Li-Ion Battery systems in Off-Grid applications

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Authors:
Rosenfeld, S., Mhanna, J., Bopp, G., Müller, M., Trittler, S., Stortz, F., Geze, N., Martell, C., Ortiz, J., Rodden, P.

Editor:
Felix Stortz

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Key Takaways

- Lithium-Ion battery storage systems are already economically feasible today in the MegaWatt (MW - power) and MegaWatthours (MWh – Energy) range in PV off-grid applications.
- The bigger the size of the required Lithium-Ion battery storage is, the better it performs compared to lead acid storage. In rather small battery storage systems lead acid batteries perform economically more feasible.
- The storage system must be monitored throughout its lifetime with the help of locally trained operators, stable data communication to the manufacturer of the system and a life-time contract for maintenance, repair and performance analyses.

Executive Summary

The standalone microgrid is getting attention and being adopted by energy communities due to several factors, such as increasing access to electrification, electrification of vehicles, and reducing greenhouse gas emissions with the help of renewable generation. Sizing and optimization are vital in deploying an efficient, reliable, and secure power supply at reasonable costs.

This report gives an overview of the current state of lithium-ion technologies in off-grid applications. One of the main contributions of the report is a classification table for off-grid systems. This provides recommendations of what battery system to use for different types of microgrids. Additionally, an overview of the lithium-ion technology is gathered, and a comparison of lead acid off-grid battery systems and lithium-ion off-grid battery systems is simulated. Furthermore, a case study with a real world system is analysed and categorized into the classification table. Finally, operation and maintenance guidance are developed and presented.

Task 18 Managers: Christopher Martell chris.martell@gses.com.au and Michael Müller mm@ofres.org

Technology

The report summarizes the most common Lithium-Ion cell chemistries. It describes the functionality of such battery cells and the possible applications.

Table 1: Overview of lithium-ion chemistries and its properties [6].

Material	Capacity [Ah/kg]	Working Voltage [V]	Energy density [Wh/kg]
NCA ($LiNiCo_{0.85}Al_{0.15}$)	200	3.7	740
LCO ($LiCoO_2$)	160	3.9	624
NMC ($LiNiMnCoO_2$)	160	3.7	592
LMO ($LiMn_2O_4$)	100	4.1	410
LFP ($LiFePO_4$)	160	3.2 - 3.4	544

Categorization

The report provides an overview on the different system applications, the typical battery system size and categorizes 4 system classes

- Class 1 : Battery size up to 0.5 kWh, portable loads and others
- Class 2 : Battery size from 0.5 – 2 kWh/d, Solar Home Systems (SHS), Street lights
- Class 3 : Battery size from 2 – 500 kWh, PV Hybrid Systems
- Class 4 : Battery size from 500 – 5000 kWh, Industrial loads and grid supporting systems

The type of load is in general independent from the classification of the system as this mainly deals with the size. However typical types of applications where identified and can be classified according to the mentioned definition.

Lithium-Ion battery systems can support all those kind of systems while especially the very small Class1 and the big Class4 are dominated by Li-Ion batteries independently from the type of application.

Case Study

In Haiti, a hospital system was built based on Lithium-Ion systems and is under operation since 4 years. The system includes two PV fields with the power of 232 kWp and 210 kWp, respectively. These PV fields harness solar energy and convert it into electrical power to meet the energy requirements of the hospital. Each PV field is equipped with inverters that convert the direct current (DC) electricity generated by the PV panels into alternating current (AC) electricity. The inverters ensure compatibility with the hospital's electrical load and enable the utilization of solar-generated power. The system comprises of four gensets, two units rated at 200 kVA and two units rated power at 400 kVA.

The gensets serve as a backup power sources to supplement the electricity supply during periods of low solar irradiation or in the event of power outages. They provide additional power to meet the hospital's energy demands. The system can operate autonomously while the gensets are off, the inverters of the BESS operate in off-grid mode and form the grid. The system has two BESS that utilize Lithium-Ion technology. The first BESS has 224 kWh, while the second has a capacity of 332kWh.

Simulations

Real system load data and site information have been used to develop a digital twin of these systems. After validating the model with the help of the monitoring data, system size parameter variations have been performed. With this simulation the load was scaled among all 4 defined system classes (see table Class1 to Class4). Optimal system sizes where calculated depending on the boundary conditions. This has been performed using Lithium-Ion and Lead-acid batteries in order to investigate which technology performs better under which conditions.

Success Factors

In order to operate Lithium-Ion battery systems in PV off-grid applications sustainably it is of crucial importance to maintain all relevant steps among the following aspects:

- **Design**: The systems needs to be designed takign into account the local boundary conditions not just from a technical point of view but also in regards to logistics human resources, communication infrastructure and the maintenance capabilities.

- **Implementation**: The installation phase shall be defined depending on the type of technology which will be installed and shall take all steps into account including adaption of the system and the Battery Management System (BMS) parameters according to the local conditions.

- **Operation**: The operation phase needs to be permanently supported by local maintenance staff to provide first level support. The supplier shall permanently monitor the system and receive status information online. With the help of data analyses, the performance of the system can be monitored