Open DC Grid Project

2021 March

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Agenda

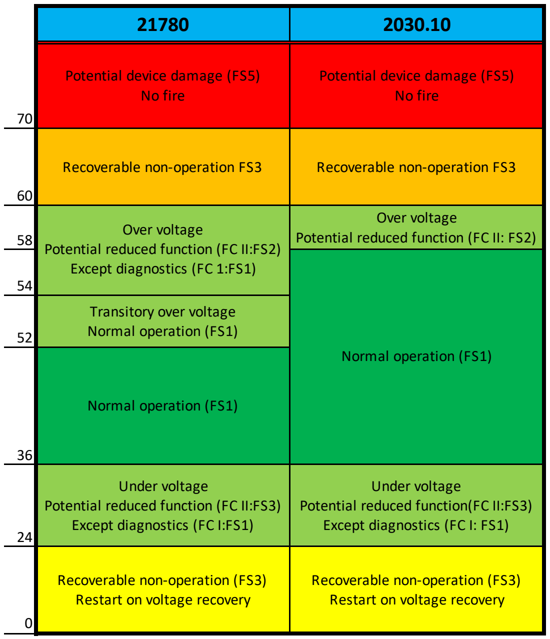
- ODG Grid Architecture
- Related Standards / Industry Developments

Conflicting Goals of Power Management

* Deliver expected power at minimal cost
  * For given expected reliability => minimize consumer cost
  * Need to consider levelized cost: fuel, capex, maintenance etc.
  * Need realistic bounds mitigated by the system
* Deliver expected power reliability
  * Meet customer expectations for predefined demand
  * Better reliability typically means higher costs
  * Possibly quantified as cost of failure – more often satisfaction
  * Defined in terms of power quality standards

Power Quality Standards

48V DC - IEEE 2030.10 / ISO 21780

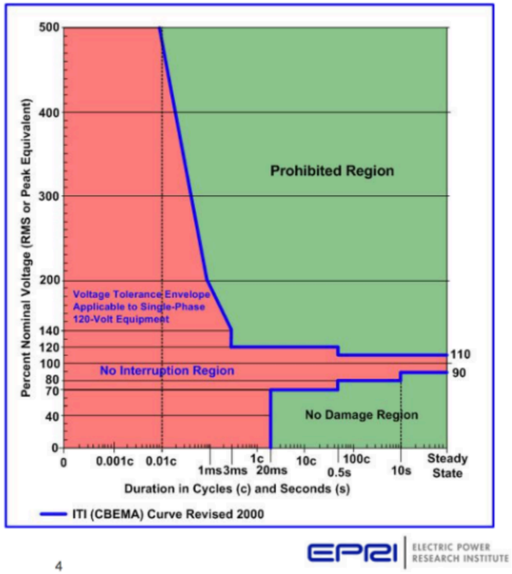


Duration (up to)	FC 1: Comm/Diag	FC II: Others	Minimum voltage
100 microseconds	FS 1	FS 1	0 V
> 100 microseconds	FS 3	FS 3	0 V
120 seconds	FS 1	FS 3	31 V
10 seconds	FS 1	FS 3	24 V

FC I: Diagnostic functions, FC II Normal functions

FS1: normal operation, FS3: degraded / off

AC Power Quality (CBEMA)



No	Parameter	Supply voltage characteristics according to EN 50160
1	Power frequency	LV, MV: mean value of fundamental measured over 10 s ±1% (49.5 - 50.5 Hz) for 99.5% of week -6%/+4% (47- 52 Hz) for 100% of week
2	Voltage magnitude variations	LV, MV: ±10% for 95% of week, mean 10 minutes rms values (Figure 1)
3	Rapid voltage changes	LV: 5% normal 10% infrequently $P_{lt} \leq 1$ for 95% of week MV: 4% normal 6% infrequently $P_{lt} \leq 1$ for 95% of week
4	Supply voltage dips	Majority: duration <1s, depth <60%. Locally limited dips caused by load switching on: LV: 10 - 50%, MV: 10 - 15% (Figure 1)
5	Short interruptions of supply voltage	LV, MV: (up to 3 minutes) few tens - few hundreds/year Duration 70% of them < 1 s
6	Long interruption of supply voltage	LV, MV: (longer than 3 minutes) <10 - 50/year
7	Temporary, power frequency overvoltages	LV: <1.5 kV rms MV: 1.7 U_c (solid or impedance earth) 2.0 U_c (unearthed or resonant earth)
8	Transient overvoltages	LV: generally < 6kV, occasionally higher; rise time: ms - µs. MV: not defined
9	Supply voltage unbalance	LV, MV: up to 2% for 95% of week, mean 10 minutes rms values, up to 3% in some locations
10	Harmonic voltage	LV, MV: see Table 2
11	Interharmonic voltage	LV, MV: under consideration

