Title
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Authors
Gerber, Daniel
Vossos, Evangelos
Feng, Wei
et al.

Publication Date
2017-06-27

Peer reviewed

The 2nd IEEE International Conference on DC Microgrids

June 27-29, 2017 Nürnberg, Germany

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A Simulation Based Comparison of AC and DC Power Distribution Networks in Buildings

Daniel Gerber, Vagelis Vossos, Wei Feng, Aditya Khandekar, Chris Marnay, Bruce Nordman

dgerb@berkeley.edu

Berkeley, CA, USA

Simulation, Emulation, and Analysis of Microgrids

International Conference on DC Microgrids

IEEE POWER ELECTRONICS SOCIETY

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Motivation

- Solar PV generation, battery storage, and most loads are natively DC
- How much efficiency savings with DC building distribution?
- Particularly relevant for Zero Net Energy (ZNE) and microgrid buildings

Research Goal

- Determine how much efficiency savings with DC distribution
- Modeled buildings for study
  - Medium sized office building (50m X 33 m, 3 floors)
  - Los Angeles, CA, USA

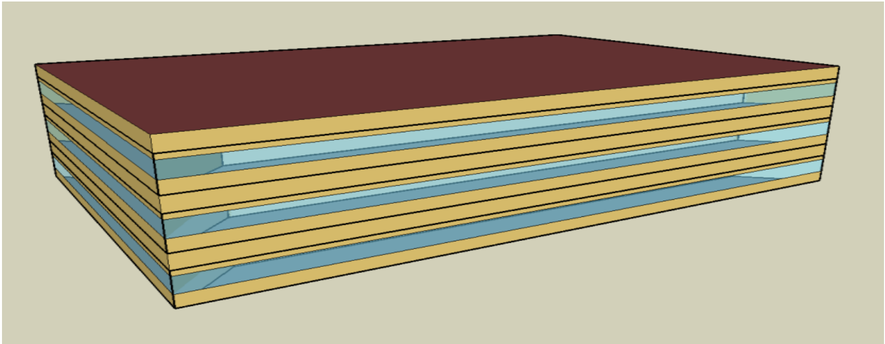
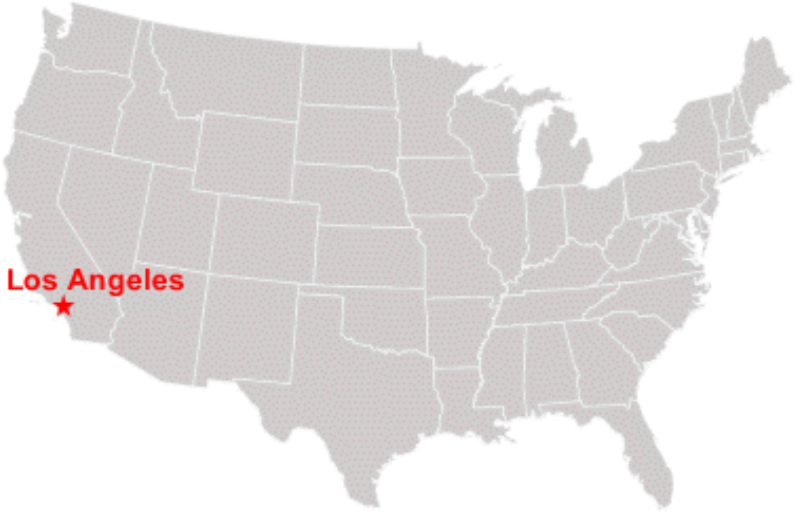
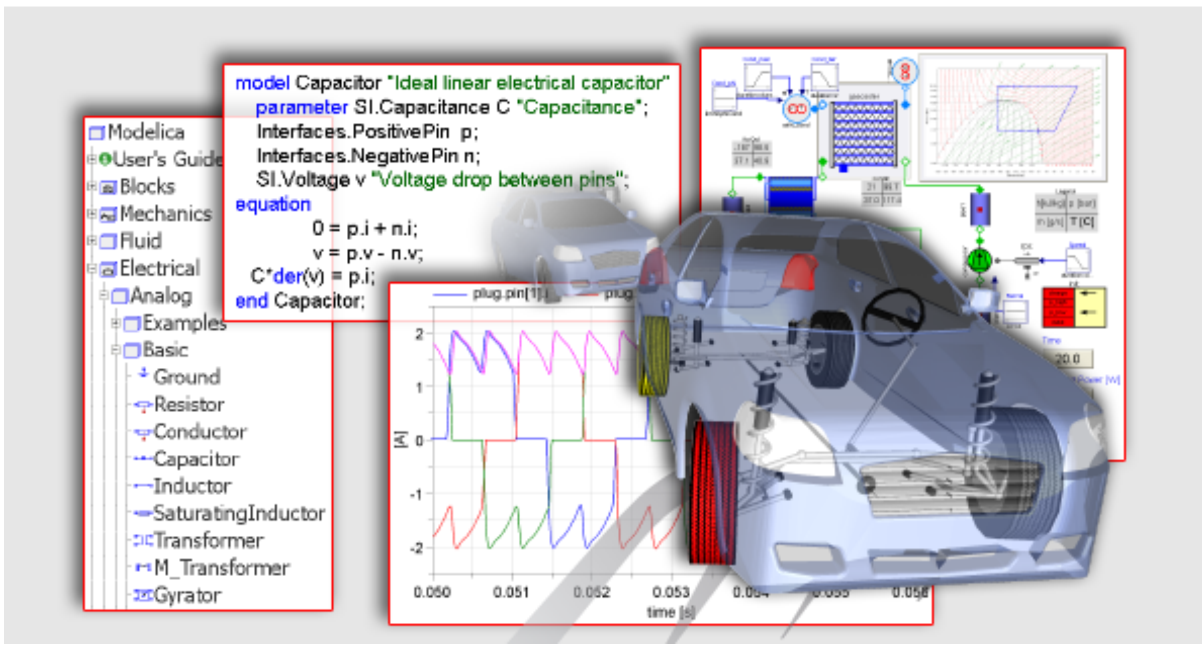


