Microgrid Design:
A Piecewise Linear Approach

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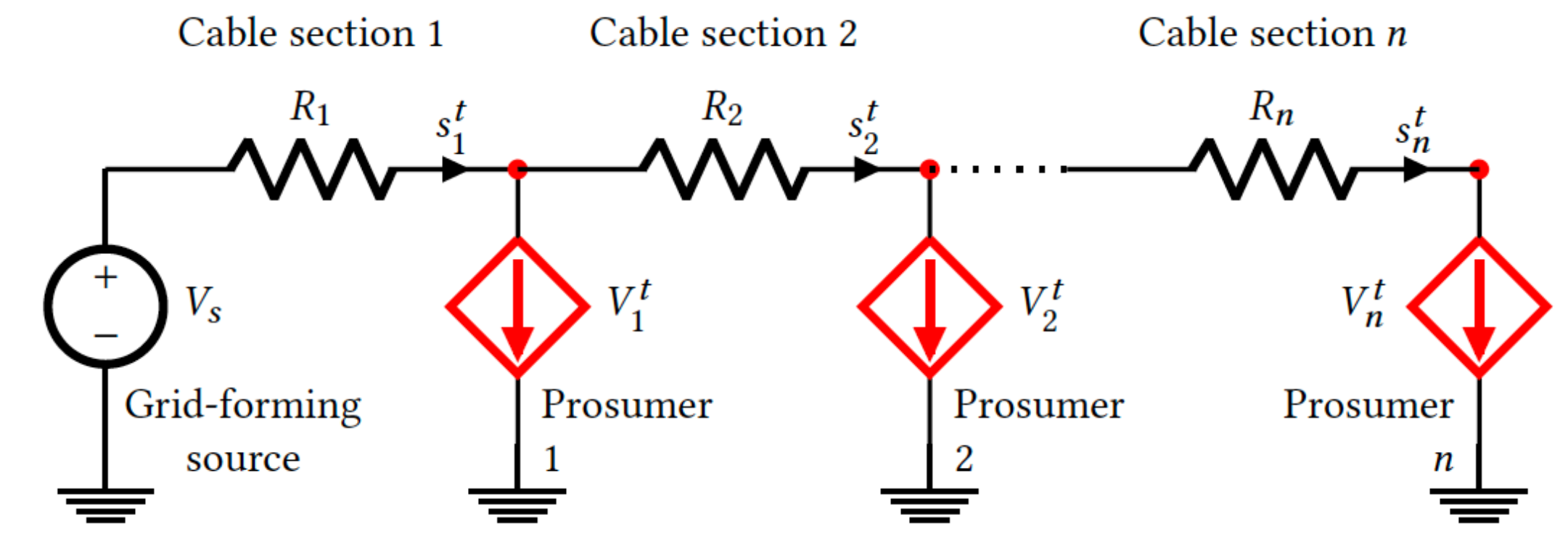
1. Introduction

- Microgrids are set to become an integral part of the modern-day electricity grid.
- Uncontrolled power injection from distributed sources leads to:
  - Power quality problems like steep voltage changes, current spikes etc.
  - Limited financial benefits - for example, solar self consumption when demand matches generation.
- Niche use-case for storage.
- Harnessing energy storage - majority literature limited to individual households - for example, [MMdH+15].
- Optimal sizing and siting of PV/storage systems combined is essential
  - Improved economics of microgrid operation,
  - Better power quality.

