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CONSEIL INTERNATIONAL DES GRANDS RÉSEAUX ÉLECTRIQUES
INTERNATIONAL COUNCIL ON LARGE ELECTRIC SYSTEMS

STUDY COMMITTEE D2
INFORMATION SYSTEMS AND TELECOMMUNICATION

2013 Colloquium
November 13 to 15, 2013
Mysore - KARNATAKA – INDIA

Is the stationary lithium-ion battery a good choice for the Telecommunications in an Electric Power Utility?

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SUMMARY

Many of the telecom systems used by the companies of the electric sector are critical and impact directly in the main business being indispensable that the processes and technological systems associated to these systems operate with no interruption. Occurs though that significant part of the unavailability registered in telecom is caused by the power systems associated.

It's observed that a factor that contributes to this situation is the fact of these systems act as backup, so it's imperceptible for those that aren't involved directly with them. This lack of visibility makes hidden problems which can become systemic because these systems permeate all the telecom structure. This scenario may be observed nowadays concerning the reliability and durability of a specific kind of batteries which has dominant presence in this area.

Trying to finish with this problem the Eletrobras FURNAS is searching for alternative batteries and for that has been searching, together to CPqD – *Fundação Centro de Pesquisa e Desenvolvimento em Telecomunicações* (Center of Research and Development in Telecom Foundation), the lithium-ion technology for stationary batteries.

This paper presents this new technology, as well as some of the obtained results.

KEYWORDS

Lithium-ion batteries, telecom, reliability, durability, VRLA batteries.

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1.0 - INTRODUCTION

In Brazil, the lead-acid battery is still the most utilized in stationary applications which need operate even in failure situations in the power supply, case of many companies of the electric sector.

With the introduction of the valve regulated lead-acid battery, were observed changes of paradigm even by the planners and the maintenance responsible people. By the point of view of the project, the fact of the batteries emits gases in a very low amount (due to the regulation made by the valve) allow them to be located near the load. As to the maintenance, it was claimed that would have a reduction in the costs since there wouldn't have water replacement. Nowadays this technology is very popular in Brazil and virtually dominates the telecom segment in the electric sector.

Occurs, however, that in the last passing years, is observed an increase of insecurity in the use of this kind of product, specially due to the feeling that the reliability and durability have not been showing appropriate to the matter of some critical systems.

Sensible and suffering with this problem, Eletrobras FURNAS has been improving its maintenance technics, but also is attentive to new technologies which might replace technique and economically the VRLA batteries. Decided to investigate then the use of stationary lithium-ion batteries and for that developed a R&D project joint to CPqD.

2.0 - MOTIVATION

Due the low maintenance characteristics, the backup systems most used on Telecommunications in Brazil are based on VRLA (Valve Regulated Lead-Acid) batteries. However in recent years the number of problems in these systems in Brazil are increasing, perhaps due to the great dependence on quality in manufacturing processes and materials used, especially when talking about the presence of impurities.

This situation forced Eletrobras Furnas to adopt expensive maintenance techniques based on conductance measurements [1], since there is no way to make visual inspections because the vessels are not transparent and the electrolyte is immobilized.

This technique is based on the concept that the aging of a VRLA battery is characterized by slow and homogeneous reduction of conductance values of its cells. When this behavior is not observed, it is considered that there is problem to be investigated.

For example, in Eletrobras Furnas´ headquarters, about 80% of VRLA batteries purchased in the last five years had some type of problem. In Figure 1 can be seen the batteries mentioned. On the far right of the photo can be seen a cabinet with a lithium-ion battery in field test. In Figure 2 can be seen a conductance measurement. In this example there are 24 time series (corresponding to 24 cells). For simplicity each set contains only nine measurements.

The first measurement was taken on October 1, 2007 and is being used as a conductance reference value (CRV = 100%). For subsequent measurements it is observed that the conductance reduction does not occur slowly and evenly as would be expected. On February 24, 2010, date of last measurement, the situation was considered critical and all the cells that had conductance less than 80% of CRV have been replaced. Capacity tests confirmed the premature degradation of these cells.

The VRLA batteries are designed for 10 years of lifetime, so we can notice how this degradation is accelerated. It's aggravating the fact that once identified this pattern, the maintenance costs begin to rise dramatically due to the need to reduce the measurement intervals. The default interval is four months in the beginning of life but can be reduced to fortnightly measurements, when the situation is critical.