Image of PNNL model of medium office building

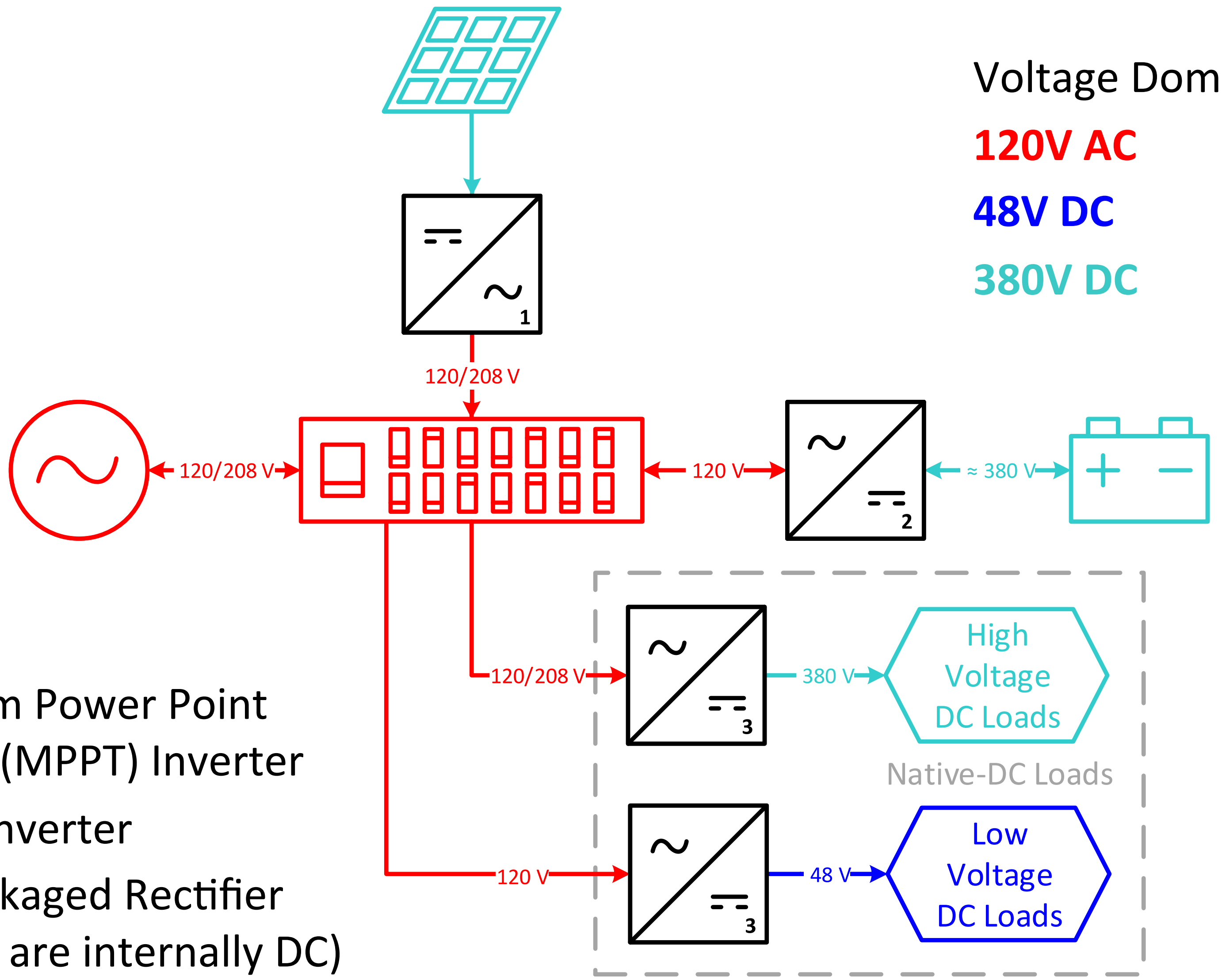


Modelica

- Object oriented modeling language
- Useful for complex systems that span electrical, mechanical, etc. domains
- GUI provided by Dymola or Open Modelica
- Popular for building and automotive simulations



Office Building with AC Distribution



Voltage Domains:

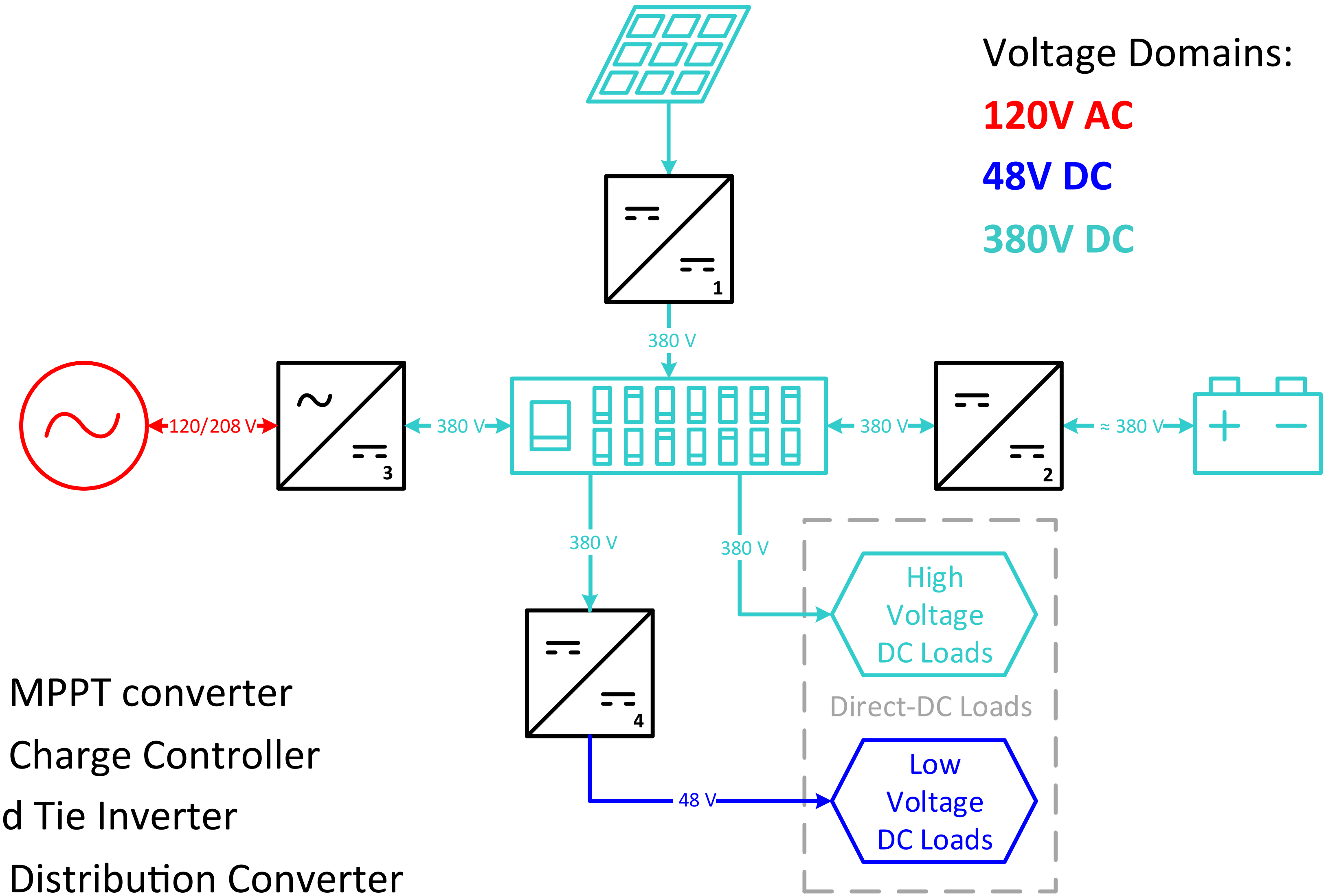
120V AC

48V DC

380V DC

1. Maximum Power Point Tracking (MPPT) Inverter
2. Battery Inverter
3. Load Packaged Rectifier (all loads are internally DC)

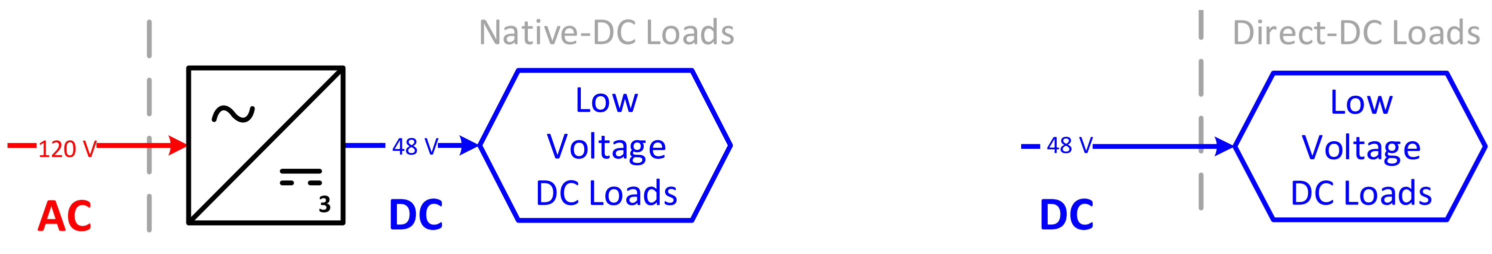
Office Building with DC Distribution



1. DC MPPT converter
2. DC Charge Controller
3. Grid Tie Inverter
4. DC Distribution Converter

Load Models

- All loads are DC or have internal DC stage
- AC building: loads are native/internal DC
  - All loads require load-packaged rectifier
- DC building: loads are direct DC
  - Lighting requires LED driver
  - HVAC (VFD motors) and plug loads assumed to be able to interface directly with DC distribution lines
- Load profiles are from Energy Plus