AC Power Quality – EN 50160

Layers of Power Management

* Fast transients (≈ < 10 ms)
  * Rapidly changing loads eg. Computers
  * Rapidly changing sources - PV?
* Human reaction time power allocations (≈ 100 ms)
  * Human initiated events – turning on a light
  * Motor powered devices - refrigerator
* Energy storage migration (minutes – hours)
  * Moving energy in response to human activities
  * Ensure power availability from intermittent sources / loads
* Forecasted energy / price changes (hours to days)
  * Time of use pricing
  * Night / day changes for PV, weather events
  * Predicted wind velocities for wind sources

Architecture: Mechanism versus Policy

* Mechanism – tools to implement policy +
  * Analog
    * Observed voltages, currents
    * Transfer switches, circuit breaker etc.
  * Digital
    * Communications protocols
    * Power electronics: DC-DC, DC-AC, AC-AC
  * Typically a combination of analog & digital mechanisms
  * Includes measurement, reporting, configuration etc.
* Policy – configuration / algorithm that optimizes goals
  * Battery charge/discharge setpoints
  * External power transfers as function of time, price, forecasts etc.
  * Local control and/or cloud control

ODG Grid Architecture

- Goals / features similar to LPD:
  - Microgrids should scale from very small to very large
  - Microgrids should support devices from multiple vendors
  - Microgrid architecture is independent of physical layer AC/DC, voltage etc
  - Hierarchies of microgrids are grid of the future similar to Internet
  - Digitally managed power
- Goals / features in different from LPD:
  - Microgrids do not need batteries or any other storage
  - Bus architecture is default
    - Link (P to P) is just a bus with only 2 devices
  - Supports rapid (< 1 sec) power allocation
  - Supports non-communicating loads
  - Supports most existing microgrids as a software upgrade

Practicality Goals for Microgrid

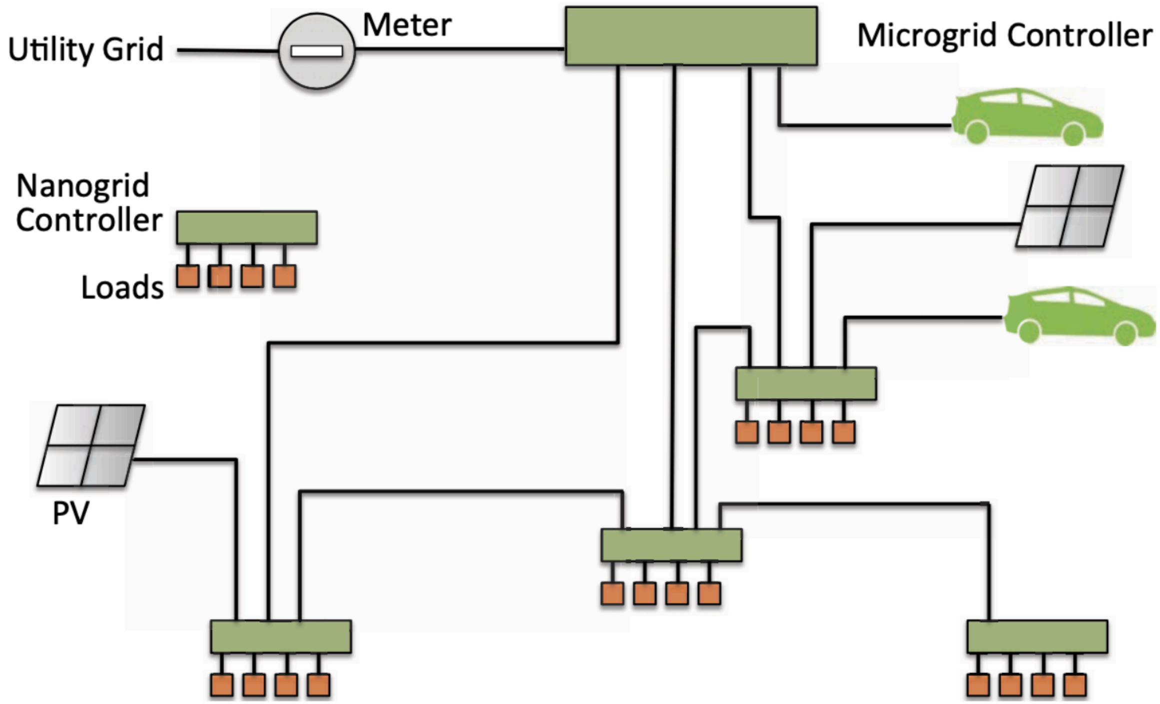
* Reliability – will it last for 50 years?
* Minimal surprises – does it behave as user expects?
* Simple installation – minimal tools, expertise
* Safe – no fires, no electrocutions