Inspections in batteries with 24 cells take only 40 minutes, but the time spent with the preparation/movement of staff and consolidation/analysis of data collected is high. Furthermore there are operational risks and organizational costs inherent in such activities as obtaining permissions to intervene on energized equipment with critical load.

Figure 1: Comparative Overview: Backup systems with VRLA batteries and lithium-ion Experiment indicated by the red arrow on the far right (Photo: Alexandre Pinhel)

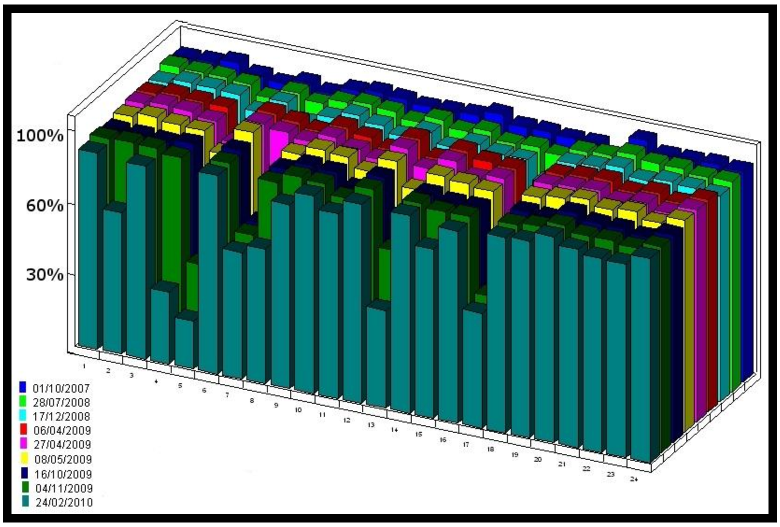

Figure 2: Graph of conductance of a VRLA battery with 24 cells

The fact that not all batteries have problems proves that this phenomenon is not due to equipment, infrastructure or human error, suggesting that this is a systemic phenomenon perhaps related to the quality of products. This perception is shared by other maintenance teams of Eletrobras Furnas and others Eletrobras' companies.

More serious than the financial loss due to the costs of maintenance and acquisition of material is the issue of reducing the reliability of telecommunications systems. As seen, loss of important information could compromise the integrity of the Brazilian National Grid causing social disorders besides generating heavy fines.
The company has mastered the technique of predictive maintenance mentioned, but this does not guarantee the reliability required. We have also tried to improve the purchasing specifications. Such action could result in better products, but has its limitations, especially in companies subject to public bidding rules. Now the adoption of new technology can solve the issue, but carries the risk of newness and usually has a high cost. This line of action should be undertaken with great support of research, as presented here for the case of lithium-ion batteries.

The gain in reliability is a great motivator, but the costs involved justify the economic analysis. The initial investment in VRLA batteries is about three times smaller, but when analyzed in total expenditure over the lifetime, the lithium-ion batteries become more attractive, especially in regimes of high temperatures [2].

3.0 - THE LITHIUM-ION BATTERY

The researching about lithium batteries started in 1912, but just in the 70's was obtained commercially viable, but its applications were with military and aerospace purposes. Just in the 90's, with the popularization of the mobile application, especially mobile microcomputers and mobile phones, they earned the global market and since 2002 there are rechargeable lithium-ion batteries for stationary applications [3].

The technical literature available argues that this kind of battery provides advantages both in projecting matter and maintenance, by these following reasons:

1. The existing lithium-ion batteries nowadays present one third of the volume and one fifth of the weight compared with lead batteries with equivalent capacity, this quite reduces the space required for its installation.

2. There are no electrolyte reposition or gases emissions, what reduces maintenance costs and allows installation in almost any place.

3. The lithium-ion batteries can be stored and operated in a broad temperature band, what simplifies hugely matters related to acclimatization of the batteries' rooms.

4. Most of the lithium-ion batteries can be stored turned off and with no acclimatization for 10 to 20 years without a significant loss of its nominal capacity. This feature, together to the low dimensions of the elements, simplifies hugely matters related with the spare management.

5. When compared to more metals commonly used in batteries, as lead, nickel and cadmium, the lithium is less aggressive to the environment what agrees with the ecological and social objectives which Eletrobras FURNAS has been taking.