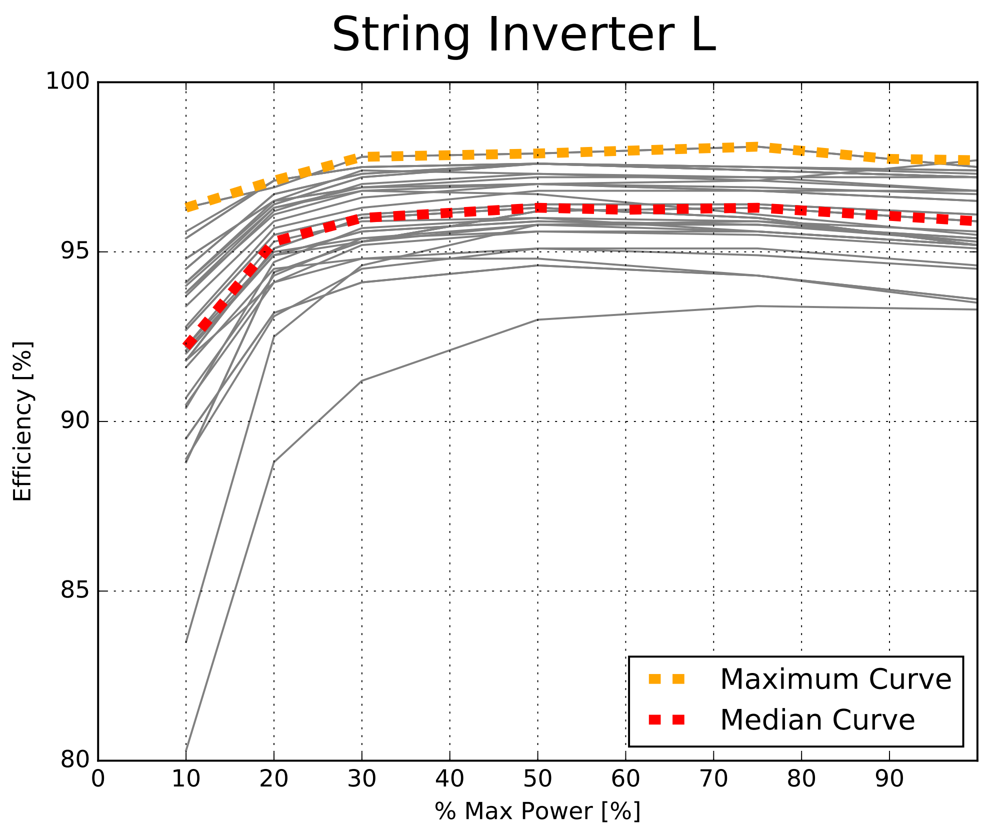
AC Building

DC Building

Converter Models

AC Product	CEC Efficiency
String Inverter	96.0%
Battery Inverter	92.1%
Low Power Rectifier	89.9%
High Power Rectifier	90.8%
