Optimal Sizing of Residential PV-Battery Systems

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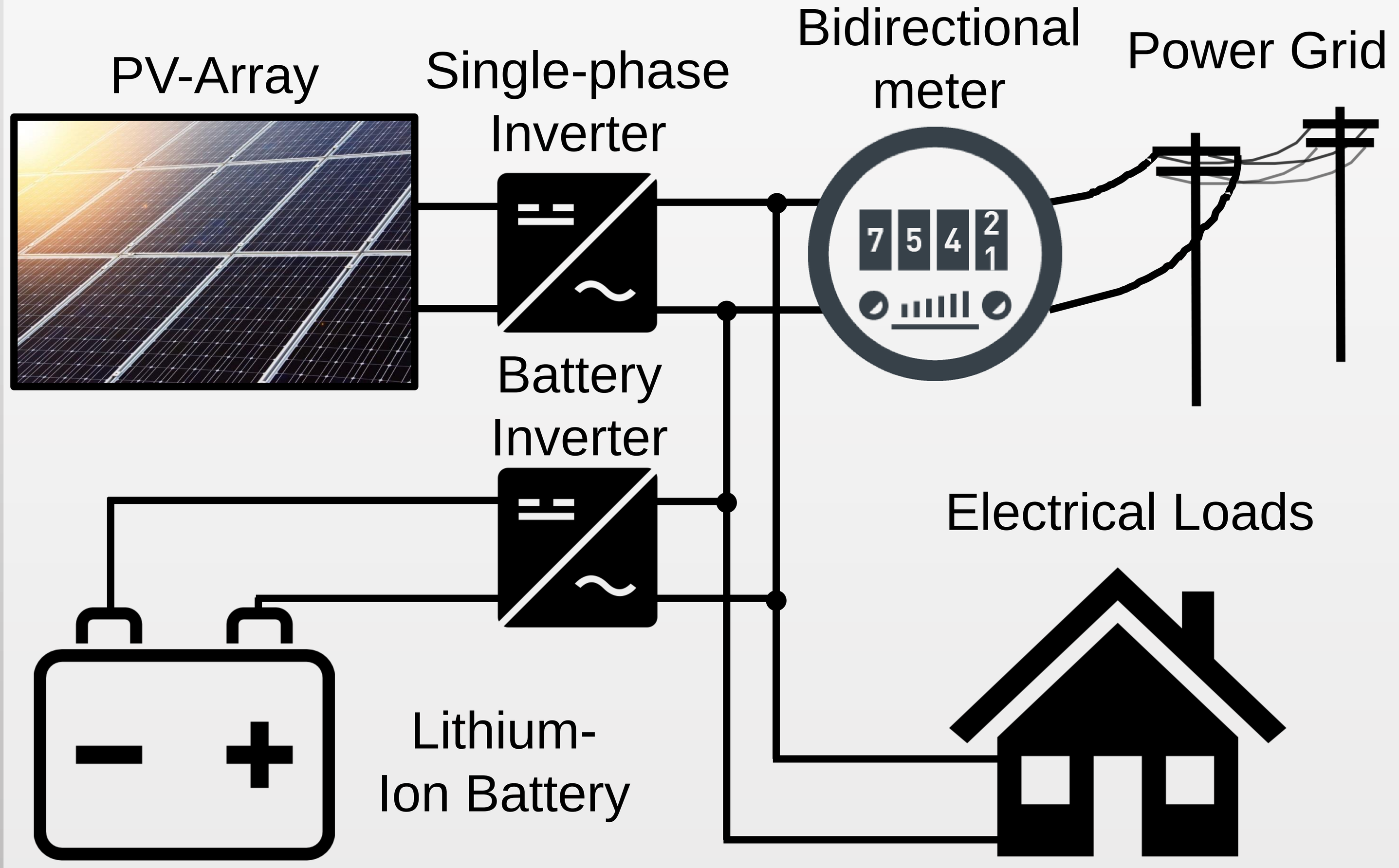
Objective

By optimizing the sizes of PV array and battery storage, the project intends to

- Minimize the system's annualized cost and maximize the self sufficiency;
- Set up a foundation for prototyping a software tool for residential PV-battery system design.