This R&D enterprise tried to verify the statements above in a way that the company could set an action line to adopt this technology. For that was developed a non destructive test protocol that comprises matters of functionality, electric performance and, specially, safety. As far as possible the tests where based in international ruling standard, but have been developed specific tests for use in the telecom electric sector scenario.

4.0 - TECHNOLOGICAL FUNDAMENTALS

Despite the characteristics inherently superior related to the energy density (up to 4 times than an equivalent VRLA), recharging speed, partial charge state and life time operating, the lithium-ion battery is less safe in its operation [4]. This is due to its materials' composition is less stable front of overcharge, overdischarge, short-circuit and elevated temperature.

This disadvantage about the safety was attacked by the manufacturer with the development of a refined electronic control which, while implements features that an electrochemical energy accumulator needs to present, creates new paradigms for operation and maintenance. This electronic control is called Battery Management System (BMS).

The BMS inputs the operational parameters of the lithium-ion by adding safety features and ease in the operation avoiding the continuity of the charge process when the battery still presents the full charge voltage, avoiding then the battery collapse and posterior explosion, which would be disastrous because in stationary applications for telecom the nominal voltage is 48V and the battery can offer a very high energy amount.

It uses two different systems. The primary is soldered directly in the terminals of the electrochemical cell. Its function is limit the charging and discharging current in the cell. The secondary is more refined and adds, further the functions of protection and voltage monitoring, state of charge (SoC) and minimum energy level in the cell, among others parameters.

There is too a robust protection system against accidental short-circuit. This protection avoids that the sample, after being discharged, presents open circuit voltage (OCV) in its terminals the battery goes into a state that the manufacturers call “sleep” and it’s necessary a voltage source with a minimum voltage of 56V (charging voltage) in its terminals for it to work again (in this case, it’s only possible the recharging operation).

Still inside a protection logic it prevents abuse and doesn’t allow changes in its devices by the operator, for example, it isn’t possible to turn off the internal current limiter. The operator uses the BMS in a passive way, without the possibility of changes in its electrical parameters. All these aspects must be and were considered in the development of an tests protocol.

5.0 - METHODOLOGY

It was made a research in the market for manufacturers that could provide samples still in the pre-commercial stage, i.e., with product’s characteristics. Inside the search were selected two manufacturers that presented models of 48V for telecom applications. The capacities of the samples are 42Ah for the manufacturer henceforth called “A” and 100Ah for the manufacturer called here as “B”.

For the Project were acquired 4 samples by the manufacturer A, all of them the same model (48V, 42Ah) and 10 samples of the manufacturer B (48V, 100Ah), all of them the same model too.

The battery of the manufacturer A is composed of a group of thirteen cells of 42Ah connected in serial. The battery of the manufacturer B is composed of four groups of cells connected in serial, each of them formed by a group of cells connected in parallel in order to achieve the nominal capacity of 100Ah. The internal settings and the cell dimensions as well as the active material of the positive board of these batteries present different compositions, making some comparisons difficult to be made, but allowing the evaluation of two different evaluations quite distinct about arranges for lithium-ion batteries.

The base to analyze the performance of this technology started of an international normative survey, with establishment of test procedures and methodology, as well as safety requirements for operation, both in laboratory and field conditions. By this survey was chosen the standard Telcordia GR-3150-CORE “Generic requirements for secondary non-aqueous lithium batteries”, published in June 2007 [5].

This standard specifies requirements for three compliances levels, which present differences of severity about performance and security, being that some destructive tests were adapted and/or discarded, in agree with the real environmental and operational conditions that were provided in the Project scope, especially about the field operation. The table 1 synthetizes some technical features of the samples, as well as some operating parameters.

Table 1: Technical features of the lithium-ion batteries models.

Parameter	Manufacturer	
	A	B
Capacity	42 Ah	100 Ah
Charge		
- Voltage	56,00 V	56,40 V
- Maximum current	5,00 A	5,00 A
- Maximum time	21 hs	24 hs
Discharge		
- C4 current	10,50 A	24,10 A
- C8 current	5,25 A	12,50 A
- C24 current	1,75 A	4,10 A
- Maximum current	90,00 A (25 min)	38,00 A (2,5 hs)
- End voltage	42,00 V	42,00 V

6.0 - TEST PROTOCOL

As the adopted standard (GR-3150) doesn't describe some relevant tests for the interested scenario usage, some new procedures had to be developed. At the bottom of the figure 3 can be seen the batteries in an arrangement of test conducted at the laboratories of CPqD. In the Table 2 can be seen the tests that are detailed below.