AC LED Driver	90.2%

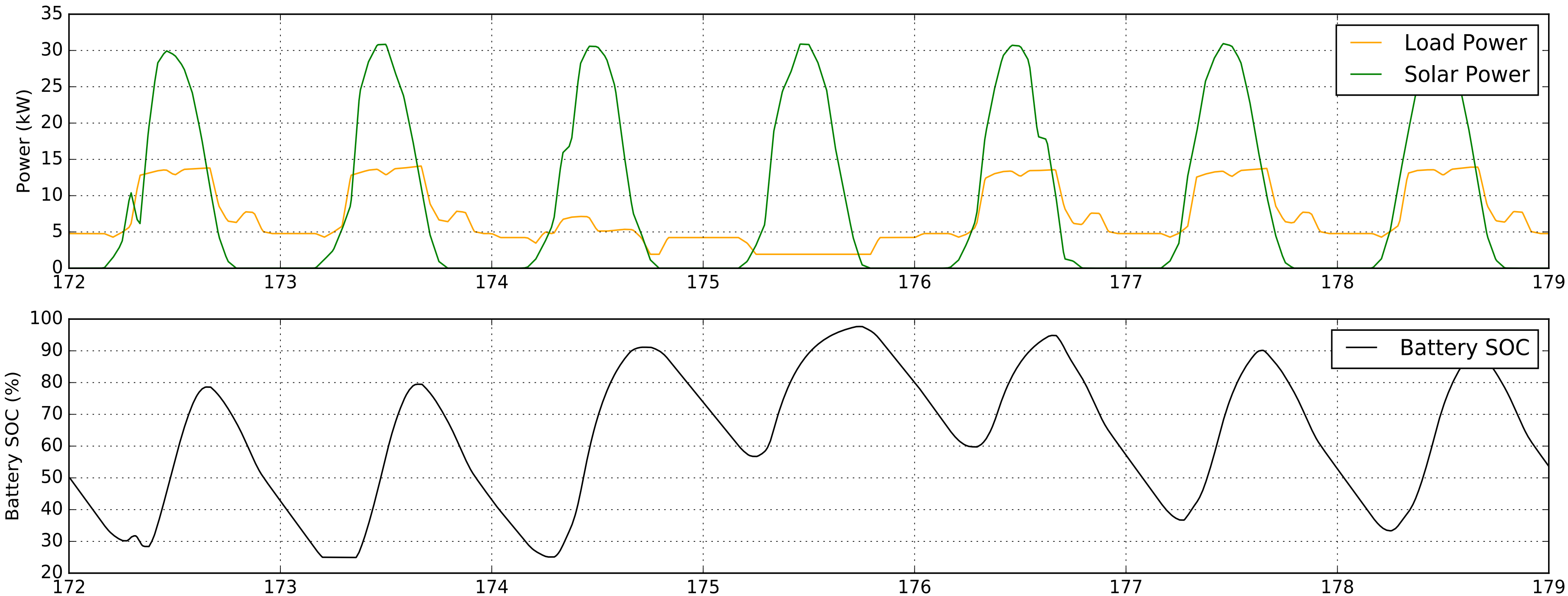
DC Product	CEC Efficiency
Power Optimizer	99.4%
MPPT Chg. Controller	98.5%
DC-DC Transformer	97.6%
Grid Tie Inverter	96.6%
DC LED Driver	95.6%



