ENABLING RENEWABLE ENERGY TRANSMISSION – ADVANCED LEAD CARBON ENERGY STORAGE SYSTEM FOR TRANSMISSION UTILIZATION IMPROVEMENT

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ABSTRACT

Advanced Lead Carbon Energy Storage Systems (ALCESS) are particularly well suited for increasing renewable energy transmission in the electric grid. In general, congestion on the grid limits the flow of low marginal cost renewable generation to load. Reducing congestion at transmission bottlenecks is the most effective way of improving flows of low-cost renewable generation to urban areas. In this application, the ALCESS is located at a congestion point to provide back-up energy storage during a contingency event, thereby allowing the congestion point's post-contingent limit to be increased by the capacity of the energy storage system. While the ALCESS is only deployed periodically, during a contingency, it allows the system operators to utilize a greater fraction of the congestion point's transmission capacity – thereby reducing congestion at that location and facilitating the flow of low marginal cost renewable generation.

Keywords: energy storage, advanced lead carbon, VRLA, transmission utilization

INTRODUCTION

The traditional role of lead-acid batteries in stationary applications has been primarily to provide backup power and, depending on location, power conditioning. In a typical application, the actual use (discharge) of the battery is fairly infrequent and it remains on float charge for the majority of its service life.

However, the use of energy storage in large grid-scale systems is more similar to some cycling applications with repeated charge/discharge operation. In these applications, the traditional standby technologies perform poorly compared to other energy storage systems. Even lead-acid batteries designed for cycling applications do not perform as well as alternative technologies without sizing the systems to such an extent or reducing the expected service life to such a level that the primary advantage, cost, almost reaches parity with other solutions.

With the development of lead carbon technology for commercial products, many of the performance limitations of traditional lead-acid systems have been reduced or eliminated. The ability of lead carbon batteries to operate in a partial state of charge (PSoC) and the stabilizing effect the technology has on the electrodes in cycling without increasing cost has increased the application possibilities for these systems.

Advanced Lead Carbon Energy Storage Systems (ALCESS) are particularly well suited for increasing renewable energy transmission in the electric grid. In general, congestion on the grid limits the flow of low marginal cost renewable generation to load. Reducing congestion at transmission bottlenecks is the most effective way of improving flows of low-cost renewable generation to urban areas.

In this application, the ALCESS is located at a congestion point to provide backup energy storage during a contingency event, thereby allowing the congestion point's post-contingent limit to be increased by the capacity of the energy storage system. While the ALCESS is only deployed periodically, during a contingency, it allows the system operators to utilize a greater fraction of the congestion point's transmission capacity – thereby reducing congestion at that location and facilitating the flow of low marginal cost renewable generation. The system can also provide contingent reserve power, peak price sales, and other market functions to further offset the capital cost of the system.

The main performance benefits of an ALCESS in this application are low relative cost, scalability, system mobility, and reliability, in terms of service life as a significant portion of the system is based upon mature technology.

LEAD CARBON TECHNOLOGY

In a typical standby power application, the primary failure mode is the degradation of the positive electrode due to corrosion. However, in the applications described in this proposal, with the additional requirements of high cycle life, possibly at temperature, and PSoC operation, the primary failure mode is found in the negative electrode.

Current state-of–the-art valve-regulated lead-acid (VRLA) negative electrodes utilize a number of additives to improve the performance and longevity of the cell [1]. Lignosulfonates are added to maintain the high surface area of the Negative Active Material (NAM) to improve utilization; barium sulfate is added to provide nucleation sites for the reaction product, lead (II) sulfate ($PbSO_4$), preventing large crystals from forming. Large crystals with a limited surface area are difficult to convert back to lead on charge. Finally, carbon black is added to increase conductivity of the plate to improve charge acceptance. While other additives can and are used within the industry, these three constitute the overwhelming majority of additives.

In an application as presented here, the current electrode design would provide very good initial performance, but degrade very rapidly as the system continued to operate. The reasons and mechanisms for this are very well understood. In a PSoC, operation the negative electrode is held a various states of charge with a percentage of the active material converted to $PbSO_4$. This $PbSO_4$ can re-crystallize over time and converts to what is commonly referred to as “hard sulfate” [1]. In turn, these crystals become sites for preferential crystal growth. The resulting sulfate crystals are difficult to convert back into lead on recharge and a steady decrease in available capacity results over time as more and more $PbSO_4$ is formed. In addition to suffering from sulfation in a PSoC operation, the negative electrode also limits charge acceptance of the cell. In a pulse charge operation, the majority of the current is converted to hydrogen evolution. This leads to dry out of the cell and also reduces the capacity over time.

Pavlov et al. [2] have demonstrated that the addition of electrochemically activated carbon (EAC) to the NAM can increase PSoC operation in high-rate applications by an order of magnitude, from 1000 micro-cycles to over 10,000 cycles. Mosely et al. [3] summarize the possible functions of the carbon additives in PSoC cycling.

(1) Electronic conductivity – The carbon particles maintain the conductivity of the active material in the presence of increased amounts of $PbSO_4$, which are electrically insulating. These conductive pathways then facilitate charging despite the increased resistance of the plates.

(2) Restriction of crystal growth – Carbon prevents the progressive growth of $PbSO_4$ crystals, maintaining surface area and improving charging characteristics [4].

(3) Hydrogen over potential impurities – Certain forms of carbon contains elements that can suppress the evolution of hydrogen at the negative improving charge efficiency.

(4) Capacitive contribution – The added carbon acts as an asymmetric super capacitor, storing charge at high rates in the electric double layer and spontaneously discharging, converting $PbSO_4$ into lead.

(5) Intercalation of hydrogen into the graphite structure – The graphite structure allows for intercalation sites for the hydrogen atoms that support the cells’ capacity.

While the exact mechanisms of EAC in the negative plate are still being investigated, a number of variations on the concept of a carbon negative are being utilized within the industry.

The method utilized for this application has focused on maintaining the negative electrode in a continuous PSoC and provides equivalent cycle life as if operating at a full state of charge.

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BIOGRAPHICAL NOTE

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Jon Anderson is currently the Director of New Technology Development for C&D Technologies Inc. He and his group are responsible for research and development at C&D, including emerging technologies and systems development. His current work focuses on the development of active materials and advanced processing methods for valve-regulated lead-acid (VRLA) batteries, energy storage systems for renewable energy applications, and lithium-ion batteries for stationary power applications. He has worked in the energy storage industry for over 12 years, holding various technical positions in the United States and Europe. Mr. Anderson's technical background is in Materials Science and Engineering and the early portion of his career was focused on alloys and active materials development for VRLA batteries for stationary and traction applications.