Optimal Investment Strategy in Grid-Scale Energy Storage Systems: A Real Options Analysis

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Agenda

Background

Motivation

Methodology

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Background

- Renewable generation has increased significantly.
  - Total installed capacity of rooftop PV systems have increased from less than 200MW in 2009 to 1.1GW in 2017 [1].
  - Total rooftop solar capacity is expected to increase from 4.3GW in 2017 to 19GW in 2035 [1].
- Rising PV penetration has led to numerous technical problems [2].
  - Over voltages.
  - Thermal problems.
  - Phase unbalance.

Background

- Network augmentation [3].
  - Upgrade transformer and line capacities.
  - Expensive and time-consuming.
- Grid-scale battery storage is an alternative option.
  - Mitigate the technical issues.
  - The cost of the technology is predicted to halve in the next decade [4].

Motivation

- Determining efficient and well-timed investment in large-scale batteries is challenging under uncertain electricity market environment.
- Traditional discounted cash flow (DCF) analysis.
    - It provides only deterministic decisions.
    - Distribution network investments are generally irreversible, and present many options (Defer, expand and abandon).
    - Investors have the flexibility to execute these options based on how future uncertainties are realised.

Real Options Valuation

- Real options valuation (ROV).
  - Highlights the value of the options under multiple uncertainties.
  - Mitigates the risk of financial losses and increase the investment value.
  - Optimal investment strategy.
- We propose a ROV framework, and demonstrate its characteristics by determining the optimal investment strategy of a grid-scale battery in a LV network.
  - Option to defer.

Methodology

- Formulate a battery scheduling optimisation problem.
- Quantitatively incorporate the benefits from the battery within the ROV.
- Use the *least square Monte Carlo* (LSMC) approach to determine the deferral option value, and the corresponding investment strategy.
- The ROV uses the *geometric Brownian motion* (GBM) coupled with a *Monte Carlo* (MC) study to simulate possible paths of future uncertainties, including:
  - varying wholesale electricity price.
  - declining cost of battery system.

Battery Scheduling Optimisation

- We formulate the battery scheduling optimisation as a *mixed integer linear programming* model.
- Objective:
  - Minimise the grid supply over 1 year.
  - Minimise the size of the battery system.
- Decision variables:
  - Battery charging and discharging rates.
  - Grid supply.
  - Size of the battery system

Costs and Benefits Analysis

- Translate the increase in network capacity into a monetary value.

$$\Pi_{t,\omega} = c^{\mathrm{B}}_{t,\omega} - c^{\mathrm{Aug}}_{t} + c^{\mathrm{g}}_{t,\omega}, \quad (1)$$

where $\Pi_{t,\omega}$ is the payoff, $c^{\mathrm{B}}_{t,\omega}$ is the cost of the battery, c^{Aug}_{t} is the augmentation cost, and $c^{\mathrm{g}}_{t,\omega}$ is the cost incurred by deferring the investment.

ROV via Least Square Monte Carlo

- The LSMC approach for determining the optimal investment strategy.
  - Calculate the *continuation value*, $\Phi_{t,\omega}$.
  - Decide the *optimal stopping time*, τ_ω.
  - The investment is executed as soon as $\Pi_{t,\omega}$ exceeds $\Phi_{t,\omega}$.
  - Calculate the *deferral option value*, F_{option}.

- The investment value considering the managerial flexibility is:

$$NPV_{\text{flexible}} = NPV_{\text{classic}} + F_{\text{option}}. \tag{2}$$

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Case Studies

- Two LV test feeders are from Electricity North West Limited[1].

Table 1: LV Test Networks

	No. of consumers A	No. of consumers B	No. of consumers C	Feeder length (km)	Transformer capacity (kVA)	Optimal battery size (kWh)
Feeder 1	98	109	93	10.2	1600	445
Feeder 2	41	60	49	4.3	800	174

[1]A British distribution network operator.

Traditional DCF Method

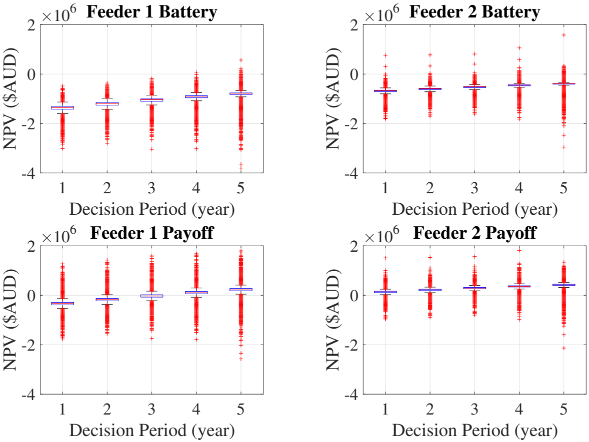

Figure 1: Cost of the battery investment and the corresponding payoff on the test feeders.

ROV

Table 2: ROV Table

	NPV_{classic} (k\$)	F_{option} (k\$)	NPV_{flexible} (k\$)
Feeder 1	-260	320	60
Feeder 2	50	55	105

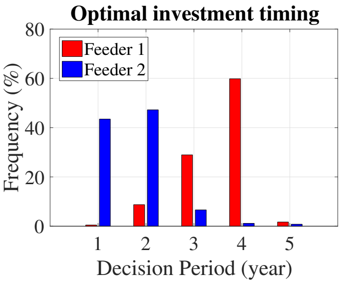

Figure 2: Optimal investment timing

Conclusions

- We developed a ROV framework, and demonstrated its usefulness by determining the optimal investment strategy in grid-scale battery systems in two different LV networks.
- The framework incorporates battery schedules within its financial analysis.
- The results show that making contingent decisions based on how future uncertainties are realised increases the investment value, and mitigates the risk of financial losses.

References

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[4] Clean Energy Council, ÄúThe Clean Energy Australia Report 2018,ÄùReport, 2018.