COORDINATED BATTERY ENERGY STORAGE SYSTEMS SIZING FOR PHOTOVOLTAIC RAMP RATE CONTROL

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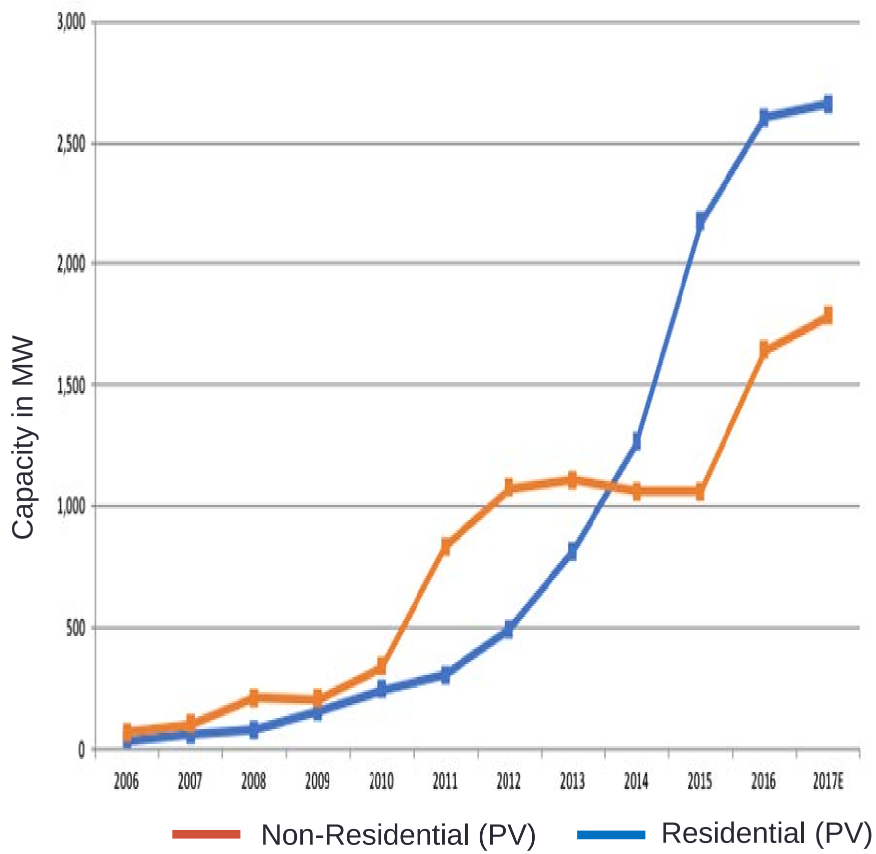
Introduction

- The penetration of solar photovoltaic (PV) units in power systems has shown an increase in the past few years and is expected to continue growing in the near future.
- This is due to several factors:
  - The drop in solar PV technology cost
  - Advancement in power electronics and control methodologies
  - New solar PV-grid connection regulations



