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A glimpse of the bipolar DC microgrid research at EnergyVille

Microgrid Symposium 2019
Fort Collins
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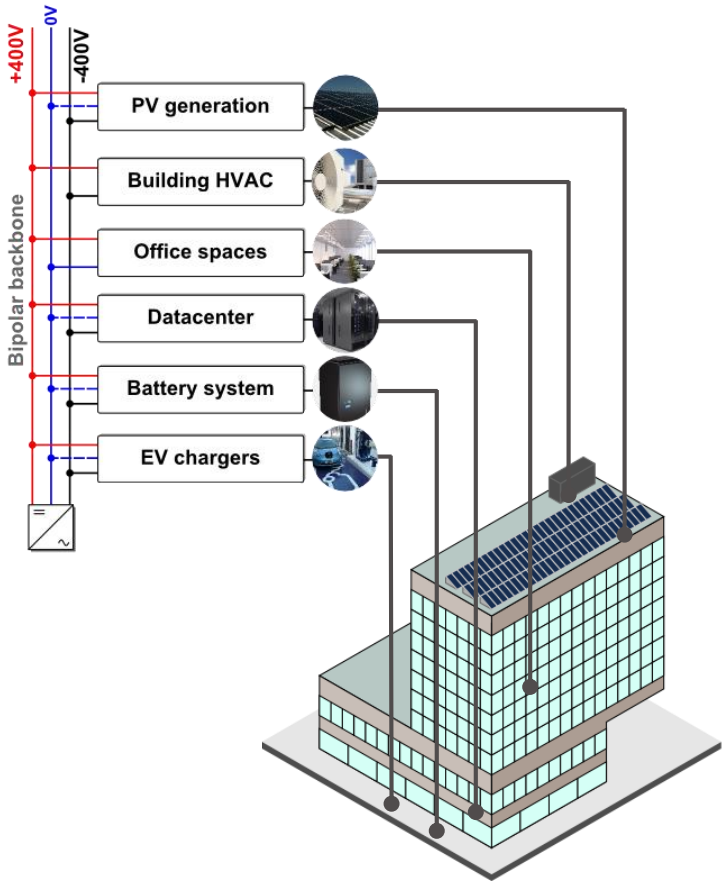
Why bipolar LVDC microgrids?



- Moviation for LVDC distribution systems
  - Compatibility with DC devices
  - Increased power transfer capability
  - Increased controllability
- Motivation for bipolar LVDC [1-4]
  - Increased power transfer capability
  - Two voltage levels available
  - Conduction losses are reduced
  - Potentially more reliable
  - But: voltage balancing converters required

[1] G. Van den Broeck, S. De Breucker, J. Beerten, M. Dalla Vecchia, and J. Driesen, "Analysis of Three-Level Converters with Voltage Balancing Capability in Bipolar DC Distribution Networks," in International Conference on DC Microgrids, 2017, 8 pages.
[2] H. Kakigano, Y. Miura, and T. Ise, "Low-voltage bipolar-type DC microgrid for super high quality distribution," *IEEE Trans. Power Electron.*, vol. 25, no. 12, pp. 3066–3075, Dec. 2010.
[3] J. Lago, J. Moia, and M. Heldwein, "Evaluation of power converters to implement bipolar DC active distribution networks—DC-DC converters," in *Energy Conversion Congress and Exposition (ECCE)*, 2011, pp. 985–990.
[4] T. Dragicevic, X. Lu, J. Vasquez, and J. Guerrero, "DC Microgrids–Part II: A Review of Power Architectures, Applications and Standardization Issues," *IEEE Trans. Power Electron.*, vol. 8993, no. 99, pp. 1–1, 2015.

