DC Microgrids

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Introduction

What constitutes a DC microgrid?
• Power generation – *PV, wind, fuel cells*
• Electrical storage – *batteries, super capacitors*
• Distribution – *wiring and electronic control*
• Loads – *computers, appliances, lighting*

Use cases
1. Small-scale residential
2. Remote/sparsely populated areas
3. Commercial/datacenters
Why DC microgrids?

- Put small-scale generation closer to load
- Enable demand-side management, cut grid reliance
- Efficient distribution: current in a 380Vdc grid is 61% of current in 230V single phase grid. Losses are 37% of the AC network.

Why DC microgrids?

- Many **renewable sources** generate DC, e.g.: photovoltaic, wind, fuel cells
- Fewer conversions - **increase conversion efficiency** – DC-to-AC inversion 85%; AC-to-DC rectifying: 90%; DC-to-DC conversion: 95%
- **Simpler** power-electronic interfaces, **fewer points of failure**
- **Easily stored** in batteries

Wireless residential/commercial use

- Solar PV panel [40W]
- Morningstar PS-15M wireless charge controller
- Sensors for ambient light/heat
- DC ceiling fan motor [24Vdc]
- Fluorescent light with DC dimmable ballast
- 12V battery bank

Rural electrification

• Sparsely populated areas with no/little grid connectivity

Commercial/standardized use

The "Zero Energy Building Model"

• **Occupied Space:** [24Vdc] Commercial interiors
• **Data/Telecom Centers:** [380Vdc] Hybrid use of AC and DC
• **Outdoor:** [24/380Vdc] Exterior lighting, signage, and electric vehicles
• **Building Services:** [380Vdc] HVAC, motor loads and high bay/industrial applications
Voltage levels

- Dependent on allowable/normal voltages for ICT equipment
- Guide testing for abnormal operating conditions and stress (inrush currents, load steps)

Voltage tolerance envelope for traditional AC-powered computers vs. equivalent DC curve
Voltage levels

Edited from source: NTT FACILITIES, INC.
Voltage levels

- LVDC: 5/48/380Vdc
- HVDC: electric ships and HV dc transmission (thousands of Vdc)

Multiple efforts to standardize:
- Emerge Alliance + EPRI task force
  - 380Vdc standard to cover telecom and building distribution.
- European Telecommunications Standards Institute (ETSI)
  - Standard for 400V dc distribution standard for telecom
- IEC SG4: 400Vdc (LVDC) distribution – goes up to 1500Vdc
Protection

- Voltage stability calculations and challenges are exacerbated as DC/AC distributions coexist
- Connected to the AC grid at *point of common coupling* (PCC)
- With converters with bidirectional power flow

Protection

• Local sources are often low-voltage, have different voltage amplitude and frequencies
• Need power-electronic converters

• Grounding
  – Ungrounded, high resistance grounded, or low resistance grounded
  – Grounded to +/- poles or to middle point of the converter

• Protection devices
  – Fuses: *appropriate for residential/small scale use*
  – Circuit breakers: *longer breaker operation time than AC*
  – Power-electronic protection devices: *faster than mechanical switches but higher losses*

• Protective relays and measurement

References

Guerrero – Hierarchical control

- Large conventional power systems: high inertia, inductive loads
- Power-electronics-based microgrids: no inertia, mainly resistive loads
- 1) The primary control is based on the droop method, including an output-impedance virtual loop;
- Inner control of distributed generation, adding virtual inertias and controlling output impedance
- Control loops applied to connect voltage source inverters (VSI) in parallel in uninterruptible power supply (UPS) systems to avoid mutual control wires while obtaining good power sharing. However, although this technique achieves high reliability and flexibility, it has several drawbacks that limit its application.
- 2) Secondary control restores the deviations produced by the primary control
- 3) Tertiary control manages the power flow between the MG and the external electrical distribution system.