Wiring systems in US house

System	Voltage	Date Install	Install Complexity	Reliability
AC Power	110/220 AC	1972	Medium	Good until arc-fault CBs
POTS (plain old telephone)	48 DC/90 AC	1972	Low	Medium - noise problems, now largely unused
Cable TV (Coax)	RF	1972	Low	Medium - multiple upgrades
Doorbell, gate control etc	24 AC	1972	Low	Good
Wired alarm	24 AC	1972	Low, Medium	Medium - mostly sensor failures
Ethernet	RF, some POE	1996	Medium	Medium - multiple upgrades
USB, USB-PD	RF, 5-20 DC	1996	M-High	Medium - drivers, power uncertainty, connectors
PV Power	600 DC	2010	Medium	Good
HDMI	RF	2020	Medium	Poor - compatibility issues, dropouts

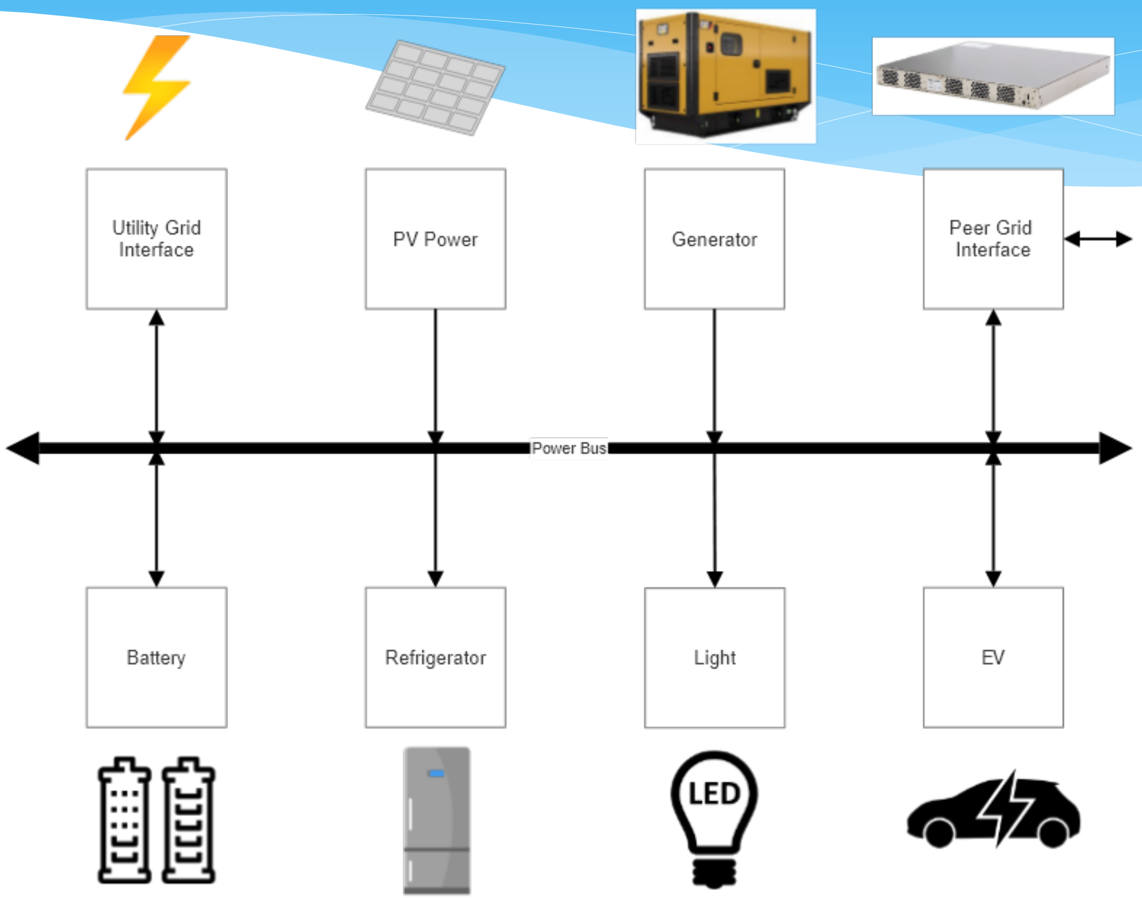
+ 5 RF nets: WIFI, Bluetooth, Z-Wave, 4G cellular, qi charging