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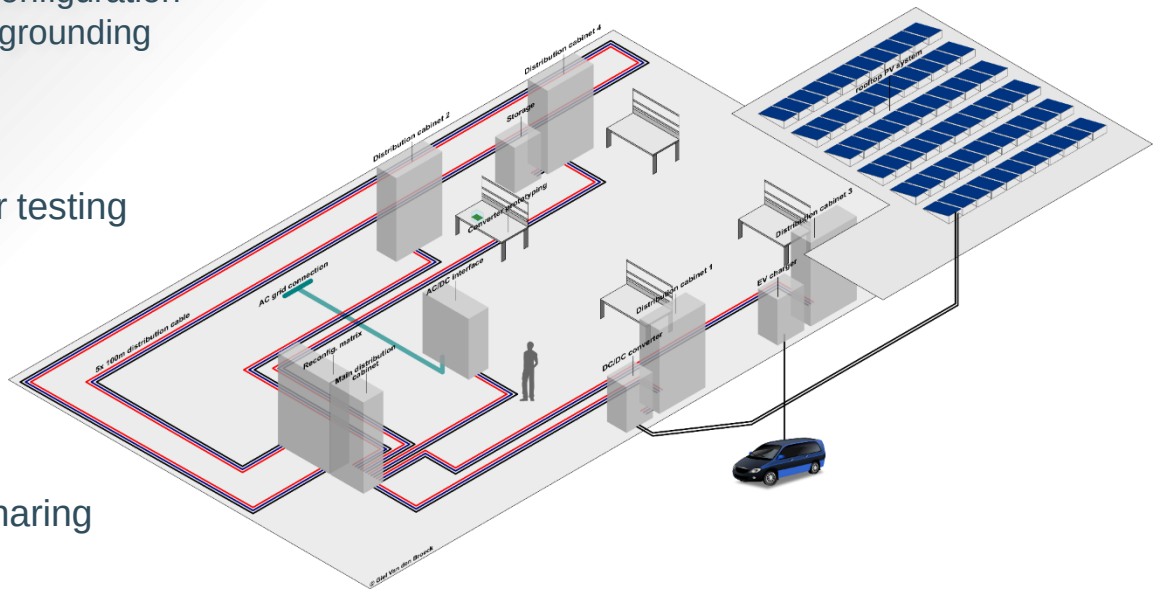
The EnergyVille LVDC lab

- Lab infrastructure
  - 100 kW (up to ±500V) DC test grid
    - Unipolar and bipolar configuration
    - TN-S grounding or IT grounding
    - **Reconfigurable**
  - Power flow monitoring
  - Voltage measurements
  - Power electronic converter testing
  - Communication interfaces
  - Connected to other labs
    - Rooftop PV test site
    - Battery laboratory
    - EV Parking
- Tests
  - Voltage stability - power sharing
  - Protection systems
  - Equipment interoperability
  - Efficiency assessment



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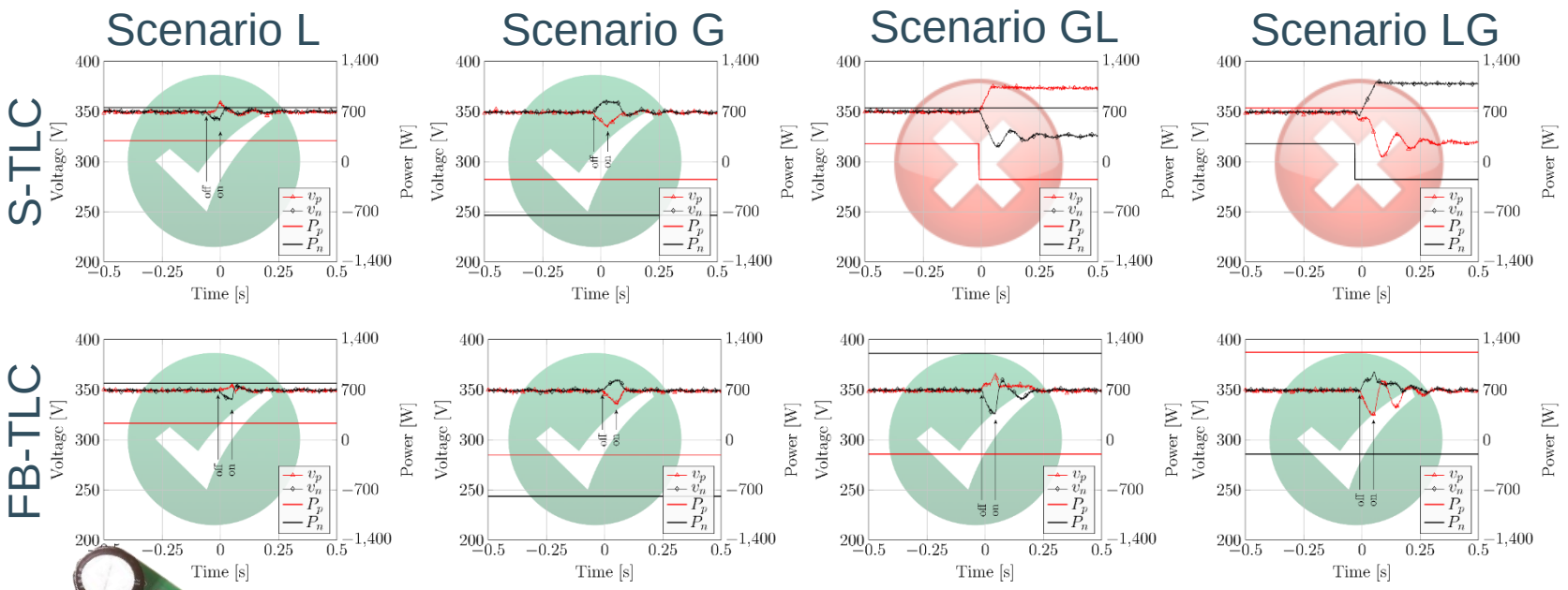
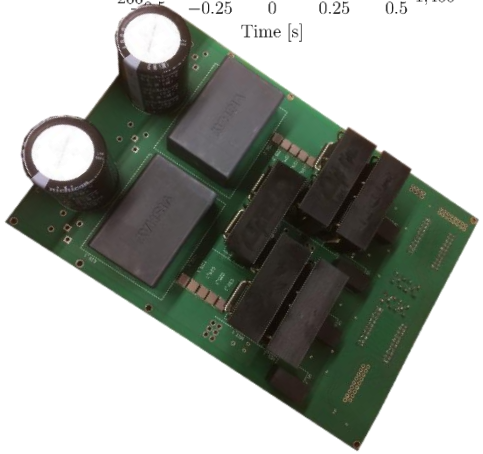
Power converters for voltage balancing