The samples were submitted to typical capacity tests in the schemes of 4, 8 and 24 hours, as well as recharges which followed the manufacturer's orientation about voltage, duration and current. In the safety tests, the samples were submitted to overdischarge, overcharge, polarity inversion and external short-circuit tests.

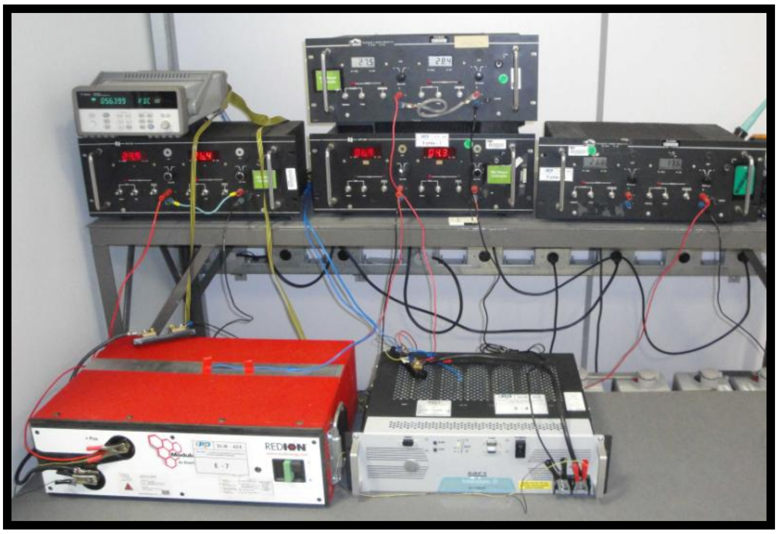

Figure 3: Tests on lithium-ion batteries in the laboratories of CPqD (Photo: Alexandre Pinhel)

Table 2: Test group for evaluation of lithium-ion batteries

Tests		Manufacturer	
		A	B
1	Residual capacity	Not realized	10 samples
2	Capacity	4 samples	10 samples
3	Safety	4 samples	10 samples
4	End discharge voltage	4 samples	10 samples
5	Recharge length	2 samples	2 samples
6	Cycling	2 samples	6 samples
7	Autodischarge	1 samples	1 samples
8	Operational tests in field	2 samples	2 samples

6.1 Residual capacity

The samples were sent by the manufacturers from distinct countries (France for the A manufacturer e USA for the manufacturer B) and were kept in the Rio de Janeiro's port for 6 months (totalizing about 10 months between sending, trip and storage).

When the samples were discharged in a 8 hours regime with the objective of evaluate the residual power quantity later the storage period. These data allowed an evaluation of the integrity conditions of the batteries' operation.

About the Manufacturer B's sample, all the samples suffered a residual discharge and the remaining power was evaluated according to the hours of power supply. In the manufacturer A's samples, it wasn't possible the execution of this test, because these stayed for a longer storage time while the Manufacturer B's ones were being tested. This fact became a problem, because according to the manufacturer's recommendations, the batteries couldn't achieve minimum state level of charge (which is achieved due to the autodischarge). When this level was achieved, a partial recharge should be applied so that the battery remained in an appropriate power lever for storage. Once this procedure had to be made, it wasn't possible anymore to verify the residual power on these samples.

6.2 Capacity

The charging conditions followed the manufacturers' recommendation, being applied in both samples the 5A limit for the charging current. The specified recharging voltage is 56,00V for manufacturer A and 56,40 for the manufacturer B. It is worth noting that for this technology doesn't apply different charging or floating voltage (as used in the lead-acid and alkaline batteries), because they operate in just one voltage.

The discharge was made with constant current, in the value adjusted according to the selected regime (C4, C8 e C24). As specified in the adopted standard, the final discharging voltage is 42,00V.

After the discharge, the samples entered in a sleep state and the BMS cuts the voltage in the battery terminals. This fact caused a trouble because, as a matter of safety, without voltage visualization in its terminals, the testing equipment automatically doesn't send the charging command. The procedure adopted was "waking up" the battery with an auxiliary DC power supply adjusted to the charging voltage during thereabout 6 seconds. After the battery "perceive" the auxiliary power supply voltage, it becomes to present on its terminals the open circuit voltage and gets ready to be recharged. As mentioned, this behavior is due to the BMS acting and is identical in the 2 manufacturers, having as an objective avoid the battery to get the condition of deep discharge, besides the safety aspects to avoid short-circuit. With the action of this device, at the end of each discharge was necessary to operate the DC power supply manually to allow the open circuit voltage measurement and the charging process restart.

