STATIONARY VRLA BATTERY EVALUATIONS: INTERNAL MEASUREMENTS AND CAPACITY TEST. AN EXPERIENCE AT THE CLARO CELULLAR MOBILE COMPANY

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ABSTRACT

The Valve Regulated Lead-Acid (VRLA) battery was introduced in Brazilian's Telecommunications Companies in 1992. Today around 70% of the telecom plant in Brazil uses VRLA batteries — the remaining ones are flooded batteries — and the use of VRLA batteries will increase in the coming years. The Brazilian telecommunications market has experienced accelerated growth since 1998, when the Brazilian Telecommunications Company (Telebrás) was privatized. This increased the competition among telecom companies to disseminate services different from voice, such as data, Internet, etc. The increase in the demand for those services, together with the world energy crisis, led to a demand for high reliability telecommunications systems, along with their associated energy systems. On the other hand, Telcos suffered a drastic reduction of their technical teams. CLARO is a Cellular Mobile Company that serves several regions of Brazil. One of these areas is São Paulo, the most important city in Brazil. The VRLA battery was introduced in this Company in 1998, and the energy system of the Main Central Office in São Paulo uses forty battery banks (-48V) in parallel; all 1400Ah AGM type, manufactured in May 1998. Four years after the installation of these batteries, CLARO decided to evaluate the conductance and impedance of the batteries to determine their condition. The objective of this paper is to report the results obtained in this experience, specifically the relationship between conductance, impedance and an actual capacity test. The influences of equalize charging on the battery capacity will also be presented.

1 - INTRODUCTION

The lead-acid flooded battery, with its transparent container and liquid electrolyte, allows its maintenance through specific gravity and voltage measurements, internal visual inspection and capacity test. On the other hand, the container of the VRLA battery is not transparent (ABS plastic) and the acid is immobilized. In this type of battery it is not possible to measure the electrolyte specific gravity, or perform an internal visual inspection. The maintenance is normally done by measuring voltage and temperature. The only well-accepted technique to show the real state of the battery is the capacity test; however this test indicates only the state of the plates and of the active mass, giving no information about the degradation of internal interconnections. Besides, the full energy of the battery system is not available during the test, or during recharge. During this time period the services provided by telecom equipment are highly susceptible to AC faults [1].

Therefore, it becomes necessary to develop other techniques to perform predictive maintenance of the batteries in a short time and without the need to remove the battery from the energy system (including keeping it charged). In CPqD we have been studying the application of conductance and impedance techniques to evaluate the degree of degradation of stationary lead acid batteries since 1996. The conductance technique has become a popular technique in Brazilian telecommunications companies since 2002 [2 and 3]

The Brazilian telecommunications market has grown significantly since 1998, when the Brazilian Telecommunications Company (Telebrás) was privatized. In 1998 Brazil had about 22 million installed wirelines, and about 7.3 million cellular subscribers. In 2003 this number increased to 49 million and 46 million, respectively [4].

2 - EXPERIMENTAL

The test was conducted on two strings, each string composed of 24 cells.

The following test sequence was planned: The conductance and impedance of the batteries was measured while in operation (float voltage), following by a capacity test (four hours of discharge), with conductance and impedance measurements at the end of the discharge. Then the batteries were recharged at the equalization voltage, left to rest for four hours; and then conductance and impedance measurements were again taken. Thereafter the whole procedure was repeated. In other words, the batteries were discharged again, with conductance and impedance measurements taken at the end of the discharge; and finally, the batteries were recharged at the equalization voltage, left to rest for four hours, and then the conductance and impedance measurements were repeated.

The conductance and impedance measurements were made according to the procedure described in references 2 and 3. The battery discharge tests were performed at constant current, at the four hour discharge rate to 1.75 volts per cell, in accordance with the procedure described in NBR 14205 [5]. The equalization charge was accomplished with the voltage limit of 2.35 volts per cell and a current limit of C/4, for 15 hours.

3 - RESULTS AND DISCUSSIONS

3.1 String 1

Figure 1 shows the cell float voltage of String 1. Figures 2 and 3 show the conductance and impedance cell measurements, given as a percentage of the reference values (CRV - Conductance Reference Value, and IRV - Impedance Reference Value), and measured in each experimental condition. Figure 4 shows the average cell conductance and impedance measurements, as a percentage of the reference values, and the capacities obtained in the first and second discharges.