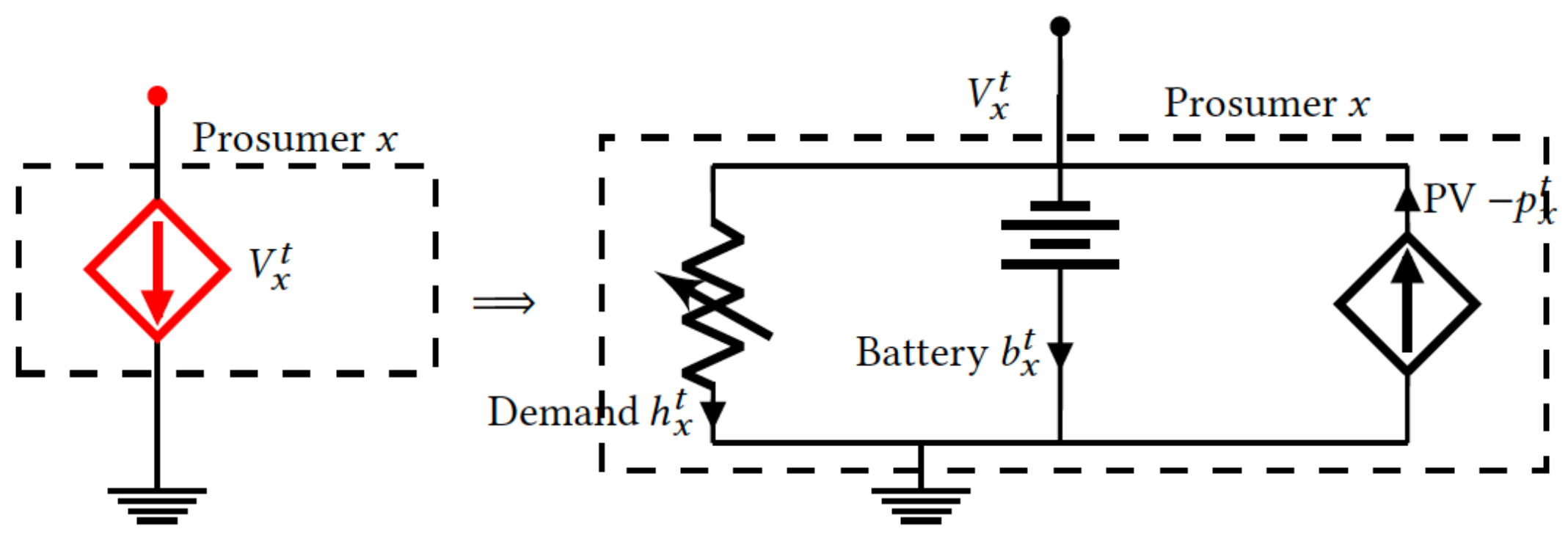
2. Contribution

- In our previous work, we developed a techno-financial feasibility model for battery sizing in microgrid networks.
- In this work
  - **PV sizing**
  - **Bi-directional power-flow**
  - **Battery degradation is penalized.**

3. Network, Cost and Constraints



(a) A high level representation of a radial microgrid.



(b) Each prosumer in the network is equipped with a photovoltaic system and a battery storage system, all of which are modelled as current sources/sinks.

Figure 1: Detailed model of a microgrid.

- Detailed mathematical model in [KdA+17].
- Current source/sink model based on unity power-factor assumption.
- **PV sizing Ψ constraint**

$$\text{PV size constraint: } 0 \geq p_x^t \geq G_x^t \Psi_x, \qquad \forall x, t$$

where x = prosumer node identifier; t = is time ; G_x^t = normalized generation pattern of a unit PV system.

- **Bidirectional power flow at varying tariff**

$$\lambda^t := \begin{cases} 1, & \text{if } s_1^t > 0 \text{ (energy import)} \\ 0, & \text{otherwise,} \end{cases}$$

is introduced modifying the operational cost to

$$OP_{Cost} := \lambda^t P_{imp}^t E_{imp}^t + (1 - \lambda^t) P_{exp}^t E_{exp}^t$$

- **Battery degradation cost** [AHM+16]

$$OP_{Cost,new} = OP_{Cost} + f(|b_x^t|)$$

- Any charge in or out of the battery decreases its lifetime.

4. Results and Conclusion

- The microgrid considered is as shown in Figure 1 with $n = 6$.
- The demand data is obtained from [Dep14].
- Passing on the demand data into the optimization algorithm as seen in [KdA+17] with modifications to add PV sizing led to initial sizing decisions.