6.3 Safety

Some safety tests defined in the adopted standard were not realized by having been considered excessive for the researching purpose. As an example of the procedures which were discarded there is a firing test in which the battery must be put above a container filled with 2 liters of methanol and put in ignition. Another test previews that the sample suffers freefell from a height of 9 meters. The adopted procedures are described below and were considered enough for a good evaluation of the battery safety.

The safety tests contemplate overcharge, overdischarge, polarity inversion and external short circuit. For the test achievement different setup was assembled, composed by a data acquisition system, cycle counter, contactor switch (for the polarity inversion test), adjustable resistive load, programmable dynamic load, shunt, DC power supply and knife switch (for the short circuit test). The data acquisition system monitors and stores the voltage values, current and temperature measured in the test course and, if the battery temperature exceeds 50ºC, the charging or discharging process is interrupted, protecting the sample.

For the safety tests the samples were submitted to the 24hs complementary charge in order to guarantee the full charge state. This procedure was necessary because, after a certain period stored, some samples already presented a state of charge less than 95% (due to the auto discharge effect) and, according to the adopted standard, before to start the overdischarge test the sample must present a state of charge higher than 95%.

In the overcharge test the battery must stay 24 hours connected to a resistive charge projected to the starting discharge current be equal to the C4 regime value. This test evaluate the BMS protection performance when the battery, providing current, reaches its end discharge voltage, promoting the power supply interruption and protecting the battery of a deep discharge occurrence, that causes irreversible electrochemical damage. After this discharge the battery must be recharged and, after that, submitted to a discharge in the maximum current regime.

After the overdischarge the battery is recharged until the full charge condition and, after that, is realized a new capacity test in the C4 regime to verify if occurred any change in the battery functionality. According to the adopted standard, the safety tests always must be interspersed with a capacity test in C4 regime. It was realized a discharge test in the C4 regime in just one sample from each manufacturer. In the remaining samples the discharge was realized using the maximum discharge value.

In the overcharge test was applied, during 24 hours, a 60V voltage between the poles. After that were executed discharge tests in the C4 regime to verify the battery integrity. The short-circuit and polarity inversion tests as were realized in factory and due to the risk analysis of BMS damage, they will be remade at the end of the research. Must be emphasized that it doesn't exist equivalent tests to these for VRLA batteries and they seek confer the BMS performance against these extreme conditions. These tests make clear the enormous safety requirements currently in vigor for the stationary application lithium-ion battery.

6.4 End discharge voltage

The samples must achieve by the adopted standard an end discharge voltage value which fits especially the telecom infrastructure already established. On the other hand, the BMS doesn't allow that any cell reach a critical low voltage level for total voltage attendance of 42V (cut value for telecom equipments). The critical low voltage level (or lower than it) damages permanently the lithium-ion electrochemical cell compromising the performance of the group and might damage, in some cases, destructive processes in the whole battery.

The test aims therefore the verifying of the occurrence of this situation and the attendance to a commitment solution between operate properly with the telecom infrastructure and the protection against damage both in the individual cell and in the group.

At the end of each discharge of the capacity tests the final discharge voltage was registered with the objective of investigate the working logic of the BMS. In many cases the end voltage didn't reach 42V because the BMS acted protecting an individual cell avoiding it to reach the critical low voltage level, that'd cause an irreversible damage in this cell, compromising all the group.

6.5 Recharging time

This test verifies what's the maximum charging current that the battery supports, how the BMS acts against abusive currents and what are the effects in the batteries after the absorption of elevated current values.

This procedure is necessary because in the present telecom DC systems, the rectifier can provide elevated current for the power storage system recharging. The safety behavior of the lithium-ion batteries must be prepared to the cell protection and so avoid permanent damages to the storage system collapse. The safety behavior of the lithium-ion battery must be prepared to the lithium-ion cell protection and avoid permanent damages to them as well as avoid accidents with the whole power storage system collapse.

For safety matters, both studied manufacturers recommend recharge using a 5A current, this implies in long delay to return to normal conditions. Despite this recommendation, timely are realized tests with higher current values once this topic is much important because in critical application like the electric sector, is desirable that the batteries return to a nominal state as soon as possible.