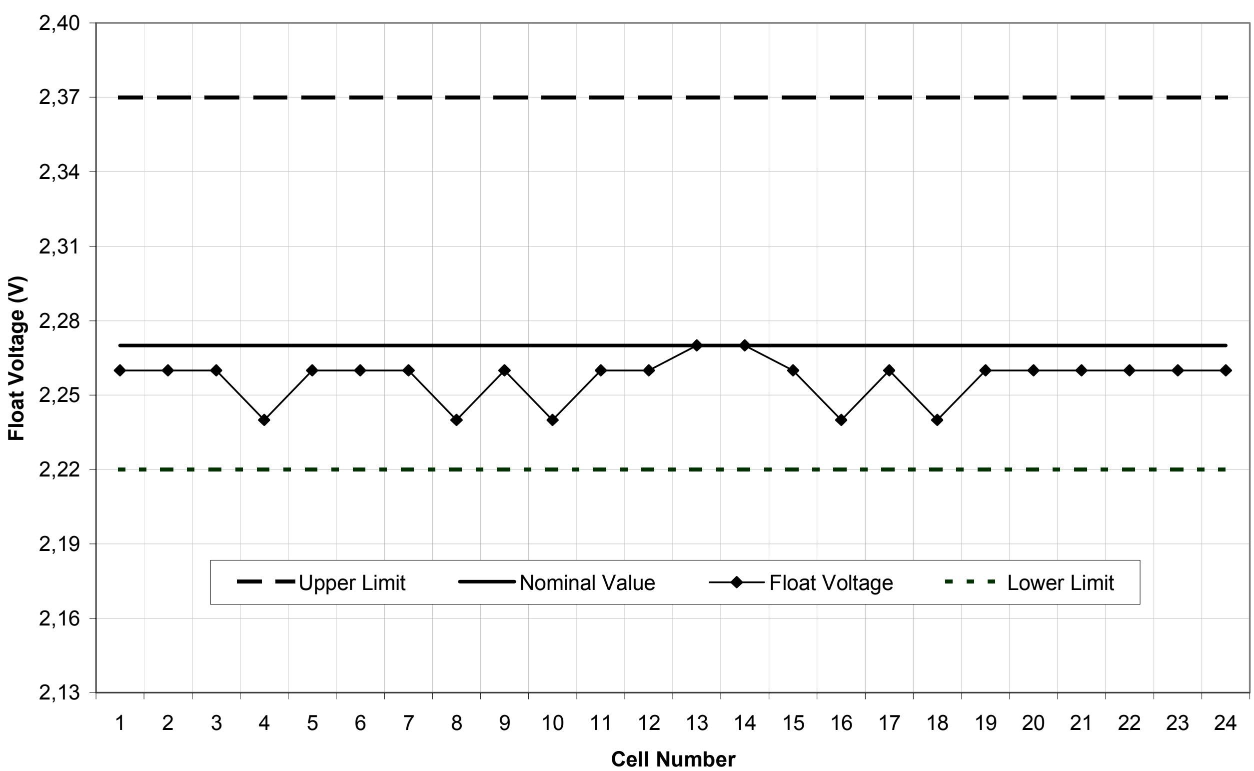

Figure 1: Cell Float Voltage - String 1

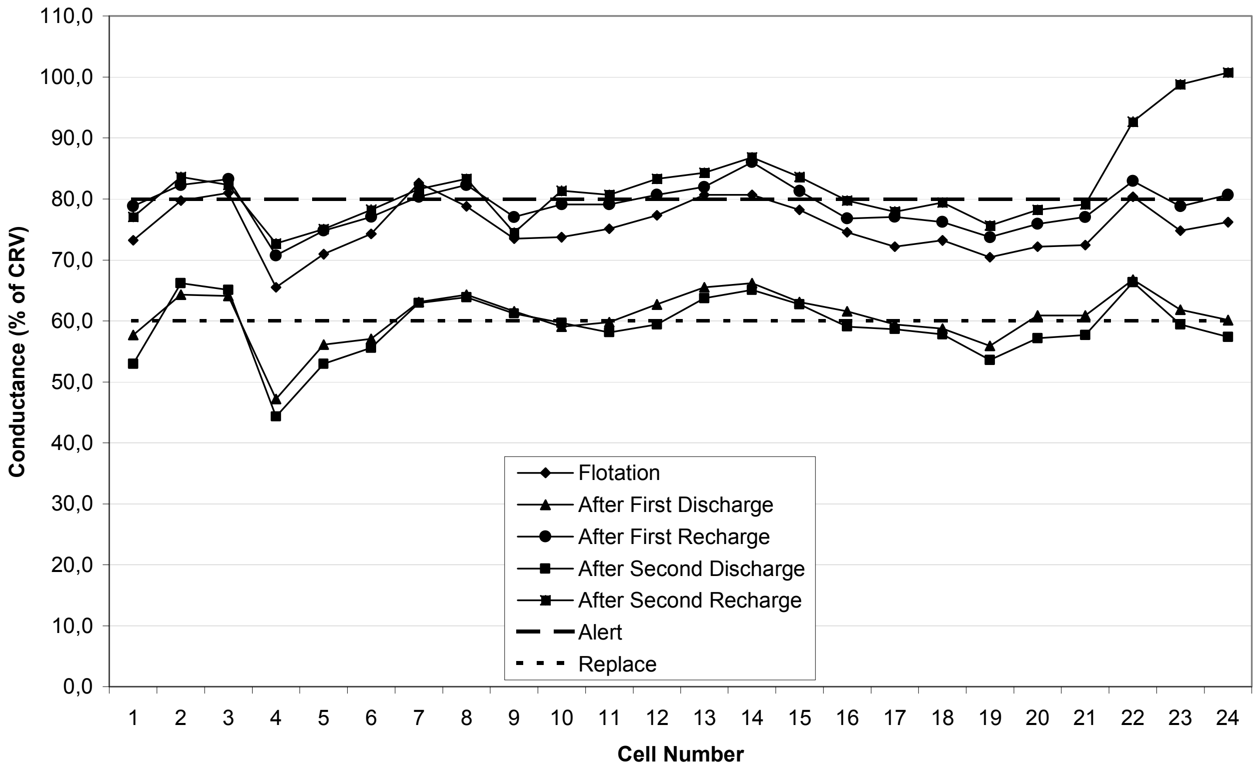

Figure 2: Conductance Measurements - String 1

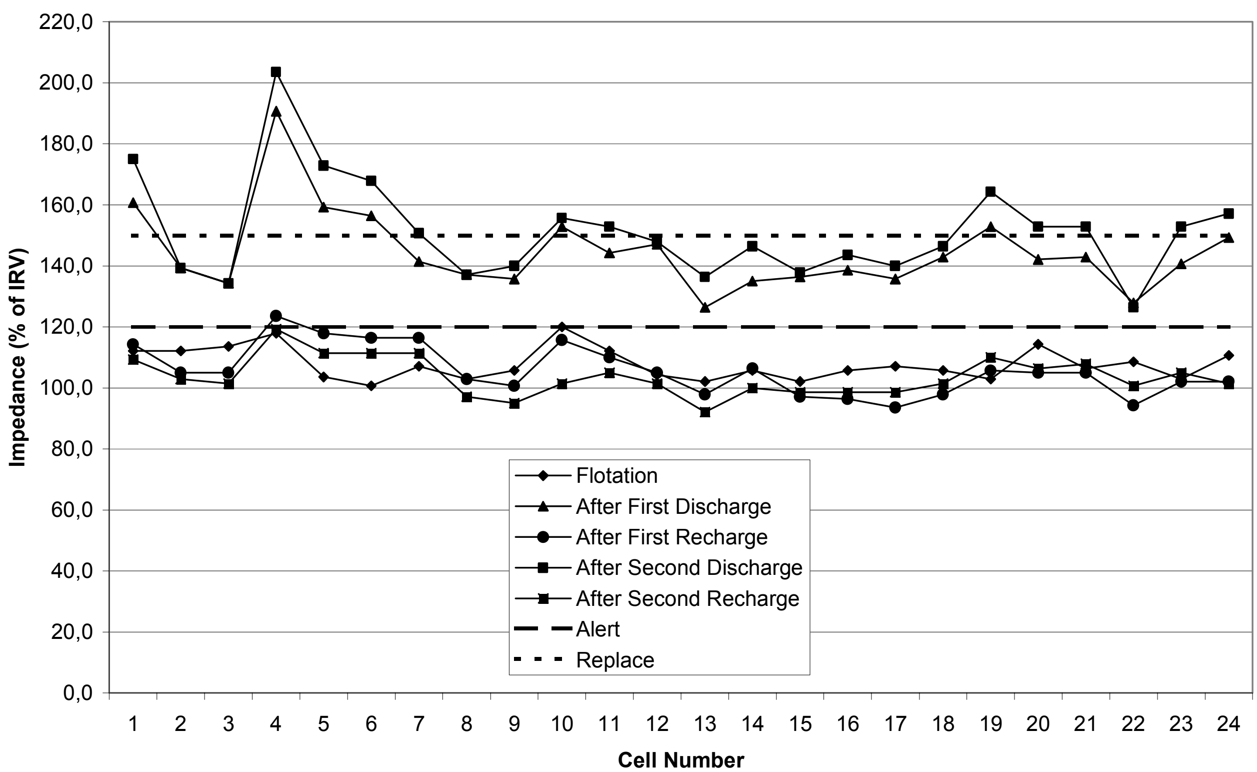

Figure 3: Impedance Measurements - String 1

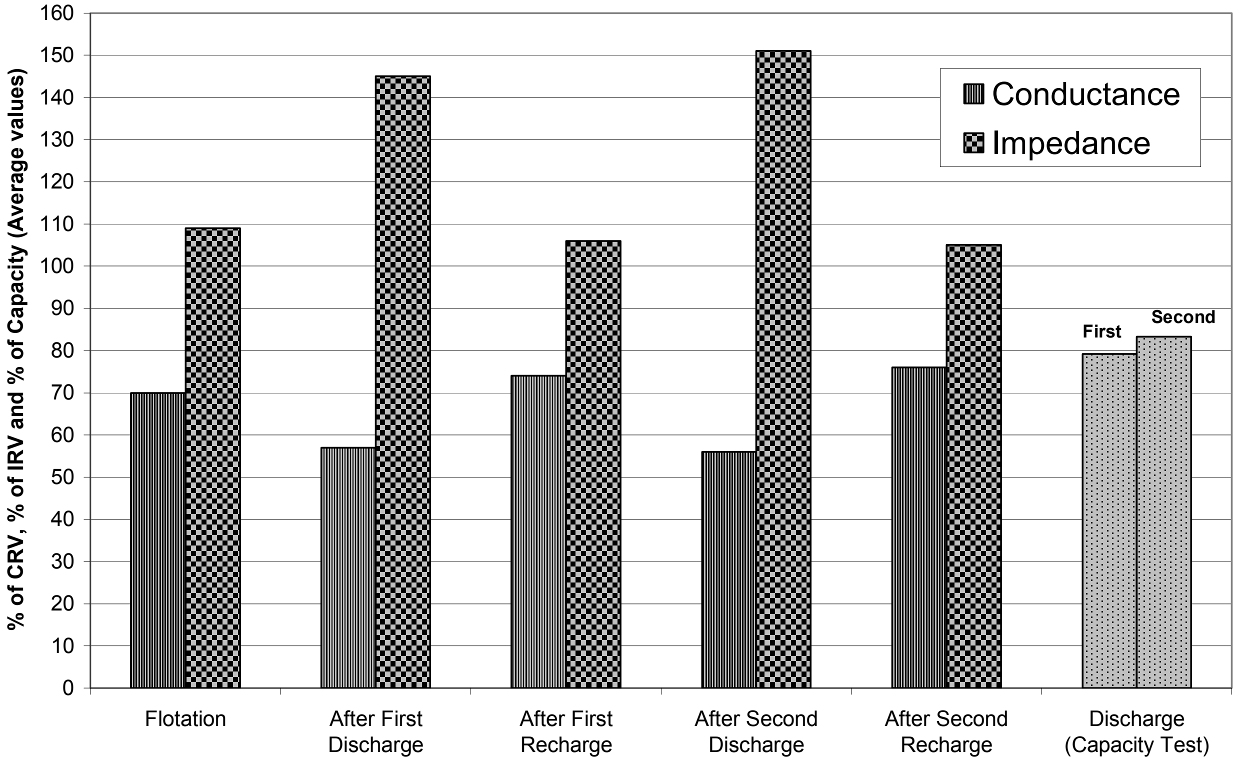

Figure 4: Conductance and Impedance Average and Capacity Test-String 1

All the cells presented voltage float values within the upper and lower limits, with a small dispersion, demonstrating a good voltage equalization (Figure 1).

In float condition the cells exhibited conductance and impedance values that were relatively stable, showing almost uniform aging (Figures 2 and 3). The cells show average conductance value of 70% of the CRV. For the impedance measurements the cells show average value of 109% of the IRV. In this condition cell number four exhibited a smaller conductance value, and a higher impedance value, than the others. In the other test conditions this cell continued to exhibit the same behavior in the conductance and impedance measurements. In the first and the second discharge, the first cell that reached the final voltage was the number four, showing then that the conductance and impedance measurements are reflecting the worst state of the negative and positive plates. So, the cell that had the least capacity also exhibited a smaller conductance and a higher impedance than the other ones.