Yearly U.S. Solar Photovoltaic (PV) Installation

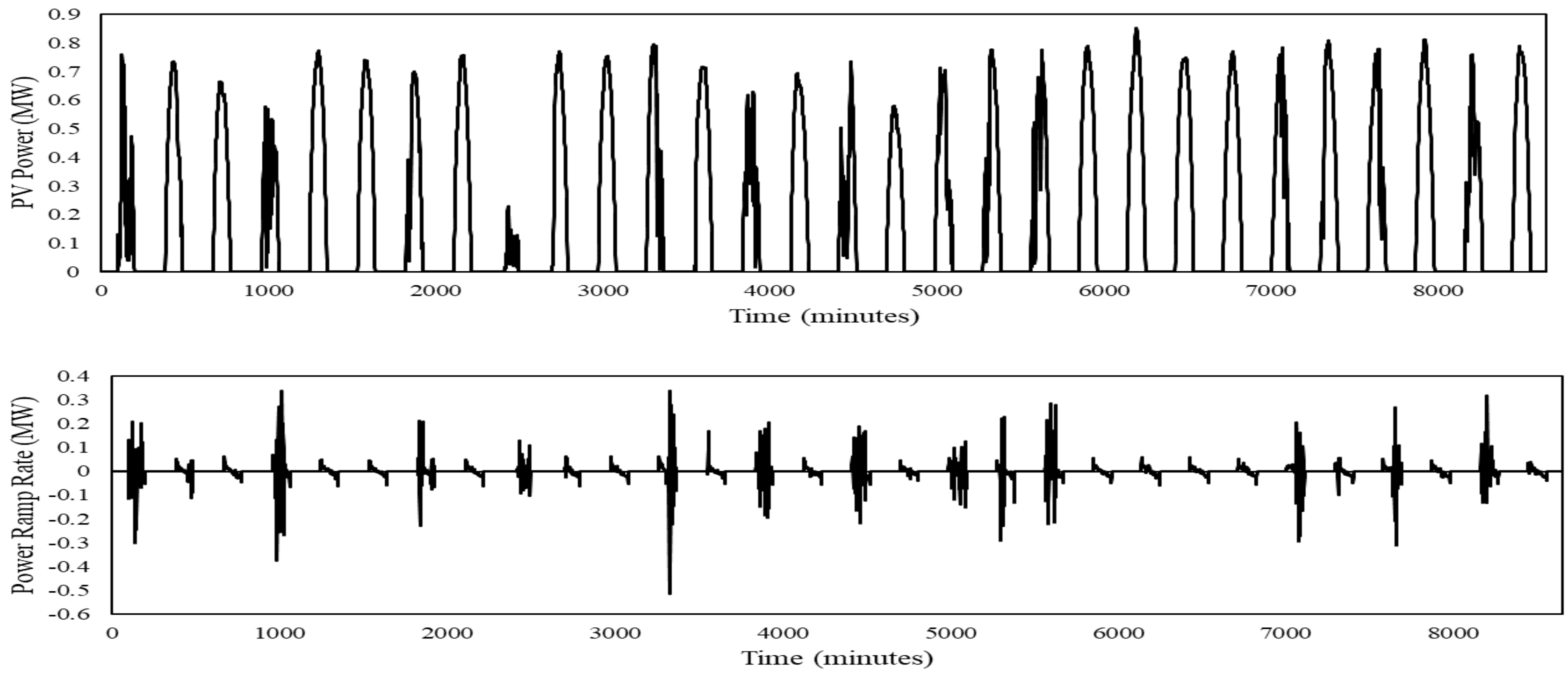
Source: Solar Energy Industries Association, “US Solar Market Insight: 2017 Year in Review,” September 2017

Introduction

- The ramp rate of the solar PV power sent to the grid must be controlled to ensure grid stability.
- Various methods have been discussed to solve the solar PV power variation issue and to control the ramp rate of the power injected to the grid:
  - voltage regulating control
  - active power reserve
  - geographical dispersion
  - energy storage integration
- Energy storage can be used to perform multiple applications (e.g., energy arbitrage, ramp rate control, and regulation services).
- Among the various available energy storage technologies, battery energy storage system (BESS) stands out to be the most mature technology that can be used for solar PV ramp rate control.

Solar PV Ramp Rate Analysis

- Solar PV ramp rates can be categorized into:
  - Small ramp rate (typical solar PV power profile)
  - Large ramp rate
- Unlike small ramp rate, large solar PV ramp rate rarely occur