- Converters represent the most significant power loss
- Loss is based on efficiency curves obtained from manufacturer product data
- Power quality is not modeled in this study

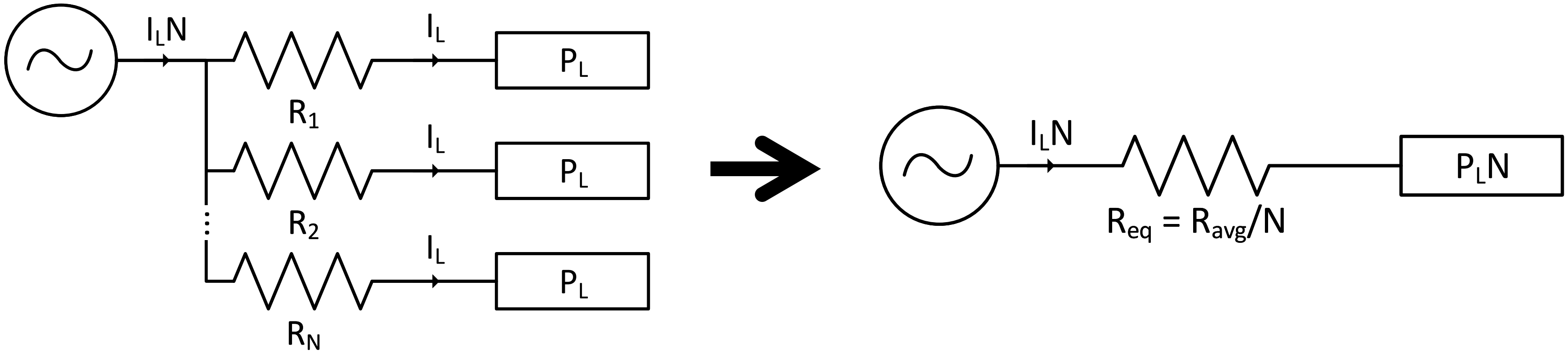
Battery Model

- $P_{excess} = P_{solar} - P_{load}$
- Charge battery when excess $P_{excess} > 0$
- Discharge battery when $P_{excess} < 0$
- Algorithm does not account for grid tariffs or multistage charging

