Comparison of AC versus DC Distribution in Commercial Building Nanogrids

### Research Objective
- research & demonstrate technical viability of DC building distribution
- focus on low (< 600) voltage DC in commercial buildings
- direct integration of renewable sources and batteries
- simulate and measure potential energy efficiency & economic benefits
- evaluate communication opportunities

### Alternating Current
- the building power we’re all accustomed to
- has huge advantage of easy voltage changes
- enables long distance transmission with local safety
- voltage and current cycles at fixed frequency
- when working well, energy is always being delivered
- approach is closely related to rotating generators
- has many power quality problems, e.g., power factor
- has few advantages at end-use, but induction motors
- end-use rectification to DC common and increasingly efficient

### Direct Current
- the vehicle power we’re all accustomed to
- many efficient DC loads (LEDs, variable speed motors, etc.)
- many power sources (PV, batteries) also DC
- less losses and power quality issues with all DC distribution
- simpler systems should be cheaper, more reliable & resilient
- creates a favorable environment for PV integration & EVs
- EVs and heat pump heating/cooling are significant DC loads
- safety and other standards needed and a formidable barrier
- easy connection to electronics permits smart distribution

### Analysis Approach

#### Motivation
- new California residential buildings to be ZNE by 2020
- all commercial buildings by 2030
- solar PV generation, batteries, and most loads natively DC
- many efficient DC devices should be encouraged
- less power quality problems & improved reliability/resilience with DC
- buildings, microgrids, and small- to medium-sized DC distribution systems

#### Research Goal
- use Modelica simulations to determine efficiency improvements
- estimate economic benefits of DC distribution
- model medium size Los Angeles office and other buildings
- include realistic profiles for solar output and load
- use converter efficiency curves, and detailed battery and wiring models

#### Modelica
- object oriented modeling language with GUI provided by Dymola
- popular for building, automotive, and other engineering simulation
- useful for complex systems that suffer significant power quality problems & improved reliability

#### Parametric Experiments
- solar experiment – baseline is amount of solar capacity needed to power a ZNE building
- battery experiment – baseline is half the amount of battery capacity needed for a ZNE building to store all daily excess solar power (generation – load)

#### Efficiency Results
- 12% baseline efficiency savings with DC
- DC is more efficient with high solar and battery capacity

#### Results

- DOE Reference Building Model of Medium Office in Los Angeles, CA
- IBEW ZNE Building, San Leandro CA

#### IBEW ZNE Building, San Leandro CA

- The DC analysis model is used to scope the feasibility of DC distribution in a ZNE office building. The simulations are run with actual solar and load profile data, along with precise building wiring.

#### Techno-Economic Analysis
- results determined from market cost data, grid tariffs, and Monte-Carlo analysis
- first cost is higher for DC
- given the enormous efficiency savings, the payback period is less than a year
- end use costs, installation costs, and other soft costs not considered in techno-economic analysis

### Future Research

#### Experimental and Field Testing
- experimentally estimate efficiency savings of identical AC vs. DC networks
- verify the savings of removing the rectification stage in various loads
- design and construct a DC microgrid, meter and measure the savings
- collaborate with DC demonstrations in Europe and Asia

#### Analysis and Modeling
- develop a generic DC efficiency modeling tool for commercial use
- improve the techno-economic analysis and create future projection models
- develop advanced control algorithms for load shedding in DC buildings
- study the non-energy benefits of DC for power quality, resiliency, etc.

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### Abbreviations & Acronyms
- CECE – California Energy Commision
- EV – electric vehicle
- GUI – graphical user interface
- LCC – life cycle cost
- DOE – U.S. Department of Energy
- ZNE – zero net energy

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