A NEW BATTERY DEGRADATION-AWARE CURRENT DERATING FRAMEWORK

An Effective Method to Prolong Lifetime and Ease Thermal Management

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ABSTRACT

In this work, an experimentally validated degradation model of a Li-ion battery is mapped offline to predetermine the degradation rates. The results are integrated into the current-derating algorithm using simple look-up tables (LUTs). This framework can be adapted to any degradation model and allows flexible tuning. The method is evaluated in simulations of an outdoors-installed battery energy storage systems (BESS) with passive thermal management, which operates in a residential photovoltaic application. In comparison to standard derating, we achieve:

(1) increase of battery lifetime by 65%;

(2) increase in energy throughput over lifetime by 49%,;

(3) While energy throughput per year is reduced by only 9.5%

MOTIVATION: TOO SIMPLISTIC DERATING

To ensure the safe and reliable operation of Li-ion batteries, the power/current is derated to prevent the battery from going outside its recommended operating range. Most derating strategies use simple heuristics to limit battery current depending on voltage, temperature or state-of-charge (SOC), and do not account for the complexity of battery degradation (see Fig. 1). Progress has been made with Li plating models for fast charging, but it is a partial solution, does not consider other degradation mechanisms, and requires relatively complex implementation, limiting adoption.

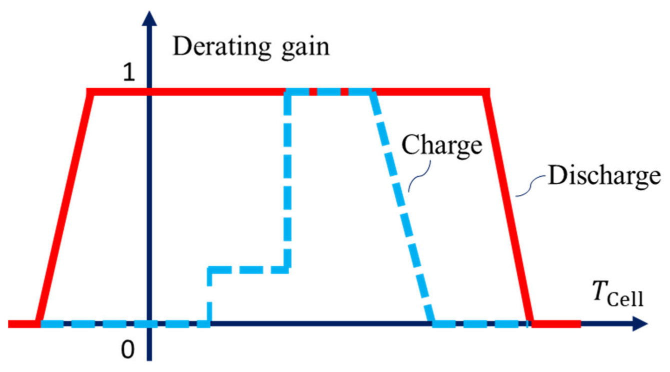


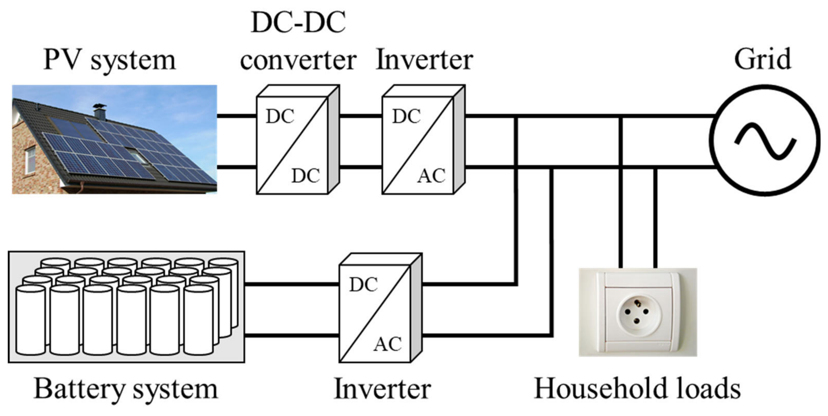
Fig. 1. Exemplary heuristics behind temperature-based current derating [1].

NEW DERATING METHOD

- Firstly, the max. degradation rates for cycle and calendar degradation are set (tuning factors) (Fig. 2)
- During operation, the battery management system provides the battery states to the algorithm
- Considering the previous data, the max. allowable battery current for both degradation mechanisms are calculated using the LUTs, directly for cycle ageing, and via the max. allowable temperature for calendar
- Using these current limits, the current request is derated, and the BESS is operated accordingly

USE-CASE EVALUATION: SCENARIO

- Residential battery system
- Application: Buffer for Photovoltaic system
- Outdoor installation
- Passive thermal management



