvements in battery quality.

This paper details some early failings of the VRLA battery and describes new surveillance techniques that have successfully reduced maintenance costs. Together with products of improved quality, these techniques will ensure that VRLA batteries regain prominence in many applications.

2. Application

All power systems within the BT network employ batteries as the primary source in the event of a break in the public mains supply. If the duration of the break exceeds 30 s, a secondary source, namely, emergency diesel generators, provides an alternative mains supply

[1] Tel: 0272 202025; Fax: 0272 257821.

0378-7753/95/$09.50
SSDI 0378-7753(94)01984-4

and the batteries return to float/standby operation. For additional security, the nominal battery reserve is a minimum of 1 h. All but the smallest systems contain multiple batteries installed in a parallel string configuration. Nevertheless, this over provision is seen as costly, both initially and concurrently, when replacements are required and has not provided additional security from group-bar corrosion.

3. Failure analysis

Despite a large investment in modern systems containing the very latest technology, power failures occurred. A high proportion of these were due to the total and immediate collapse of the VRLA battery. Analysis of the cause of system downtime revealed a weakness within computer and telecommunications systems to restore service both quickly and cleanly. Short-duration power failures can cause hours of system downtime and result in loss of revenue and customer confidence.

3.1. Negative-group bar corrosion

Further analysis into the cause of the power failures revealed internal group bar corrosion as the primary failure mechanism. This type of corrosion appears at random and has affected the products from one particular manufacturer. Identifying and replacing similar batch types has not guaranteed security. The electrochemical reactions that cause this corrosion have been described by Berndt [1]. Parallel-string configurations gave little additional security, the same failure mechanisms occurred in each string.

Group-bar corrosion has cast grave doubts over the suitability of the VRLA design and, in particular, battery manufacturing quality for telecommunications applications. Yet, within the BT network, there are many VRLA products that do not suffer from this catastrophic failure mode and are continuing to provide excellent service past their 10-year life. Recently, manufacturers have responded in producing more suitable alloys and implementing quality manufacturing techniques with rigorous quality control. A greater degree of confidence can be expected in the improved performance of VRLA batteries and the containment of group-bar corrosion. Frequent testing by impedance/conductance meters will detect any increase in internal resistance caused by this corrosion. Although, by its nature, this type of corrosion can accelerate rapidly and the only true guarantee against system failure is replacement.

3.2. Premature capacity loss

With careful monitoring and early replacement, this type of failure mode has not been a primary cause of system downtime in telecommunications applications. This is in part due to the provision of emergency generators and an initial over-sizing of the battery capacity. It does, however, question the financial wisdom of converting from traditional lead/acid designs to VRLA products that only achieve a 5-year life. An improved life span of 8–10 years at 25 °C, coupled with very low-maintenance requirements, would favour VRLA when costs are compared with those of more traditional flooded-electrolyte designs. This requirement has been achieved by some manufacturers, and it is anticipated that recent quality initiatives will deliver substantial improvements for others. Conductance testing has been successful in monitoring the fall in battery capacity.

3.3. Temperature

The effects of increased temperature on the VRLA design are well documented and clearly understood by battery manufacturers. By comparison, users (and, in particular, power-system designers) are failing to appreciate the detrimental effects of high temperature on service life. These pressures will increase as telecommunications operators comply with environmental legislation that will reduce the use of refrigerant gas in cooling systems and precipitate a move towards fresh-air cooling. Clearly, there are major improvements to be made in rack design and battery layout. The agreement of national standards for VRLA installations will go some way towards ameliorating this situation. BT has recently started a temperature-compensation trial to reduce the effects of overcharging and internal heat-generation at higher temperatures.

4. Maintenance

The key enabler in delivering the considerable advantages of the VRLA design is quality of product. Manufacturers are working with BT to gain a greater understanding of the telecommunications application. This has already resulted in substantial changes to manufacturing processes and improvements in quality are being seen for all new products. The problems associated with older products forced a total revision of maintenance practices in the light of new experience, together with a greater appreciation of failure modes. The inability to use traditional methods of determining battery state-of-health, or an ability to make internal visual inspections, has initiated a search for new techniques that are both accurate and reduce maintenance costs.

4.1. Discharge testing

Sheer volume prevents off-line discharge testing for all products, although smaller samples are taken as reference data. On-line discharge testing of older products has caused system failures and any data obtained proved to be of little value due to different discharge rates. A far more efficient indicator of battery state-of-health is required. Extensive trials and experience with the Midtronics conductance tester have proved this to be a valuable maintenance tool in identifying gross failure.