Methodology

MATLAB was used for:

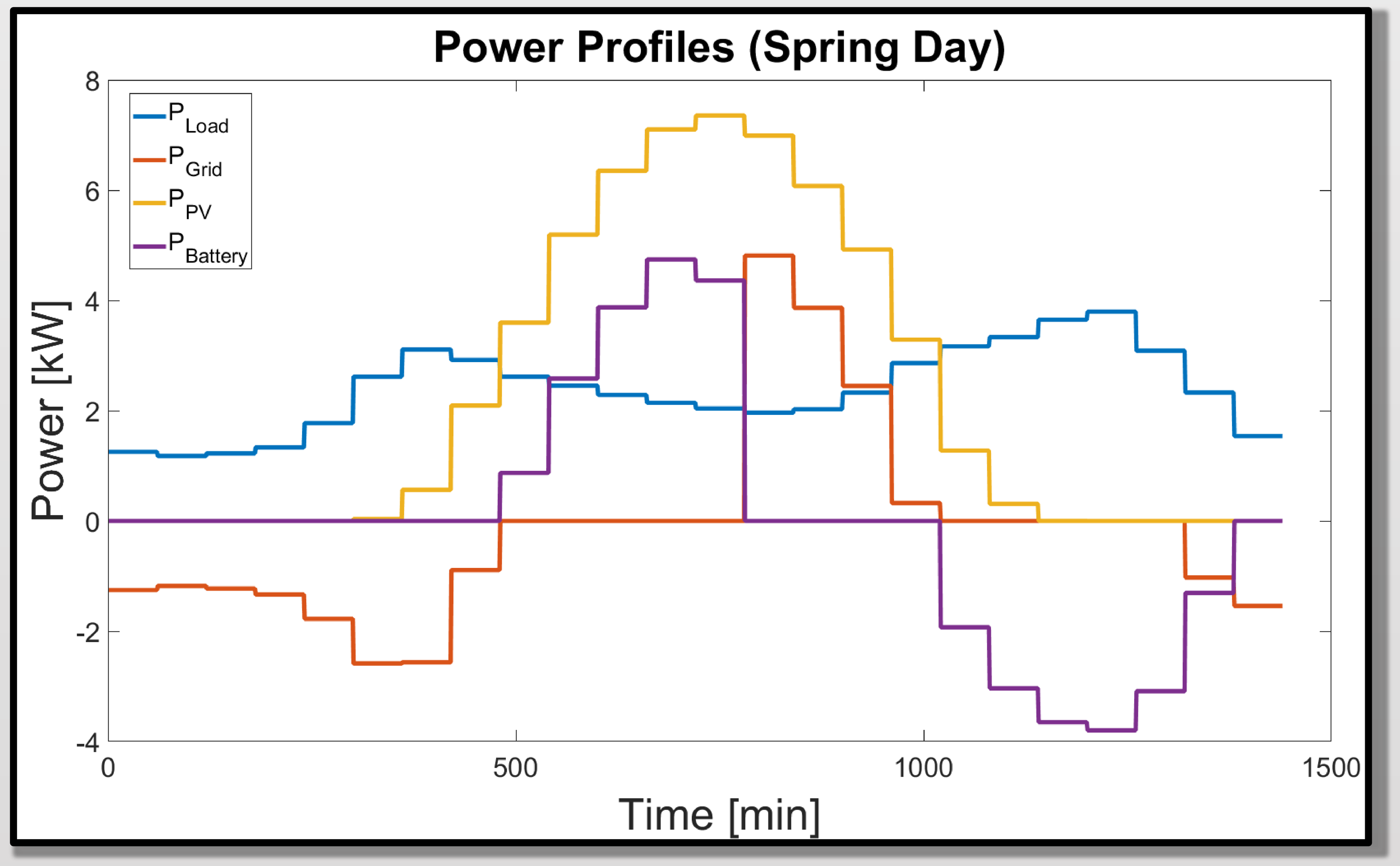
- Single-diode PV cell performance modeling and lithium-ion battery charging and discharging;
- Conventional power management strategy (PV power is used directly for the load first. Surplus energy is charged to the battery or exported to the power grid. Deficit power not satisfied by the PV-system is imported from the grid.);
- Representative load profiles for single-family detached houses, typical metereorological year weather data, and residential tariff structure in Charlotte;
- Iterative simulation of different combinations of PV (1.25 ~ 37.5 kW_p) and battery (2.12 ~ 106 KWh) sizes;
- Investigation of two scenarios with different battery costs.