After the first and the second discharge test, the average cell conductance was 57% of the CRV, and the average impedance was 148% of the IRV (Figures 2, 3 and 4). As expected, when the cells are discharged, there is an increase in its internal resistance, which is manifested as an increase in the impedance and a decrease in the conductance of the cells.

After the first recharge the cells showed conductance values approximately 5% higher than conductance values measured in float condition. On the other hand, the cells showed impedance values 4% smaller than the impedance measured in float condition. At the end of the second recharge the cells showed average conductance values about 3% higher than at the end of the first recharge, and average impedance values about 2% smaller than at the end of the first recharge. This indicates that after the recharge the internal resistance of the cells decreased. This fact is reflected in the result of the second discharge (capacity test), where the battery showed a capacity 5% higher than in the first discharge (Figure 4). The recharge applied higher voltage than float, probably decreasing the slow self-discharge of the negative plates of the VRLA batteries. This practice, if carefully applied, could contribute to increasing the performance of the VRLA batteries. This should be the object of a more detailed study.

In float condition the cells showed an average conductance value of 70% of the CRV; and for the impedance measurements the cells showed an average value of 109% of the IRV. After the first discharge the battery exhibited a capacity of 79%. Both ohmic measurements, conductance and impedance, weren't strictly proportional with the capacity percentage, since the capacity test evaluates only the energy stored in the plates, while the conductance and impedance measurements evaluate the degradation of all the components of the battery (plates, separators, posts, electrolyte, etc.). Thus, it is to be expected with battery aging that the conductance measurement would show a larger reduction than the capacity test.

3.2 String 2

Figure 5 show the average conductance and impedance measurements, as percentages of the reference values; and also shows the capacities obtained in the first and second discharges of the cells of String 2.