4.2. Conductance testing

Conductance testing applies an a.c. voltage signal of known frequency and amplitude and measures the resultant a.c. current flowing in response. The ratio of this current to the a.c. applied voltage can then be displayed as the true conductance value for the cell or battery and is measured in Siemans (Mhos). Impedance and conductance testers differ in the method and frequencies used and, to a greater or lesser degree, concentrate on the in-phase resistive component. With conductance, the measured value can be displayed as a direct reading or as a percentage of the known conductance for that particular design. Parameters obtained from reference data are used to set the 100% threshold.

Within BT, a slightly different approach has been to standardize the conductance setting and alter the pass or fail threshold values for different makes of VRLA battery. This has simplified field use, but further developments may enable a return to specific settings for different products. Early experience with conductance testing has led the Wales & West, Worldwide Networks Division of BT to become a pilot for the introduction of conductance testing as the main maintenance test performed on VRLA batteries. The main objectives of this trial were:

(i) to establish whether conductance testing could provide a common and standard indicator of battery state-of-health;

(ii) to reduce maintenance costs in relation to more traditional testing methods;

(iii) to prevent service failures by indicating gross battery failure;

(iv) to provide statistical data that will determine where and when to initiate a battery-replacement programme.

The necessity to indicate exact ampere-hour capacity is not seen as a major requirement. An indication of: good/requires attention/requires replacement is perfectly adequate to meet maintenance needs.

4.3. Method

Initially base-line data were obtained by measuring conductance for a variety of products and comparing this with actual timed discharge results. Fig. 1 shows simplified results for products from manufacturers A and B. It can be seen from these graphs that suitable thresholds can be drawn depending on system security and financial considerations.

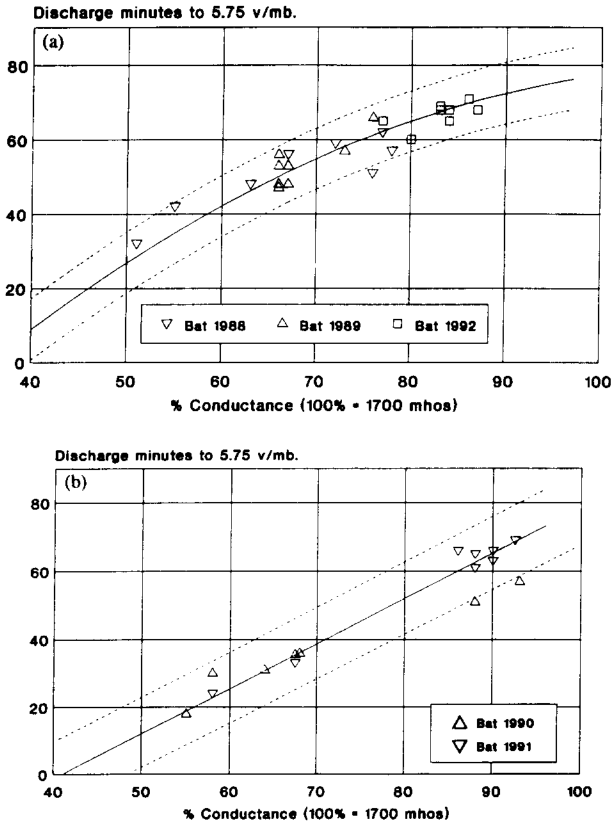

Fig. 1. Discharge capacity vs. conductance for: (a) product A, 100 Ah, 6 V monobloc at 22 °C; (b) product B, 100 Ah, 6 V monobloc at 25 °C.

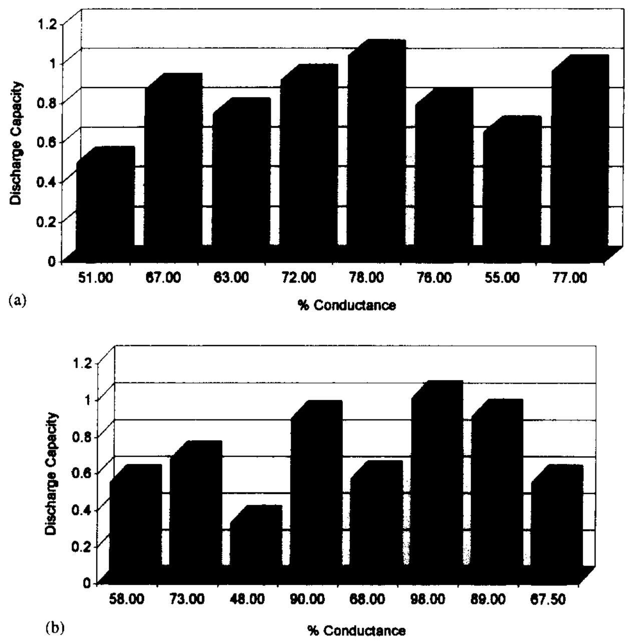

Fig. 2. Discharge capacity vs. conductance for (a) product A and (b) product B (see Fig. 1 for details).