Parameters	Life (Year)	Battery Price ($/kWh)	PV-Module Price ($/$kW_p$)	Discount Rate (%)	Electricity Price ($/kWh)
Values	25	500 (100)	0.64	5	0.112

Results and Outlook

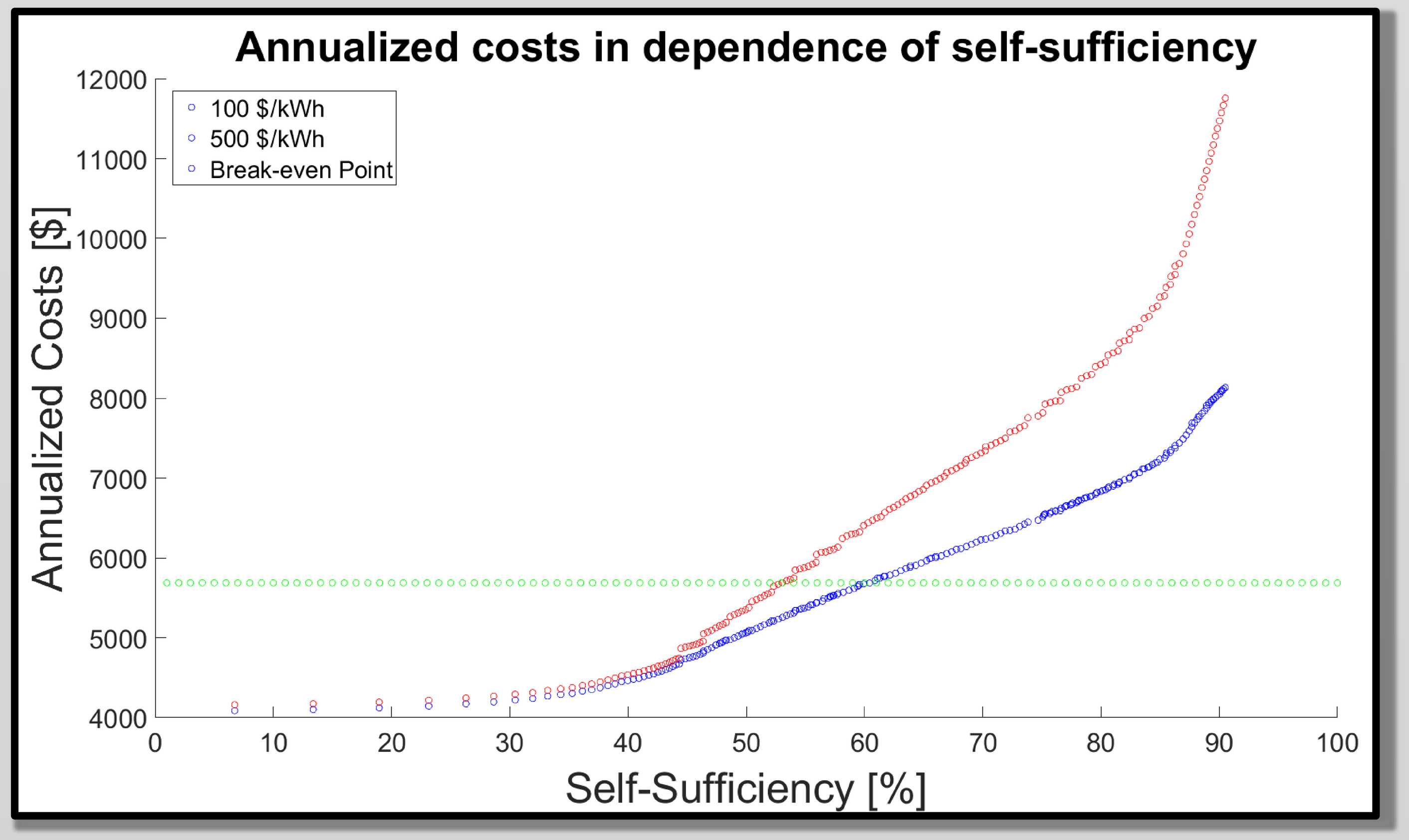
Major findings:

