Battery Storage Project

Battery End of Life Plan

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Contents

Introduction

Project Description

A Lithium Ion Battery Storage Project (the Project) will consist of Batteries, Battery Racks, AC/DC Power Conversion Stations, medium-voltage step-up transformers, medium voltage collection system and medium voltage switchgear. A Project will include also access roads, a specific purposed enclosure for housing the batteries, an electrical enclosure and other ancillary facilities and equipment.

Purpose and Overview

GlidePath Development LLC (the “Owner” or “GlidePath”) recognizes the importance of understanding the End of Life process and procedure for a system prior to implementation. With this Battery End of Life (EOL) Plan, GlidePath is seeking to share information regarding end of life actions associated with the battery system. This EOL Plan is developed to support the decisions surrounding the end of life for battery cells. The EOL Pan discusses the following:

- Battery Components
- Battery Chemistry
- Battery Monitoring
- Battery Degradation
- EOL Plan
- Disposal Options
- Project EOL Plan
- Project Decommissioning Plan

1 Lithium Ion Batteries

1.1 Battery Components

A Li-ion battery cell is comprised of a cathode, an anode, an electrolyte as well as other materials that are used in the packaging and internal connections.

A Li-ion battery energy storage system comprises of single cells that are interconnected and assembled into packs. A number of packs are then interconnected and mounted in racks that are then housed in buildings or containers making up the Battery Energy Storage System (BESS).

Battery monitoring is typically done using integrated battery management systems (BMS) that continually monitor battery parameters and system operation.

1.2 Battery Chemistry

Typically, the Cathode is a metal oxide such as NMC (nickel manganese cobalt) or LFP (lithium iron phosphate) and the Anode is carbon such as Graphite or LTO (lithium titanate) with the electrolyte being a lithium salt with exact chemistry dependent upon the Cathode and Anode. Material and chemistry combinations are dependent upon the manufacturer.

1.3 Battery Monitoring

Battery monitoring is typically done at pack level by the system BMS. The BMS continually monitors salient parameters including temperatures, voltages and charge/discharge currents. Based on these measurements, the state of health and the remaining capacity of the batteries are estimated and monitored over the cell life. Other parameters that are influenced by degradation mechanisms include the internal resistance and self-discharge rates of the cells.

1.4 Battery Degradation

Several degradation mechanisms are prevalent in the battery cells including structural changes of the anode, cathode and solid electrolyte interface (SEI). The BMS will attempt to manage the controllable cell parameters to slow down or mitigate the degradation mechanisms in an effort to maximize performance and extend cell life. This is done by controlling the charge and discharge rate of the cells, ensuring that the cells operate within specific temperature ranges and balancing cell voltages within a pack.

Despite the above, degradation is inevitable and will continue to occur, and cells will reach a stage where the capacity has degraded to a level where replacement must take place. These cells are classified as end of life (EOL) and are removed from site for disposal.

2 Battery End of Life

2.1 EOL Plan

To address end of life, an EOL Plan will form part of the Owner's augmentation strategy that is managed by the system supplier as part of a capacity maintenance or long-term service agreement. This plan has several stages starting with defining the EOL associated with the system components, removal of the spent racks and disposal requirements. The EOL is typically defined as 70% of Beginning of Life (BOL) capacity however this value can change per Owner requirements and project objectives.

When cells are deemed to be at EOL the modules are disconnected and fully de-energized, where-after they are packaged and/or staged for transport to a disposal facility. If modules are not immediately transported off the site, they are stored per manufacturer recommendations to minimize risk of damage.

The responsibilities of the Owner and original equipment manufacturer (OEM) pertaining to the disposal of EOL cells/modules will be agreed to as part of the supply contract. Depending on the arrangements, the Owner may be responsible for the disconnection and transportation of the spent battery components to the processing facility or the OEM will be the responsible for removal and transportation. The OEM is typically responsible for all recycling and final disposal of the cells/modules.

2.2 Disposal Options

Currently, the U.S. Environmental Protection Agency (EPA) does not regulate the disposal of batteries (of any chemistry) in small quantities. Large quantities of traditional (e.g. lead-acid) batteries are typically regulated under the Universal rules of Hazardous Waste regulations (40 CFR PART 273). Lithium-ion batteries, however, do not fall under these regulations since they are less toxic than other types of batteries containing lead or cadmium, therefore they are not required to be collected by manufacturers for recycling per current legislation. Nevertheless, it is typical for utility-scale energy storage projects to voluntarily develop EOL plans and seek to dispose of EOL cells in a responsible manner.

EOL lithium-ion battery cells are not only generated by utility-scale storage projects but also from electric vehicles and consumer electronics (e.g. smartphones, laptop computers, etc). As such several different disposal methods are in use across the country. Large quantities of lithium-ion batteries are recycled (as described below) with others sent to an incinerator at a hazardous waste facility or, where recycling or hazardous waste facilities do no exist, put into landfills. As the use of lithium-ion batteries continues to grow it is likely that additional recycling facilities will become available and the use of landfills will decrease. At the federal level, the US EPA is attempting to put forth regulation regarding the disposal/recycling of Lithium-ion batteries however these regulations have yet to be published or implemented.

For cells that are delivered to a recycling facility, the cells are processed in a furnace where metals and metal alloys are recovered. Exhaust fumes are processed by a gas cleaning facility to avoid the release of harmful pollutants such as dioxins and furans.

Other hazardous materials such as fluorine and chlorine are recovered from the process. The metal alloys processed in the furnace typically contain Co, Cu, Fe and Ni and will undergo a further metal separation and refining process to recover the materials for potential re-use.

Unfortunately, some battery elements such as iron, copper, nickel and cobalt can be recycled however, in many locations, current commodity prices do not support processing for re-use and these materials are landfilled once separated from the battery cell.

Typically, the recycling facility is owned and operated by a third-party and is contracted by the OEM based on the specific requirements and applicable law. Often a recycling facility will serve several OEMs as well as other industries with similar materials.

The Owner will often identify and make arrangements with one or more recycling facilities to continue to recycle spent batteries after the contract with the OEM has expired, or in the unlikely event the OEM does not fulfill their recycling obligations.

3 Project Plans

3.1 Detailed EOL Plan

Prior to construction of the Project, the Owner will prepare a detailed EOL plan with the OEM as part of a long-term service agreement during the procurement of the equipment. This plan will define the EOL associated with the system components and include the requirements to recycle batteries utilized as part of the supply of this project to the furthest extent practical. This plan will also include contingencies for proper disposal if the preferred recycling facility closes or the OEM is no longer able to fulfill its disposal obligations.

3.2 Decommissioning Plan

In addition to the plan for cell EOL disposal during operations the Owner will also prepare a detailed decommissioning plan for the Project addressing removal of the Project once it, as a facility, has reached the end of its useful life. This plan will typically include provisions for EOL recycling of all battery cells within the facility (or, in the event of useable cells, the potential for transfer to other facilities). In addition to EOL processing of the battery cells, the plan will also detail removal of the other project components such as electrical equipment, racking, and cabling. The battery enclosures may be repurposed for other uses (e.g. warehousing, data centers, storage, etc.) depending on their configuration and local regulations, or they may be removed. Equipment and materials removed from the site will be transferred to other facilities, recycled, or otherwise properly disposed of based on the materials involved and the available processing facilities. In the event the facility is entirely removed from the site, the footprint will be restored by removing fences, pavement and other surfaces, regrading to match the site's natural topography, and replanting with native vegetation.

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