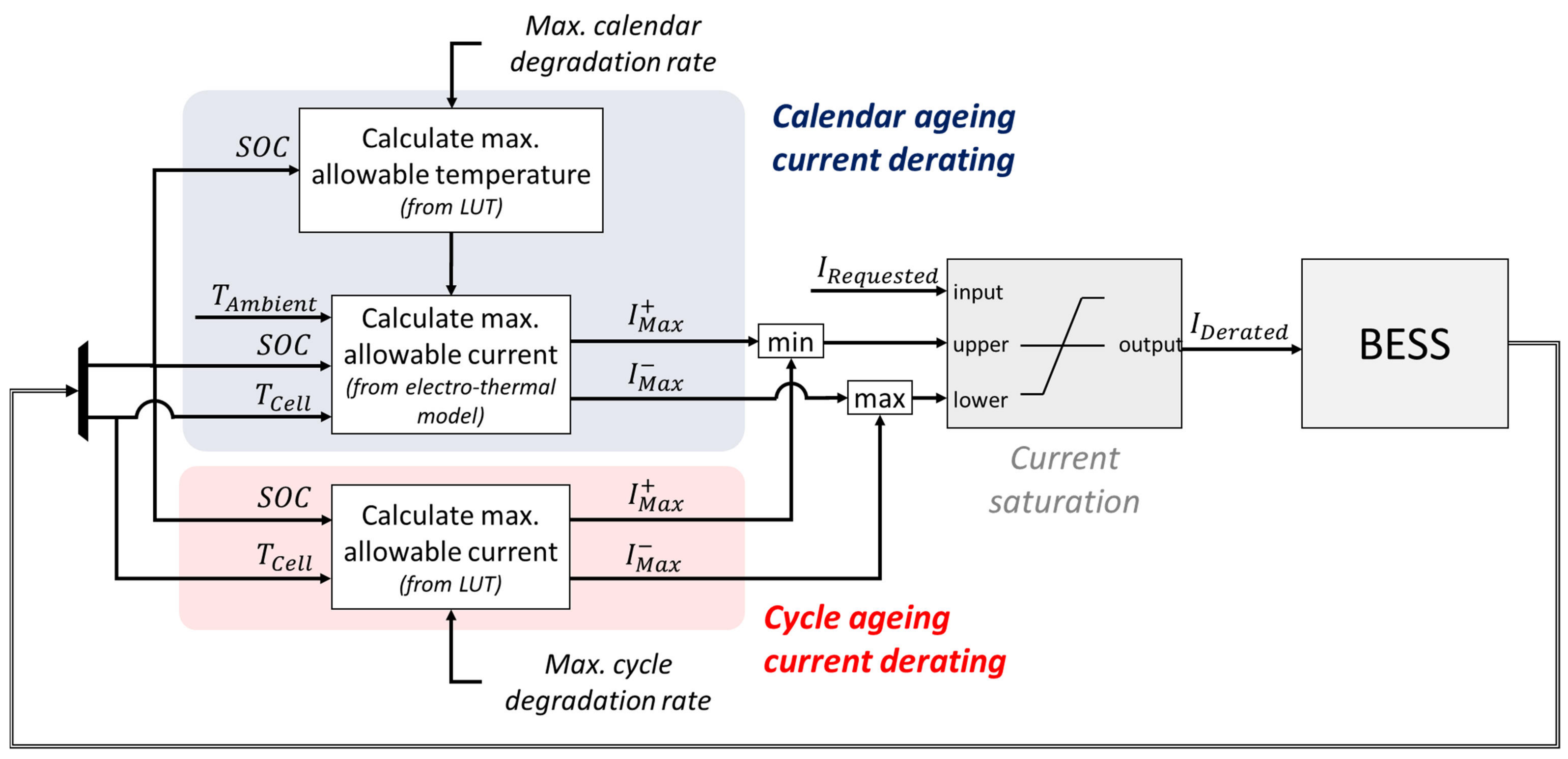