Network Style Microgrid

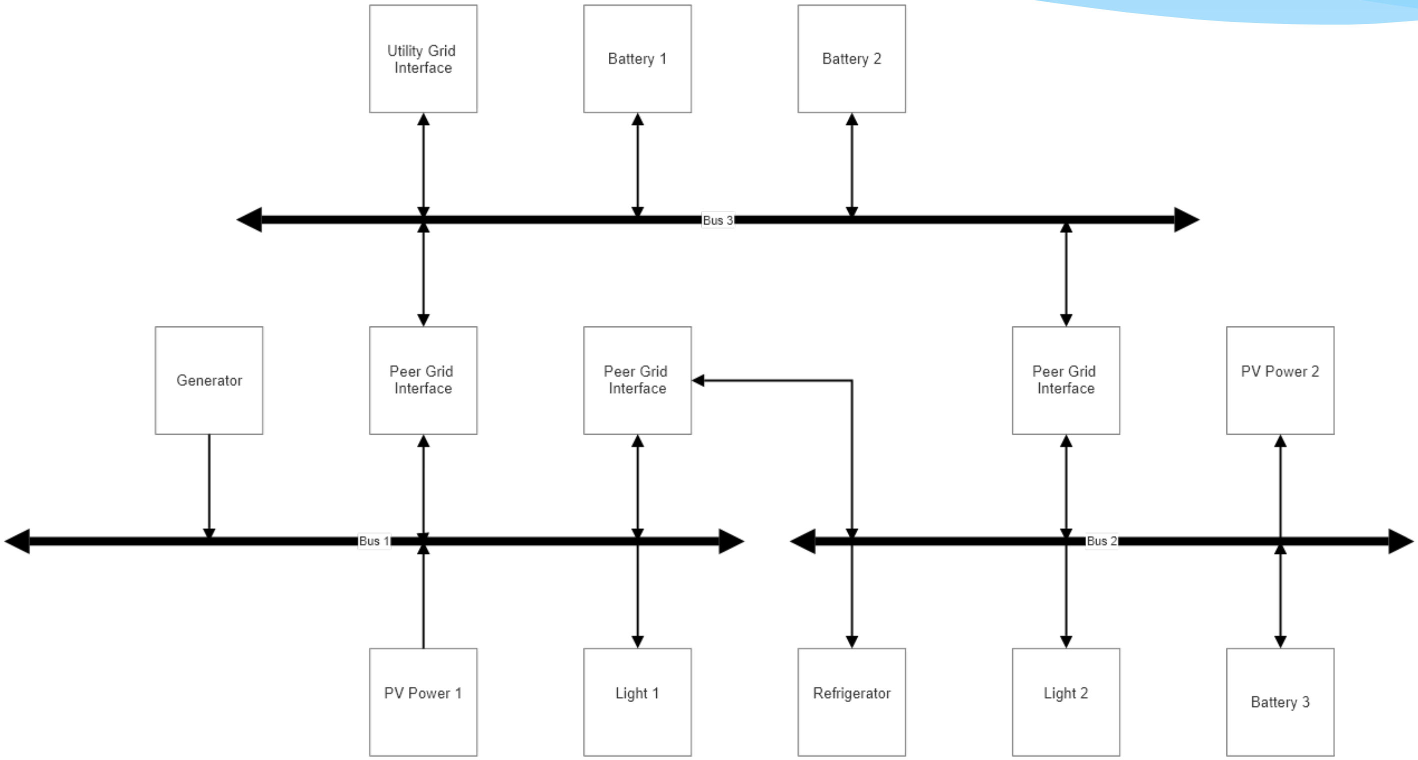


From Nordman et al.