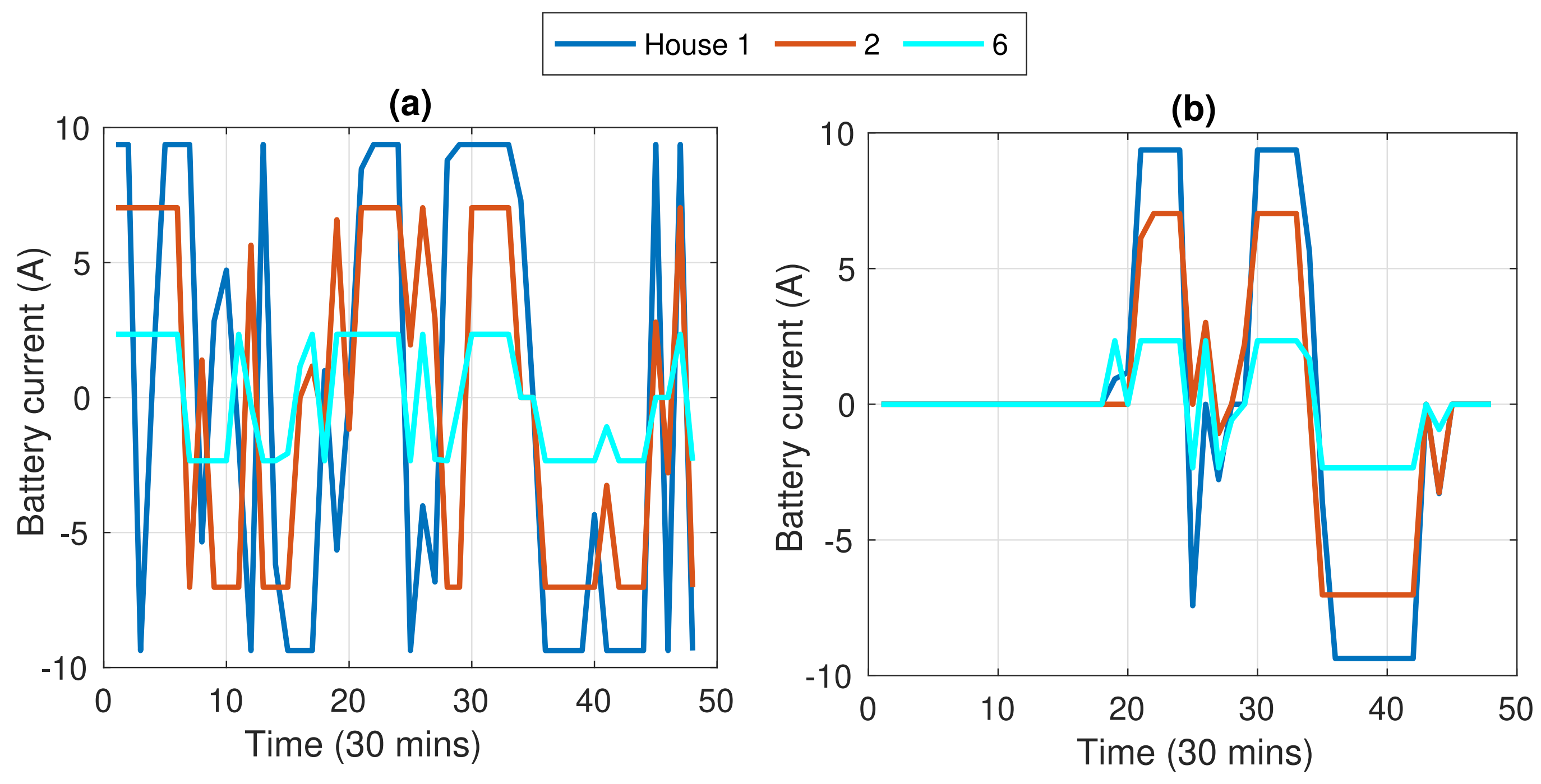


Figure 2: *Battery current b_x^t decisions (a) without and (b) battery degradation costs as a centralized optimization.*