[1] G. Van Den Broeck, S. De Breucker, J. Beerten, J. Zwysen, M. Dalla Vecchia, and J. Driesen, “Analysis of three-level converters with voltage balancing capability in bipolar DC distribution networks,” in *2017 IEEE 2nd International Conference on Direct Current Microgrids, ICDCM 2017*, 2017.

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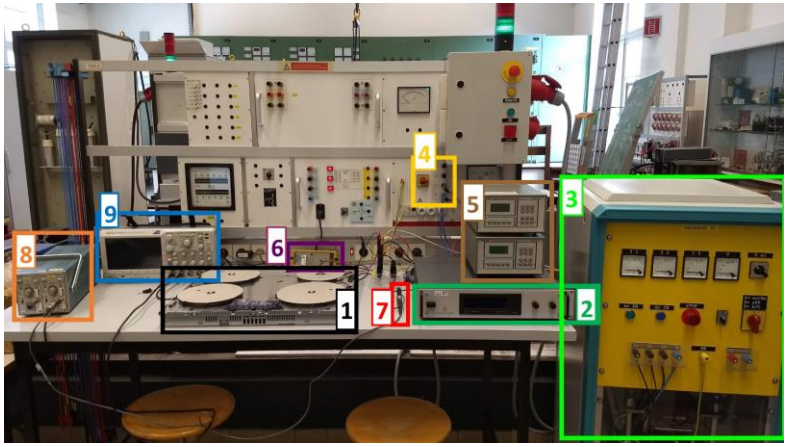
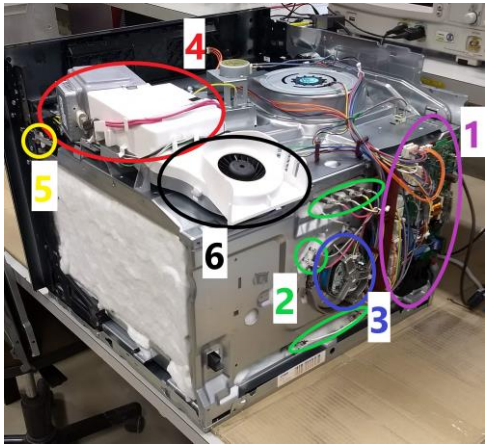
Are domestic appliances DC compatible?