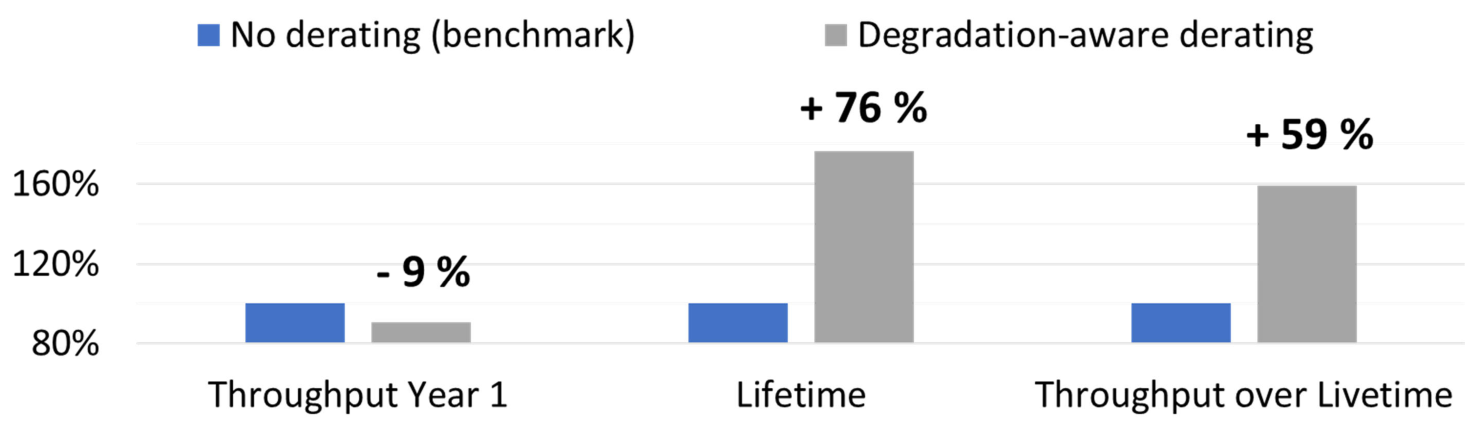