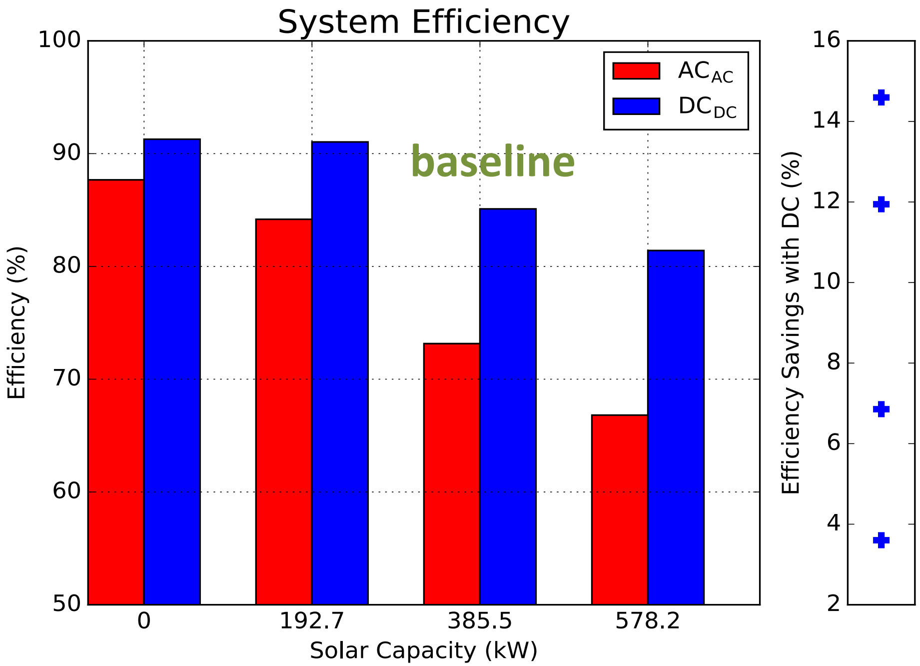


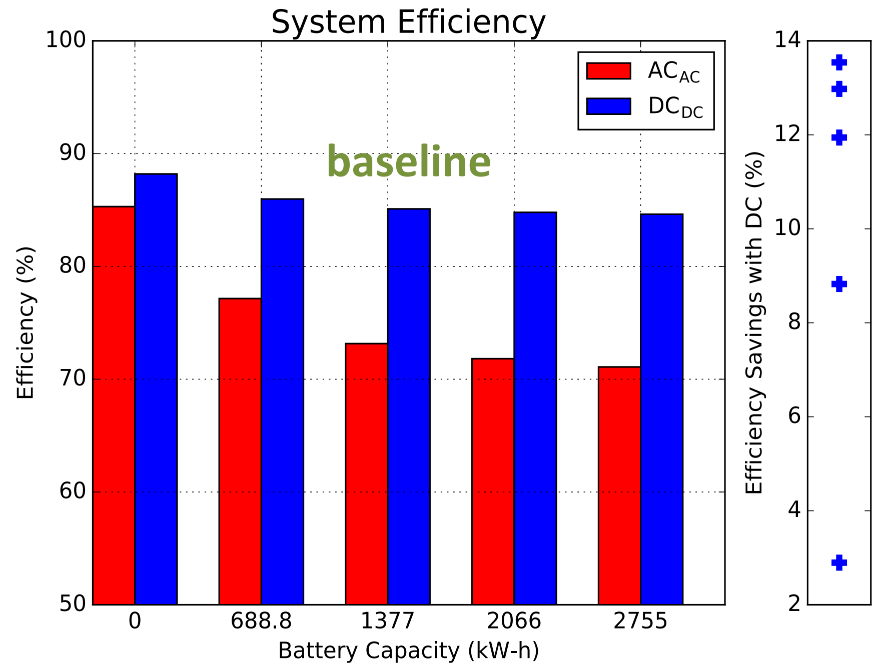
Wire Model

- Model resistive losses as lumped resistance
- Wire gauge from expected load ampacity
- Wire length modeled by geometric methods



