Second Life Battery Characterization

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Introduction:

Reusing batteries provides many benefits, both environmentally and economically. Many batteries, such as those used in vehicles, are discarded before their usefulness is at an end. While car batteries may no longer provide the performance required for their original application, there are other uses that these used batteries will fulfill. The purpose of this project is to characterize the charge and discharge properties of used lead acid and lithium ion batteries. These characteristics will provide detailed information as to what applications these used batteries may be used for. For example, used car batteries may be the perfect solution for a backup home battery or for storing renewable energy. Another use may be load following for the power grid.

Project description:

In this paper the possibility of utilizing second life batteries in microgrids was explored. Most batteries whether lead acid or lithium ion are recycled when their energy capacity reaches 70%-80%. It has been noted that after reaching this point the batteries still can have significant life left in them. If the second life batteries could be used within a BESS to assist with power reliability and stability this would not only help with environmental concerns, but would also enable an efficient use of already available electrical power. In the experimental portion of the project 6 batteries were characterized (4 lead acid, 2 lithium ion) in both ambient and cold temperatures. One of the used lead acid batteries had two cycle tests run on it to observe the discharge characteristics when the voltage was allowed to drop to 7 volts. The primary characterizations between the two battery types were as expected. The lithium ion battery delivered a much longer and more stable charge than the lead acid batteries. Also, as expected, colder temperatures decreased the performance in both batteries. However, there was one unexpected observation. When the two cycle tests were run the initial discharge curve dropped as expected, but in both tests the voltage leveled out at approximately 7.5 V and the rate of decrease in the discharge curve slowed significantly. If this phenomenon were present in other second life batteries it could show that the power delivered by a lead acid second life battery could be significantly longer than previously expected. It was also observed that when compared with necessary time-discharge requirements for ancillary services most of the second life batteries could be used in second life BESS on their own. However, it was also determined that if a control system were developed that could switch batteries in and out of the BESS all of the second life batteries could be used in such a system.

Future plan

The water pump system conductors are sized for 30 A, and the motors are rated for a two hour run time (impeller pumps) at 15 A each. During this study, the maximum experimental run time was 85 minutes at an average current of 23 A. During the 85-minute discharge, each impeller pump drew around 9 A – 10 A, and they were very hot. Theoretically the motors can run at 15 A each for two hours, but it is not recommended by the authors of this paper. The authors recommend that the system limits should be 25 A total current draw for 90 minutes. The findings of this work can be shared to a larger audience through attending different conferences, visiting different research labs, and publications in journals. Further research can be done on the following grounds:

- In order to use second life batteries in a BESS there are two primary aspects of battery life that must be taken into consideration. Should the discharge be stopped at the standard cutoff voltage or should the cutoff voltage should be ignored to get the maximum short term power out of the system at the cost of degrading the battery faster? If the desire is to prolong the life of the batteries a control system should be developed to cut the power when cutoff voltage is obtained. In either application of the batteries, the control system would also need to start batteries in standby to make sure the power delivered is constant.

- When the cycle test were run on the lead acid batteries the discharge curve was not as expected. Once the “knee” was shown the curve should have continued downward dropping at a faster and faster rate until the battery was depleted. In both cycle tests (2^{nd} and 3^{rd}) the rate of decrease leveled off significantly at approximately 7.5 V and continued at an expectedly steady rate until the arbitrary value of 7 V was obtained. If several other used lead acid batteries could be cycle tested to see if similar characteristics are observable in these batteries, this could be a very relevant observation for power systems applications.

- Perform the previous tests with lithium Ion batteries and possibly others.

- Test the battery characteristics when connected in series and in parallel. This would require rewiring the nema panel for the appropriate ampacity, but would be significant in terms of real world observations. BESS use various combinations of series and parallel connections to obtain the desired voltage and current parameters.

- An economic analysis of the benefits of second life BESS would be beneficial in determining the feasibility of such systems. Once the costs were established an analysis of revenue from the various ancillary services could be performed to determine the most viable applications.
- DC to DC converter to boost voltage back up to 12 V, and see how long the battery will deliver power.

- Use an oscilloscope to view the signal waveform. An inductive load was used in this study in order to make it more true-to-life. When BESS are used in electric power grids, the load on the battery is inductive. Electric power grids are kept at a power factor of around 0.95. It should be determined how the inductive load in this study compares to an electric power grid at 0.95 power factor.

Unfortunately, the lithium ion batteries used in this study were never discharged on the water pump system. Battery characterization was an important first experiment, and the authors ran out of time. Characterization of the lithium ion batteries required a 5-hour discharge, but the water pump system was only rated for two hours. The theoretical discharge current for the UR18650W2 lithium ion batteries is 1 A for 90 minutes. In order to reach the system voltage of 12 V, three batteries in parallel are needed. In order to reach the 25 A maximum current draw, 25 batteries would have to be connected in series. Three batteries in parallel and 25 batteries in series gives a battery pack containing 75 batteries. Such a pack would require a protective circuit.