6.6 Cycling

This test verified the battery usage. The samples were charged and discharged 200 times and kept capacity greater than 90%. In this application it is considered that 30 discharges is equivalent to ten years of operation. By this criterion the battery life would surpass 60 years but this reasoning applies only to degradation due to operation, not taking into account the natural aging of the electrochemical cells and the electronics failures, which are random [6].

6.7 Autodischarge

The autodischarge effects can take the battery to a critical low voltage level in the cell. The occurrence of this critical level causes permanent effects in the battery and reduces its reliability when put in use.

This parameter evaluation allows the definition of a maintenance protocol for periodic recharges when the battery is stored. The results of this test will format a verifying routine which will allow the increase of the battery's lifetime. This routine will consist of a periodic recharge aiming not to achieve the minimum voltage level.

6.8 Operational Field tests

Besides the adopted tests of the standard GR-3150, were defined specific tests to verify the adequacy to the interested scenario, i.e., Telecom in the Electric Sector. These tests are provided to be realized after validation of the technology about its electric operation and safety aspects. These tests try to evaluate:

- The possibility of high current recharge in non-controlled situations.
- The operability of the batteries working in parallel to others of the same model.
- The operability of the batteries working in parallel to VRLA batteries.
- The maximum discharging current allowed.
- The possibility of determinate the batteries' capacity through the open circuit measurement.

7.0 - RESULTS

The recharges applied in the lithium-ion batteries are made with limited voltage and current values. In the manufacturer B, the observed voltage in the batteries' terminals increases slowly due to DC supply current limitation, and reaches the limit value in around 20 hours. In this period the current value remains constant in the limitation value, and from this point decreases slowly.

The Manufacturer A has a slightly different behavior, the voltage of the battery's terminals quickly reaches the limit value, but the current doesn't keep constant, starts with the battery demanding a value near to the limit and slowly decreases during about 16 hours of charge, when the current increases again to a value near to the limit and slowly decreases to the half during the next 3 hours, when the battery itself finish the charging process. It was observed that the testing equipment measures voltage/current in the battery's terminals, while the BMS measures the behavior of the electrochemical cells, showing that the charging process programming of this battery is internally controlled by the BMS.

In the discharge curves was observed that the voltage decreasing is too slow, presenting an abrupt fall just when the power fatigue of the battery, taking to its switch off by the BMS. In other word, these batteries present a voltage landing with low variation during its discharge, allowing the supply of a high power quantity almost constant in the whole autonomy time. This is another differential characteristic of the lithium-ion technology related to the alkaline and lead-acid batteries.

It's noted too that in the 4 hours regime (C4) the 2 samples presented capacity slightly higher than 100% of the nominal value. In the 8 hours regime (C8) the batteries presented capacity of 87,5% (manufacturer A) and 95% (manufacturer B), lower than 100% of the value in this discharging regime. Probably the capacity in this discharging regime needs to be better defined by the manufacturers, once that this technology is in development phase.

The manufacturer B's samples finished the discharge before to achieve the final voltage 42V, cause probably one or more cells that compound the group to form this battery achieved the individual voltage limit of discharge of 2,5V. In this situation, despite the battery not to achieve the final voltage 42V, the BMS, to protect the cell, acted and interrupted the discharge.

Through the balance and integration of the power quantity furnished/removed (Ah) during the charges and discharges, was observed that the recharging efficiency of the lithium-ion battery is around 90 to 98%, differently of the lead-acid and alkaline batteries, which is around 70 to 80%.

Overcharge tests confirmed the strength of the safety furnished by the BMS against possible high voltages unduly applied in the poles. The overcharge tests confirmed the capacity data furnished by the manufacturers but, besides the laboratorial already realized, will be made operational field tests to verify the maximum capacity of current supply, information that can influence in the future systems dimensioning. After the risk analysis about the possibility of damage in the BMS, the short-circuit and polarity inversion tests will be realized in the end of the research.

8.0 - DIVULGATION AND STANDARDIZATION

These results provided knowledge and confidence to prepare a purchase specification for operational deployment. In November 2011 Eletrobras Furnas made the first Brazilian bidding for this type of equipment making this technology a reality in Brazil (Figures 4 and 5). This bidding caused interest in about 20 companies.