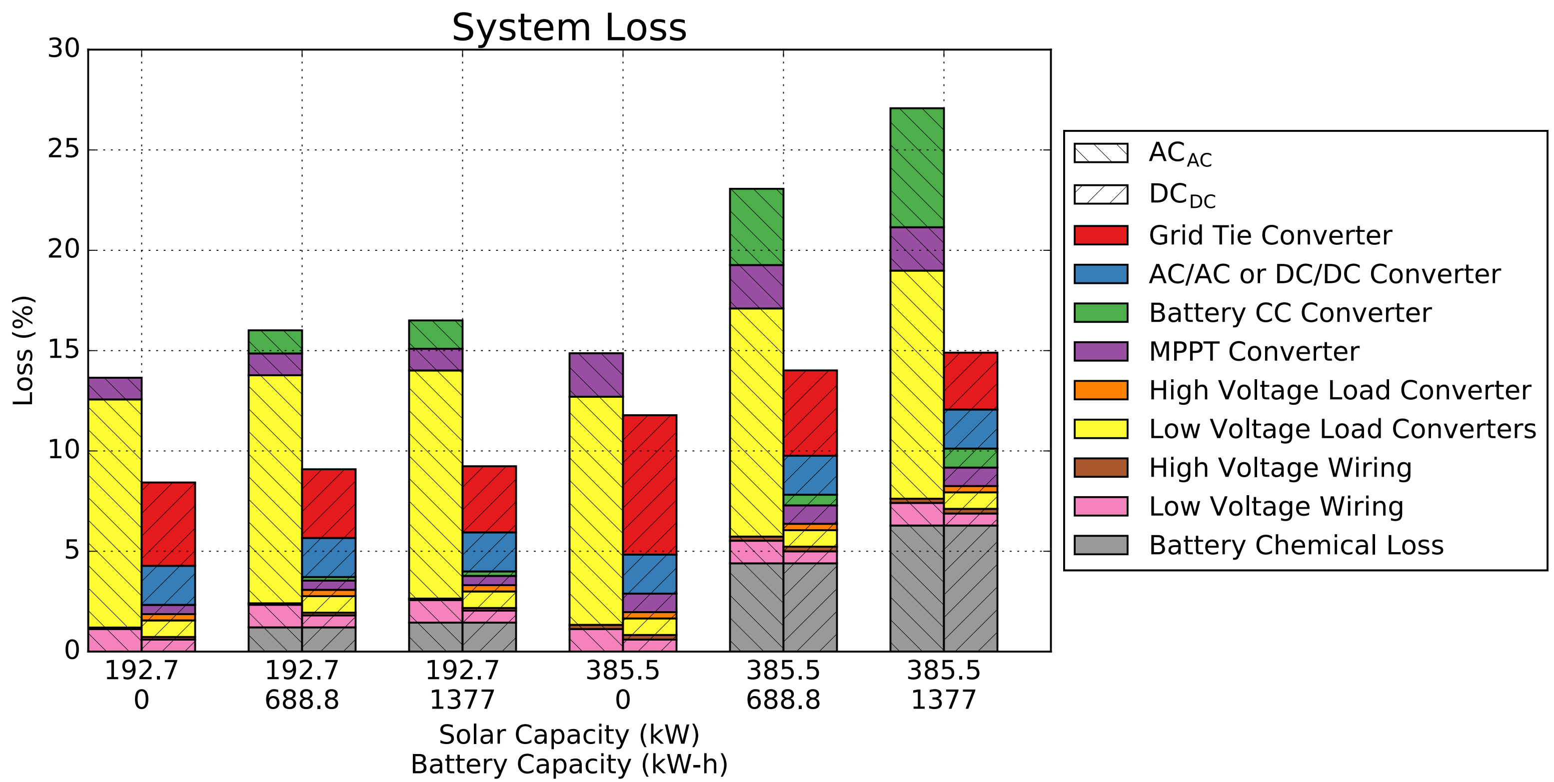
Efficiency Results





- Efficiency for annual simulation: 1 – (Total Loss / Total Load)
- Efficiency savings with DC increases with solar capacity and battery capacity
- Baseline parameter values
  - 390 kW solar capacity – amount required for ZNE
  - 1380 kW-h battery capacity – 50% of amount required to store all excess solar on sunniest day

Loss Analysis



- AC building loss dominated by **load packaged rectifiers** and **battery inverter**
- DC building loss dominated by **grid tie inverter**
- Both buildings suffer **battery chemical loss**

Techno Economic Analysis

TABLE II. LCC AND PBP RESULTS FOR BASELINE SCENARIO

Description	Network	Value
Total Installed Cost ($)	AC_{AC}	252,098
	DC_{DC}	301,155
Net Annual Electricity Consumption (kWh/yr)	AC_{AC}	176,775
	DC_{DC}	100,656
Average LCC Savings ($)	AC_{DC} vs. DC_{AC}	61,487
% Cases with Net Benefit - DC Network	AC_{DC} vs. DC_{AC}	>90%
Average PBP - DC Network (Years)	AC_{DC} vs. DC_{AC}	0.7

$$LCC = Total\ Installed\ Cost + Lifetime\ Operating\ Cost$$

$$PBP = \frac{Installed\ Cost_{DC\ System} - Installed\ Cost_{AC\ System}}{Operating\ Cost_{AC\ System} - Operating\ Cost_{DC\ System}}$$

Thank you!