- Definitely a potential to make existing appliances DC compatible
- Although hardware can be DC compatible, firmware can still generate errors
- Precaution with auxiliary components (door contacts, relays, etc.) and inrush currents

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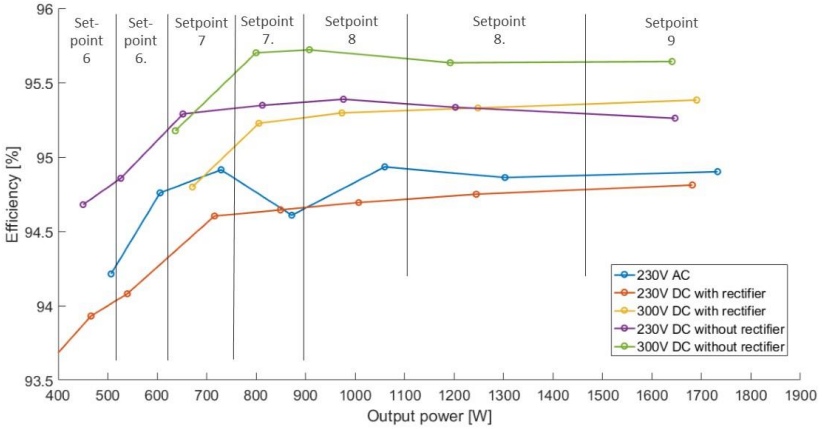
Are domestic appliances DC compatible?

- The efficiency increases
  - with the voltage level
  - without the rectifier
- There is a marginal potential for efficiency increase at the appliance-level
  - **1.06 kWh** (230Vdc w/o rectifier)
  - **1.68 kWh** (300Vdc w/o rectifier)
  - Relative to 230Vac



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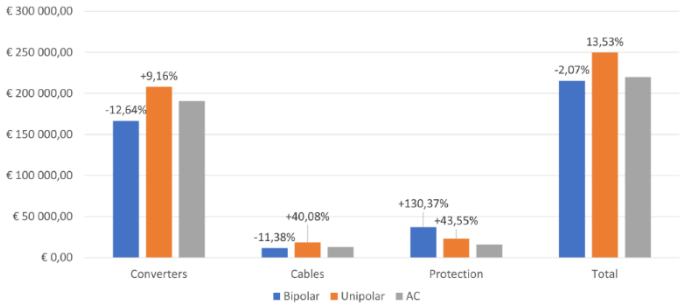
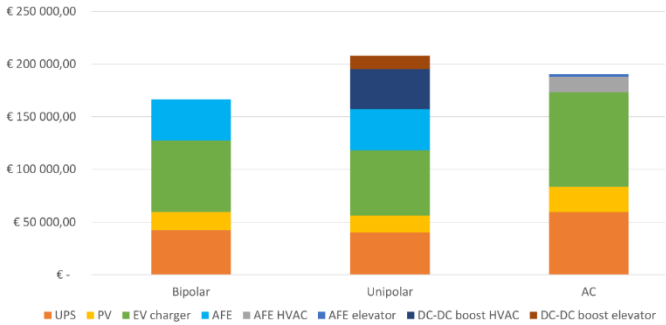
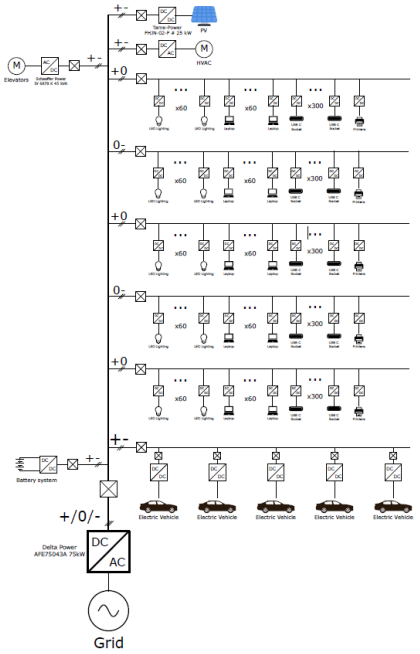
DC microgrids from an investment perspective







- Converters are the cost drivers
  - High-power devices first
- For inverter-driven loads a +600V voltage level is essential
  - Not available in the 350V or 380V unipolar configuration, so intermediate boost stages are required
- DC protection based upon commercially available devices (regardless of the protection speed) offsets the cost reduction of the converters

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Remaining challenges

- Voltage stability and control
  - Inherently intertwined with power quality (tbd)
- Protection from an availability point-of-view
- System-level interoperability

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