Fig. 2. Integration of new degradation-aware current derating in system simulation/control [4]

USE-CASE EVALUATION: RESULTS



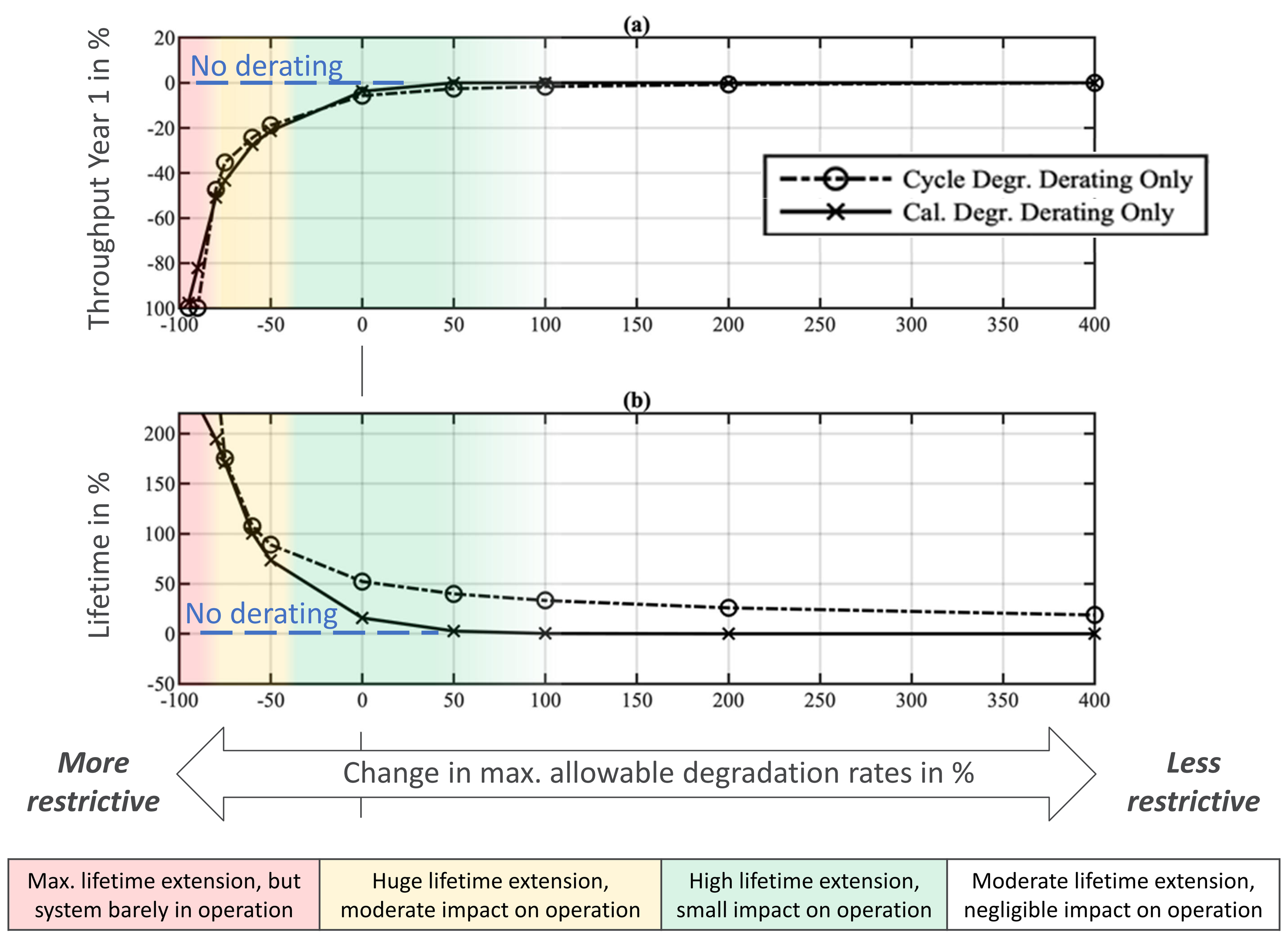
Negligible reduction of performance,	game-changing increase in lifetime...	and lifetime throughput!

CONCLUSIONS: GAME-CHANGING INCREASE IN LIFETIME

- Advanced degradation models are extremely effective to optimize sizing and operational strategies of batteries
- The models can be used to make informed derating decisions… Or be integrated in the derating algorithm!
- In general, unpractical to embed advanced degradation models
- But ALL degradation models can be mapped offline in LUTs and used online
- This is an effective way to prolong lifetime and ease thermal management

USE-CASE EVALUATION: SENSITIVITY ANALYSIS

- If the max. allowable degradation rates are set lower, the derating is more restrictive, resulting in longer extension of battery lifetime but also lower annual energy throughput
- Conversely, if the allowable degradation rates are higher, the derating is less restrictive, resulting in shorter extension of battery lifetime but virtually no impact on annual energy throughput



IMPACT: THE NEW STANDARD?

- Universal framework: applicable to all degradation & performance models
- Easy to implement online with LUTs, without optimization routines
- Easy to tune: more or less restrictive
- Considers both calendar and cycle ageing, charging and discharging
- Provides high-level insights

FUTURE WORK

- Techno-economics studies: find optimum between short- and long-term revenues
- Evaluation in e-mobility (xHEV)
- Lifecycle analysis in e-mobility: savings in terms of gCO2e/Wh
- Implementation side-by-side with advanced balancing systems to control cell-to-cell variations

REFERENCES

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BIO: JORGE VARELA BARRERAS

Jorge combines an academic role at Imperial College London with an industrial role at CTAG. Previously, he was a postdoc at Oxford and PhD fellow at Aalborg.

+25 peer-reviewed articles and +10 years of R&D experience in +20 projects with a budget over £100M.

His interests are around batteries in e-mobility and BESS, and span testing, modelling, management, balancing, techno-economics, lifecycle analysis, safety and novel concepts.

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