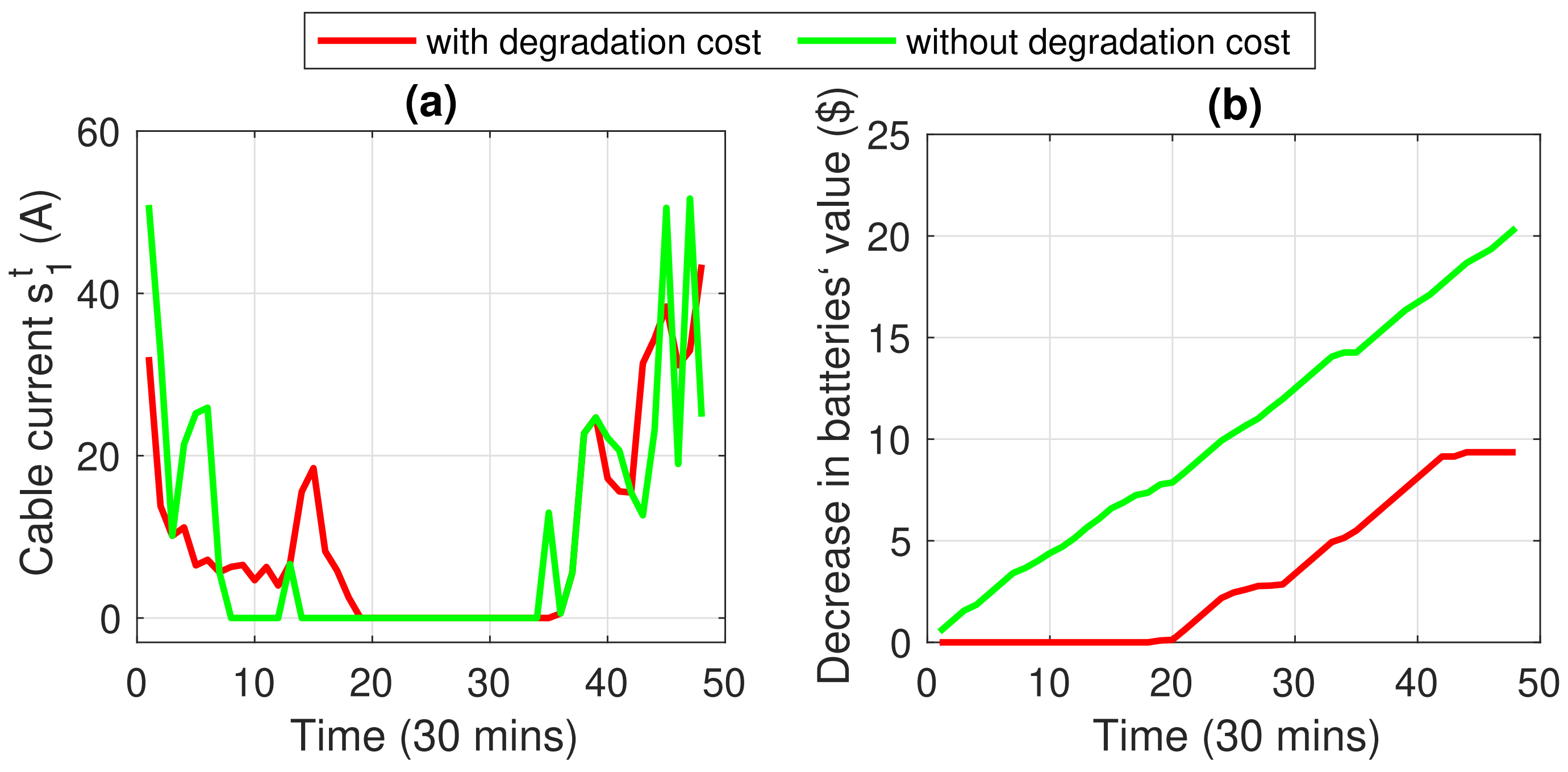


Figure 3: *(a) Cable currents in (A) and (b) depreciation in battery value with and without battery degradation cost as a centralized optimization.*

- **Doubled battery lifetime $\Longleftrightarrow$ about 26% overall benefit**
- **Linear model $\Longleftrightarrow$ computationally flexible**

References

[AHM+16] K. Abdulla, J. De Hoog, V. Muenzel, F. Suits, K. Steer, A. Wirth, and S. Halgamuge, *Optimal operation of energy storage systems considering forecasts and battery degradation*, IEEE Transactions on Smart Grid **PP** (2016), no. 99, 1–1.

[Dep14] Department of Industry, Innovation and Science , *Electricity consumption benchmarks*, `https://data.gov.au/dataset/electricity-consumption-benchmarks`, 2014, [Online; accessed 20-September-2017].

[KdA+17] R. R. Kolluri, J. de Hoog, K. Abdulla, I. Mareels, T. Alpcan, M. Brazil, and D. A. Thomas, *Siting and sizing distributed storage for microgrid applications*, 2017 IEEE International Conference on Smart Grid Communications (SmartGridComm), Oct 2017, pp. 128–133.

[MMdH+15] V. Muenzel, I. Mareels, J. de Hoog, A. Vishwanath, S. Kalyanaraman, and A. Gort, *Pv generation and demand mismatch: Evaluating the potential of residential storage*, 2015 IEEE Power Energy Society Innovative Smart Grid Technologies Conference (ISGT), Feb 2015, pp. 1–5.