Figures 4 and 5: Tests on lithium-ion batteries in the factory and final installation in the company
(Photos: Alexandre Pinhel)

The recognition obtained with this research enabled the company to take over the coordination of standardization work of the Brazilian Association of Technical Standards (ABNT) by the Brazilian Committee of Electricity, Electronics, Lighting and Telecommunications (COBEI).

The first Brazilian standard is called "lithium-ion accumulator for use in stationary 48DC - Specification". This document establishes the minimum requirements necessary for this type of battery and was published in March 2013. It will be used in preparing the standards of the National Telecommunications Agency (ANATEL) increasing the use of this technology in Brazil.

As a continuation of this standardization work, is in progress the development of the standard "lithium-ion accumulator for use in stationary 48DC - Test methods". This document details the test procedures established as required by the standard referred to above.

The next step is starting the tests of this technology in the substations and power plants in the 125DC class voltage.

9.0 - ENVIRONMENT

Lead is a harmful element and its exploration and uses are environmentally aggressive and causes bad effects in human health [7]. This negative scenario explains the removal of lead from various technological applications, currently leaving a few exceptions. The most significant of these is the lead-acid battery and this is due to the lack of economically viable alternative.

This environmental aggressiveness is partially reduced by the reintroduction of lead in their supply chains. This is particularly noticed in the industry of lead-acid batteries. The recycling in Brazil is around 95% of the total lead-acid batteries used.

As an example, in 2011 the five largest Brazilian producers of stationary batteries put into circulation about 5,000 tons of lead, generating about 250 tons of waste destined for landfills. In addition to care with the lead, the sulfuric acid, which is the electrolyte is also treated and generates environmental liabilities.

The lithium-ion batteries are fully recycled through various techniques, mainly by melting and refining [8], with no significant environmental liabilities. It is not yet economically viable the reuse of lithium in the manufacture of lithium batteries, but the recycling process gets aggregate material with aluminum for use in the cement and ceramics industry (Figure 6). The copper, nickel, cobalt and iron are refined and recycled (Figure 7).

This environmental advantage will become more visible when the stationary lithium-ion batteries begin to be produced in large scale.

Figures 6 and 7: Al-Li aggregate used in cement and ceramics industry and Cu-Co-Fe-Ni alloy for refining and reuse in the lithium-ion batteries industry (Photos: Alexandre Pinhel - Material provided by SAFT / Umicore - Real Size)

10.0 - CONCLUSIONS

The lithium-ion battery for stationary application needs a complex electronic system to satisfy its function with the minimum explosion risks and permanent damages, what would impact its capacity and lifetime. The presence of this system interferes in the elaboration and execution of testing procedures such that, to realize them, is needed to know deeply the battery working.

Despite all the electronic embedded, these devices are still considered batteries, knowing that they need to supply power in failing situations on the primary supply. So all the common tests must be applied, but considering the possible interferences caused by the intrinsic supervision systems (BMS), without the perfect comprehension of this scenario, we can't realize tests that generate conclusive results.

Despite the batteries present specificities about its operation and performance, the questions which involve protection present similar aspects. Some difficulties found point that the technology still needs maturation, but the preliminary results showed that there is potentiality in the stationary application and that the crucial fact for its effective adoption is the BMS reliability.

If adopted as an alternative to the VRLA battery, the lithium-ion battery will change significantly the maintenance procedures and operation doing the companies to review many concepts. Considering what was studied, these batteries should be threatened as electronic equipment and not as an electrochemical devices. This change will bring changes in the maintenance plans and will need specialized training but the benefits, especially about reliability and durability, look justify fully this way.

The overcharge tests confirmed the high capacity of these batteries, but the time to recharge them following the manufacturer's recommendation is too long once that the current can't exceed 5A. Despite considering positive the high worry with the safety by the manufacturers in this matter, in the future will be made tests to verify the maximum current to realize a safe charge. If not possible recharge these batteries in a shorter period of time, the dimensioning of the Project should consider this aspect.

The next step of this Project is the operational validation of the technology. For that will be implanted 2 testing sites in the Eletrobras FURNAS, in the Rio de Janeiro where will be realized the tests described in the item 5.8.

Finally, another result of the researching that deserves to be mentioned is the start of the normative about this subject in the Brazilian technical standards association (*Associação Brasileira de Normas Técnicas – ABNT).* It's expected with that, promote debates in the society, creating a demand and stimulating improvements by the manufacturers, contributing with price reduction and creating a sustainable cycle to consolidate the use of this technology in Brazil.

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