Maximizing the potential of lithium-ion batteries for power grid applications

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A new study from the University of Vaasa, Finland, introduces a noteworthy approach to optimizing the use of lithium-ion battery energy storage systems in power grid applications.

Modern power systems are adapting to reduce greenhouse gas emissions by incorporating renewable energy sources (RES), such as solar and wind power technologies. The issue lies in the intermittent nature of these sources, which poses serious challenges to grid stability. To overcome this, battery energy storage systems emerge as the key solution. In particular, the adoption of lithium-ion battery energy storage systems (Li-ion BESSs) as a flexible energy source has been rapid.

"Li-ion BESSs are widely used today mainly because of their superior technical characteristics and falling costs. However, their performances are non-linear, which makes determining their operational window in the field challenging. In addition, ambient operating conditions also impact their performances, adding to the complexity," explains Chethan Parthasarathy.

The non-linear characteristics of Li-ion BESSs, which are further influenced by parameters such as state of charge, temperature, depth of discharge, charge/discharge rate, and battery-aging conditions, have traditionally hindered efficient and economical utilization of these batteries, often leading to their underutilization and over-sizing. Chethan Parthasarathy's doctoral research at the University of Vaasa addresses these issues by developing accurate battery performance and aging models and integrating them into their control structure.

One of the main contributions of his dissertation is the development of new adaptive control methods for grid applications. They allow optimal use of Lithium-ion BESSs by ensuring their performance thresholds are always upheld, thereby preventing both under-usage and over-usage of the battery systems. They also support higher penetration of RESs and help to keep the power grid stable.

"My main accomplishment has been embedding accurate battery models for battery integration in power system simulation environments. The development of such battery models is a complex process that involves extensive experimental testing and characterization in a controlled laboratory environment. Eventually, this led to the setting up of a new battery cell testing laboratory at the University of Vaasa," says Parthasarathy.

Streamlining Li-ion BESS control and techno-economic study methods

Parthasarathy's dissertation also emphasizes the inclusion of Li-ion BESS aging degradation dynamics in their control topology. This approach allows real-time adaptation of energy and power outputs to minimize degradation, thereby extending the lifespan of Li-ion BESSs.

"This not only improves the longevity of batteries but also enhances understanding of their economic viability in power grid applications," explains Parthasarathy.

The technical contributions of the dissertation include the design of a grid-specific control architecture for active network management (ANM) schemes, the development of accurate battery models for Li-ion BESS grid integration studies, improved power system simulation modeling methods, and mapping of the required battery parameters for advanced control design. The dissertation also presents an aging-aware adaptive control for Li-ion BESSs, enabling ANM simulations and techno-economic studies.

More information: Dissertation: urn.fi/URN:ISBN:978-952-395-090-0

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