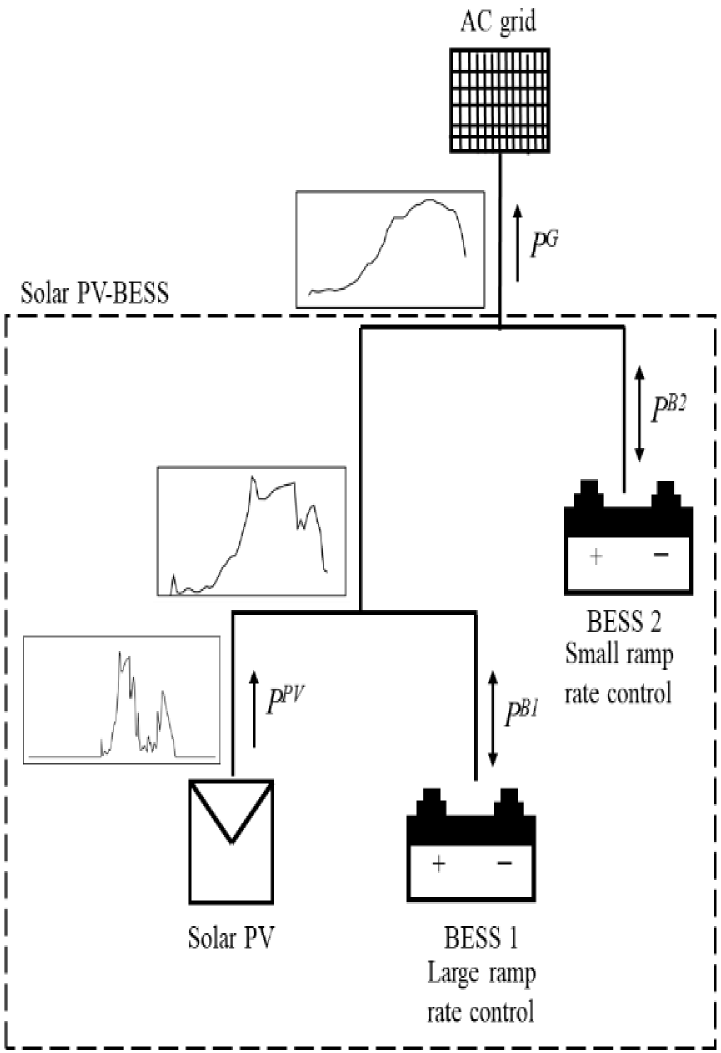


BESS Installation Challenge

- The main challenge that often faces BESS installation is the associated high investment cost.
- The BESS investment cost is strongly related to the selected technology and size.
- If one BESS is used to control the solar PV ramp rate, it will need to have both high lifecycle and high capacity.
- A BESS with such characteristics is expensive and might not be economically viable to be purchased and installed.

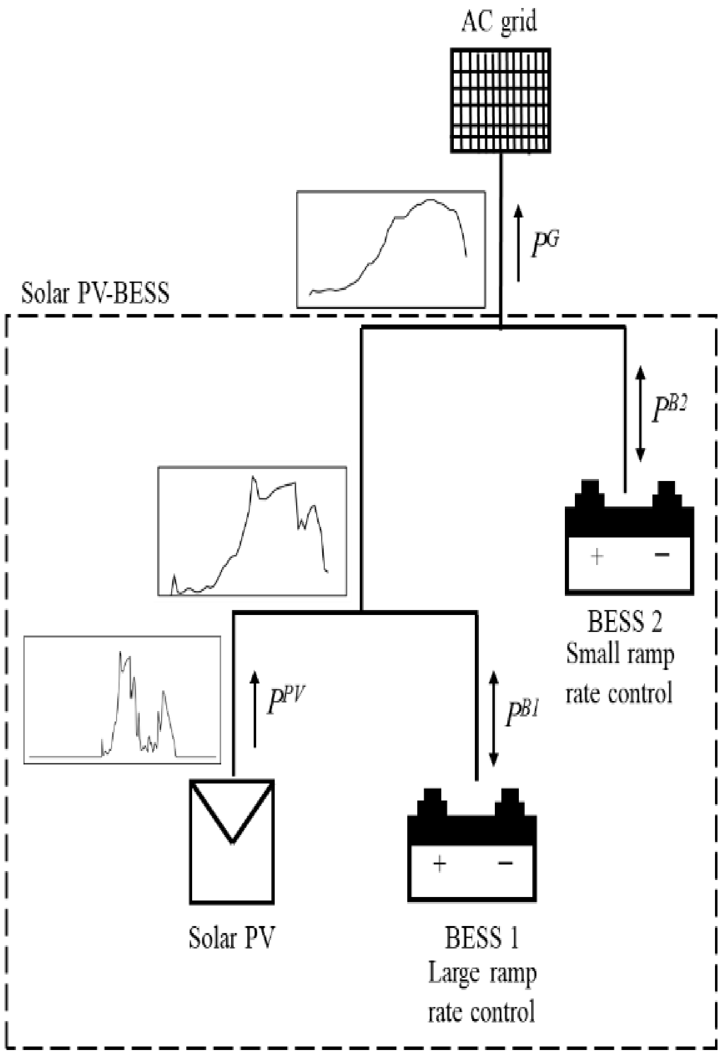
Solution

- The small and large solar PV ramp rate controls are decoupled and two different BESS technologies are used to perform the PV ramp rate control.
- BESS 1 → large ramp rate control
  - Low cost
  - Low lifecycle
- BESS 2 → small ramp rate control
  - High cost
  - High lifecycle



Objective

- A coordinated BESS sizing method is proposed to determine the optimal size for both BESS units
  - Minimize the total BESS investment cost
  - Satisfy the grid operator ramp rate limit
- The proposed model is formulated using Mixed Integer Linear Programming (MIP) and solved in GAMS.



Case Study

- The proposed coordinated BESS sizing model is tested on a 1 MW solar PV unit.
- Two BESS technologies are used to control the solar PV ramp rate

BESS Technology	Power Rating Cost ($/kW)	Energy Rating Cost ($/kWh)	Depth of Discharge (%)	Round Trip Efficiency (%)
Lead acid	600	400	70	75
Li-ion	1300	800	90	95