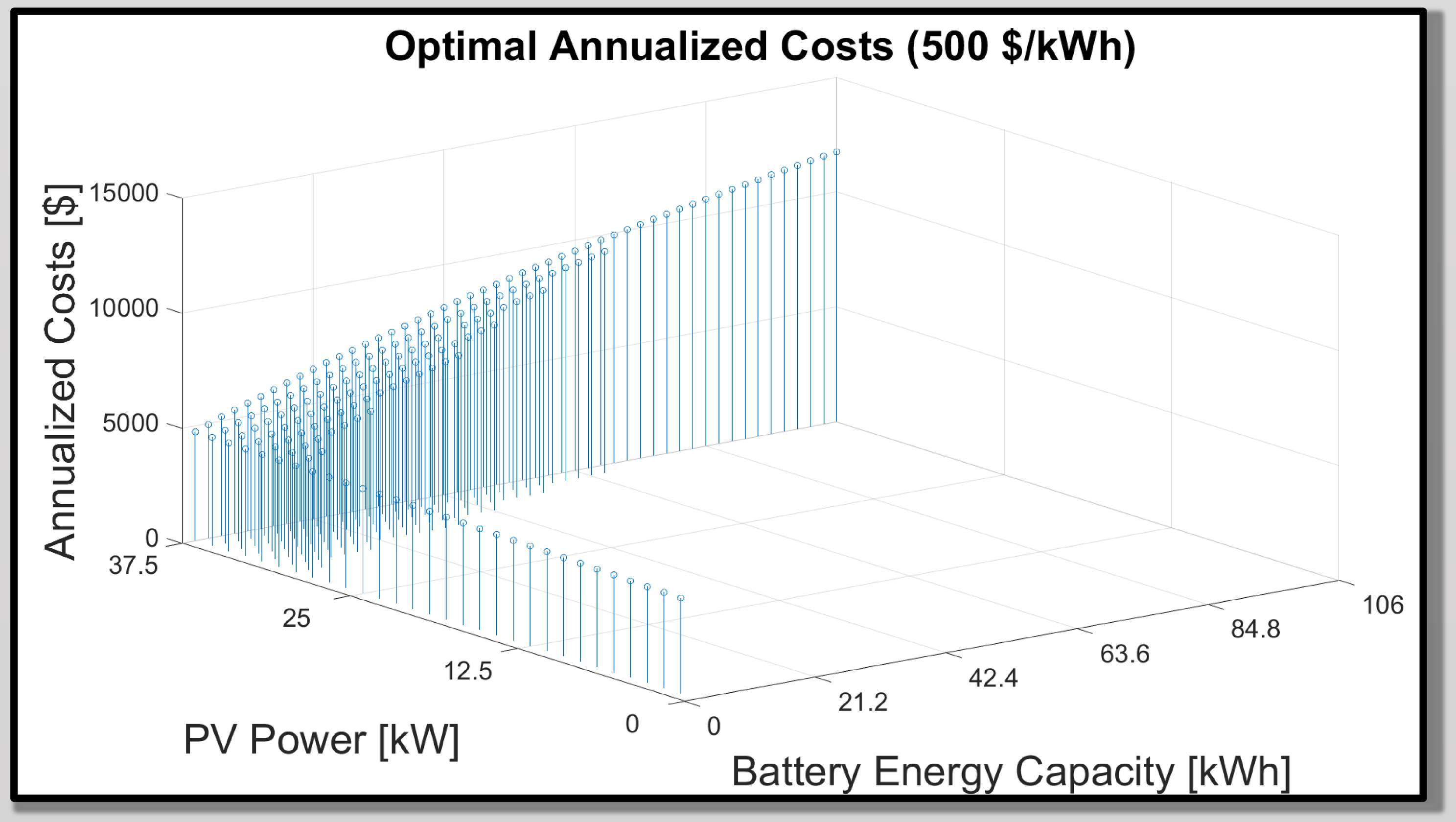
- For the optimal solutions with lower annualized cost (<$4744), the smallest battery size is used; the self sufficiency increases gradually with the PV array size.
- More battery is needed to achive self sufficiency more than 44.32%. The annualized cost increases significantly with battery size.
- The break even point has 32.5 kW PV and 12.7 kWh battery if the battery costs $500 per kWh, and 28.7 kW PV and 23.3 kWh battery if the battery costs $100 per kWh;



Future work:

- Techno economic assessment of PV-battery systems with different tarif structure, electricity prices, load profiles, and etc.
- Consider PV module title and orientation in the optimization problem.





References

[1] X. H. Nguyen and M. P. Nguyen, "Mathematical modeling of photovoltaic cell/module/arrays with tags in Matlab/Simulink", Environmental Systems Research 2015, 4:24.

[2] K. Ardani, E. O´Shaughnessy, R. Fu, C. McClurg, J. Huneycutt and R. Margolis, "Installed Cost Benchmarks and Deployment Barriers for Residential Solar Photovoltaics with Energy Storage: Q1 2016", 2016. Technical Report, NREL.

[3] J. Weniger, T. Tjaden and V. Quaschning, "Sizing of residential PV battery systems", Energy Procedia, 2014, 46: 78-87.

[4] M. Bortolini, M. Gamberi, A. Graziani, "Technical and economic design of photovoltaic and battery energy storage system", Energy Conversion and Management, 2014, 86: 81-92.

[5] R. Hendron and C. Engebrecht, "Building America House Simulation Protocols", Technical Report - U.S. Department of Energy, 2010.