The same data are presented as bar charts in Fig. 2 against true battery capacity. Again, conductance variations match capacity results and standard threshold

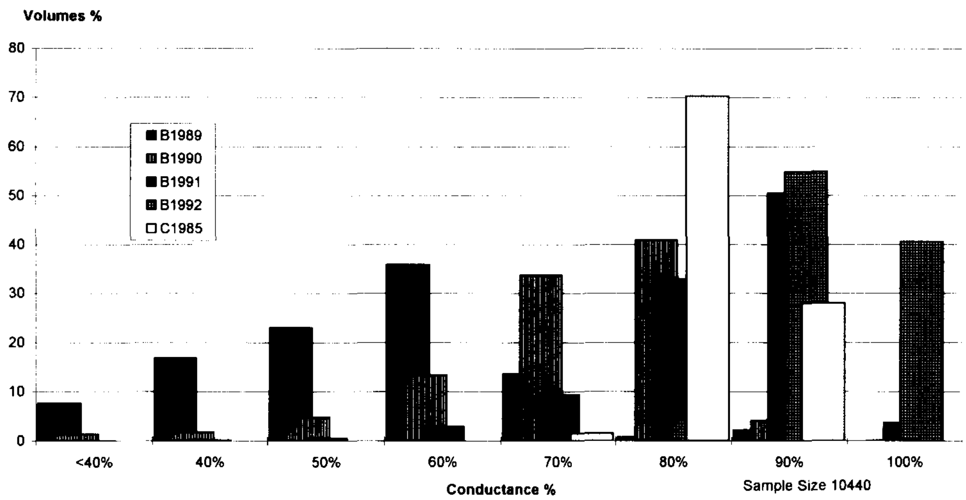

Fig. 3. Trend analysis of conductance by year/make.

indicators can be produced. This method does show the inherent inconsistency of poor quality monoblocs as they age or corrode at different rates.

Testing time per unit has been reduced considerably while, at the same time, volume testing has increased. Experience has shown that good batteries can be identified quickly and further testing is not required. Similarly, faster corrective action can be taken on the minority of poor batteries. This method has proved particularly useful when disruptions to a.c. power supplies are planned or are unavoidable.

The recommended method has been to test off-line as an additional safety precaution and to prevent distortion of the results from harmonics from the charging source. More recently, comparisons have been made between on- and off-line testing and, due to the quality of switch-mode rectifiers, little difference has been observed. Off-line testing is now acceptable for single battery installations.

5. Battery-replacement programme

An important and often neglected aspect of battery maintenance is the management of a suitable battery-replacement programme. Batteries by their very nature require periodic replacement or expensive repair. VRLA batteries are designed to be put into service for a recognized length of time with little or no maintenance, and then be replaced. Timing of the replacement is critical in preventing failures and avoiding increased costs. Careful management requires an excellent inventory database that contains critical information such as: make, age, type, location, load and, if possible, an indication of battery condition. Monitoring via conductance provides an opportunity to establish performance trends.

Data for typical conductance trends are shown in Fig. 3 for more than 10K monoblocs. In conjunction with base-line data, this demonstrates the usefulness of conductance in determining which make and year of manufacture require replacement. In the example given, two manufacturer's products have been plotted and represent good and poor characteristics. Such data are extremely valuable in tracking ageing quality. All monoblocs between <40% and 50% have very little capacity and require immediate attention. This kind of representation can be used to support smaller batch-sampling data and, added to results obtained from manufacturers' tear-down analysis, provide a much clearer picture of battery condition.

6. Conclusions

VRLA batteries have been in commercial use within BT for 10 years. Failures in some makes have caused increasing concern that has detracted from the excellent service achieved by others. Recent quality improvements, as well as new surveillance techniques, are contributing to improved performance that will reduce costs considerably as confidence in a quality product returns. Only manufacturing quality will realize the full potential of this safe and cost-effective design.

Reference

[1] D. Bernt, *Proc. 8th ERA Battery Conf., Birmingham, UK, 1994.*