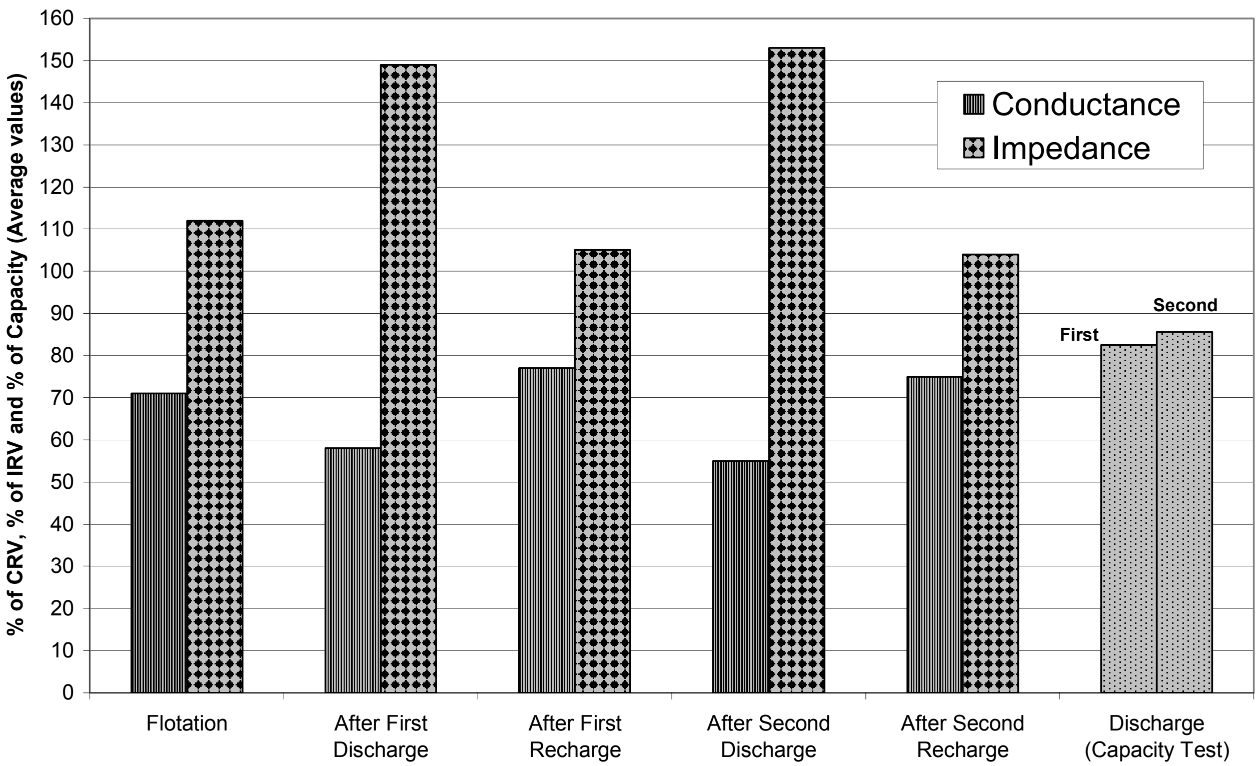

Figure 5: Conductance and Impedance Average and Capacity Test - String 2

String 2 measurement results are very similar to those of battery String 1.

In float condition the cells showed an average conductance value of 71% of the CRV; and for the impedance measurements the cells exhibited an average value of 112% of the IRV (Figure 5). Cell number twenty exhibited a smaller conductance value and a higher impedance value than the others. In the other test conditions this cell continued showing the same behavior in the conductance and impedance measurements. In the first and the second discharges, the first cell that reached the final voltage was number twenty, showing again that the conductance and impedance measurements are reflecting the worst state of the negative and the positive plates. So, the cell that exhibited the lowest capacity also exhibited the smallest conductance and the highest impedance.

After the first recharge the cells showed conductance values approximately 6% higher than the conductance values measured in float condition. On the other hand, the cells exhibited impedance values 7% smaller than the impedance measured in float condition. This indicates that after the recharge the internal resistance of the cells decreased. This fact is reflected in the results of the second discharge (capacity test), where the battery shows a capacity 3% higher than in the first discharge (Figure 5). At the end of the second recharge the cells showed similar average conductance and impedance values to those obtained at the end of the first recharge. Again, like in the String 1, the recharge applied higher voltage than float, probably decreasing the slow self-discharge of the negative plates of the VRLA batteries. This result serves only to reinforce that this practice, if carefully applied, could contribute to increased performance of the VRLA batteries.

In float condition the cells showed an average conductance value of 71% of the CRV; and for the impedance measurements the cells exhibited an average value of 112% of the IRV. In the first discharge the battery had a capacity of 82.5%. Both ohmic measurements, conductance and impedance, didn't present results strictly in proportion to the capacity percentage, since the capacity test evaluates only the stored energy in the plates, while the conductance and impedance measurements evaluate the degradation of all the components of the battery (plates, separators, posts, electrolyte, etc.). So it is to be expected that, as the battery ages, the conductance measurement will exhibit a larger reduction than the capacity test.

CONCLUSIONS

- The impedance and conductance measurements provide equivalent results.
- In general, an increase in impedance or a decrease in conductance may be correlated with a reduction in the cell capacity.
- A sudden increase in the internal resistance indicates that something inside a cell is changing, as posts/bars corrode or dry-out. Sometimes these degradations may not directly affect the cell capacity.
- A capacity test only determines the battery's capacity, but the conductance and impedance measurements have the ability to identify degradation in individual battery cells/monoblocs.
- Despite the fact that ohmic measurements cost money, it should be considered to be an important tool for battery evaluation, and a cost-effective procedure to assure the reliability of the telecommunications plants.
- Impedance and conductance tests have been demonstrated to be a good and cost-effective techniques to use in the prediction of replacement needs, avoiding unexpected faults in the DC Power System due to a lack of knowledge of the real health of the battery.
- The monitored equalizing voltage recharge probably contributed to decreasing the slow self-discharge of the negative plates of the VRLA batteries, that are normally sacrificed due to the internal oxygen cycle. This practice, if carefully applied, could contribute to increased performance of VRLA batteries. This practice should be the object of a more detailed study.

REFERENCES

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2. Rosolem, M.F.N.C; Junior, M.G.R.; and Beck, R.F.; "*Evaluation Tools for Batteries Employed in Outdoor Cabinets - An Experience of a Brazilian Telecom Company*", INTELEC 2000 - Phoenix / USA.
3. Rosolem, M.F.N.C.; Beck, R.F. and Soares, L.A.; "*Failure Detection of Stationary Lead-acid Batteries in Service in Various Regions of Brazil*", INTELEC 2002, Montreal / Canada

4 www.mc.gov.br/telecom/metas/comutado_tabi.htm - Table 1 on February 2004, Brazil

5 "*NBR 14205 - Valve Regulated Lead-Acid Batteries - Procedure*" emission September 2002, Brazil