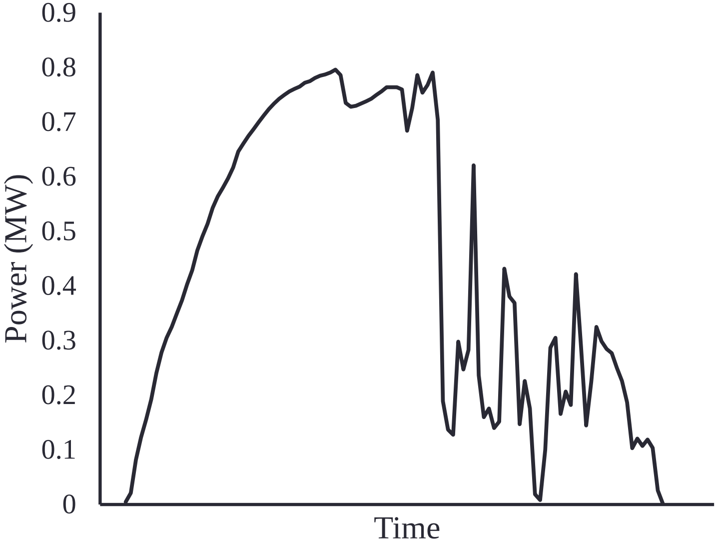
Results-BESS Optimal Size

BESS Technology	Optimal Power Rating (KW)	Optimal Energy Rating (KWh)	Investment Cost ($/year)
Lead acid	205	96	24,048.6
Li-ion	58	10	12,426.6

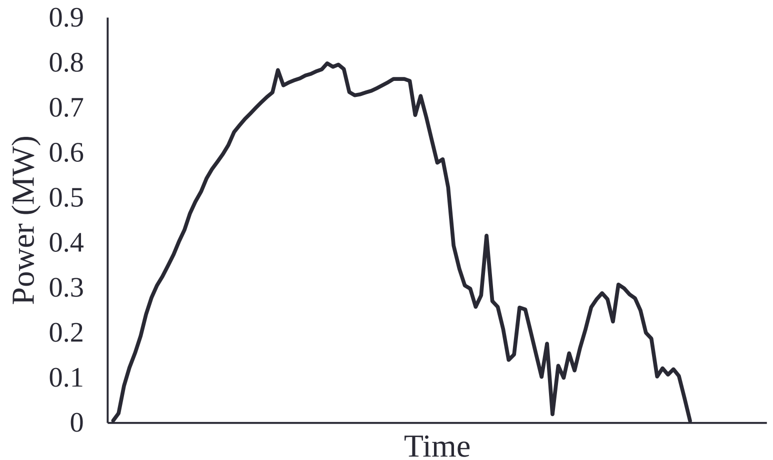
Results- Ramp rate analysis

Ramp Rate Percentage (%)	No. of violations		
	in original Solar PV	after using BESS 1	after using BESS 2
5	2040	1104	0
10	828	12	0
15	444	0	0
20	228	0	0

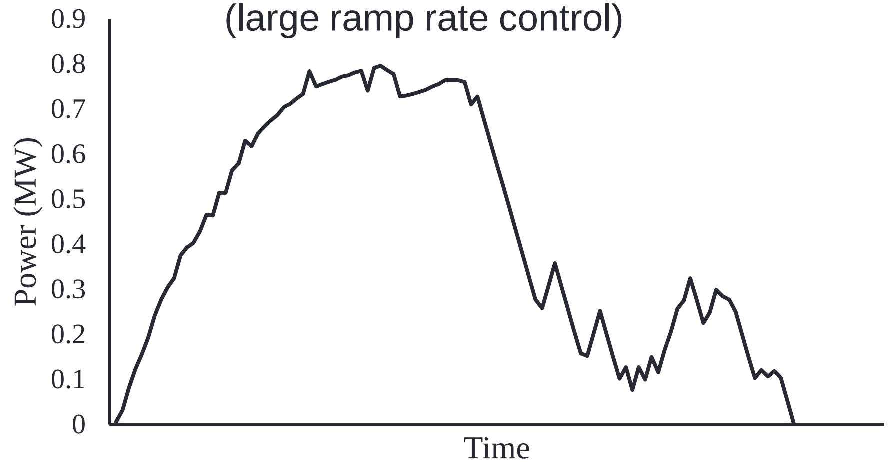
Results-Obtained Power Profiles



Solar PV power profile



Power profile after BESS 1
(large ramp rate control)



Power profile after BESS 2
(small ramp rate control)

Conclusion

- A coordinated sizing method was proposed in this work to determine the optimal size for two different BESS technologies that are installed to control solar PV ramp rate.
- The BESS technology with lower lifecycle and capital cost was selected to control the large solar PV ramp rate while the BESS technology with higher lifecycle and capital cost was used to control the small solar PV ramp rate.
- This way, the overall investment cost is reduced compared to using only one BESS to perform PV ramp rate control application.
- The results obtained from numerical simulations showed that the proposed method was able to determine the optimal size of both BESS technologies while at the same time satisfying the ramp rate limit imposed by the grid operator.

Thank you

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