Bus Style Microgrid



Mixed Bus/Network Microgrid



Microgrid Device

* One or more digital power ports (power + comm)
* Port power can be unidirectional or bidirectional

Bus Protocol Overview

* Device connects to bus via a port
  * Devices can have multiple ports
* Each port has a role: manager or worker
  * Ports can change roles
* Bus has one manager at a time
  * Manager role can move to a different port/device (failsafe)
* Sources should be capable of assuming the manager role
  * => Any load can attach to any source and create a 2-port microgrid
* Manager controls power on bus – sources and loads
* Bus can have static state replicated on all sources identifying dumb loads
  * Static state is manually configured by human installer
  * Dumb loads are just a fixed, static load known to all sources

Battery Issues

- Goal: multiple batteries, different types on one bus
- Goal: only switches required, voltage change not required
  - Full DC-DC conversion adds significant costs – inductors, caps, cooling
- Issue: different batteries have different charge voltages
  - Bus manager must set bus voltage to appropriate charge voltage
- Issue: controlling charge current - PWM?
  - Must keep bus noise below required limits - caps
- Issue: allocating discharge current / droop
  - Must allocate current from multiple sources – droop curve
  - Must keep discharge current within battery limits
- Potential compromises
  - All batteries same type
  - Require DC-DC conversion with mixed battery types

ODG Messages

* ODG Messages
  * Register (request / ack)
  * Request (worker to manager)
    * Allocate response (idempotent) manager to worker
  * Renegotiate (manager to worker)
  * Keep-alive (manager broadcast)
* Framed using CoAP
  * Optionally carried over layer 2 - unrouted link layer
  * Optionally carried over layer 3 – normal UDP

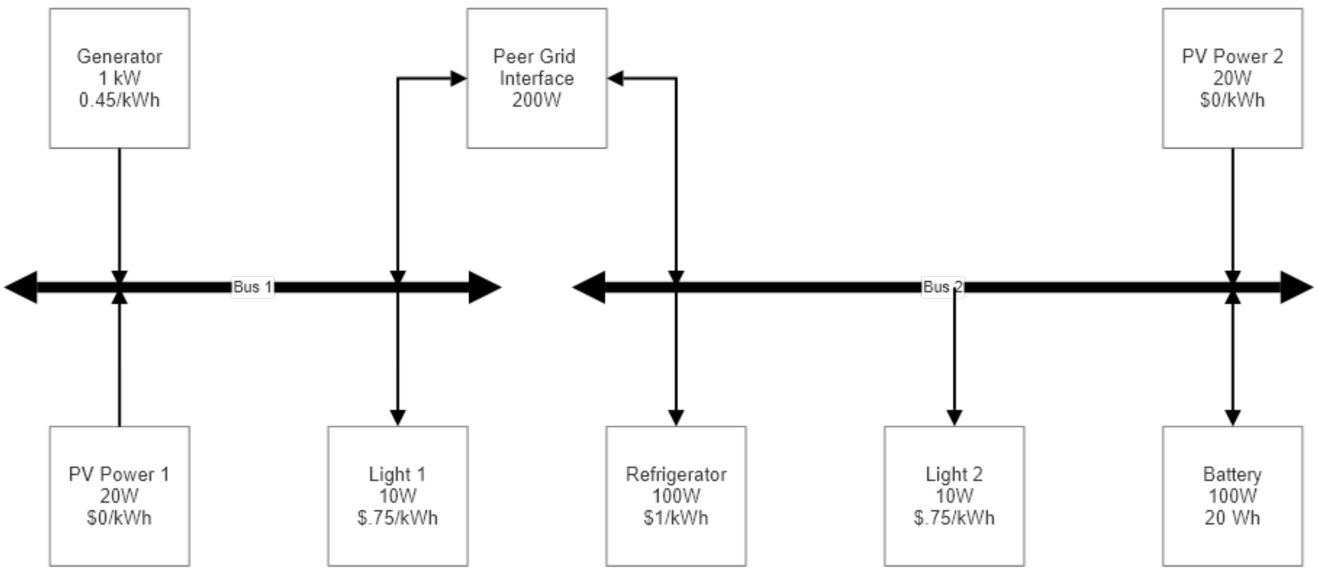
Device Phases

* Registration
  * All ports attempt to register as worker to an existing manager
  * If worker registration fails, sources attempt to assume manager role
* Normal operation
  * Workers (and manager) can potentially source or consume power
  * Workers offer to sell and/or buy power at a price
  * Manager grants request at a specific power level
  * Manager can force renegotiation – broadcast or per port
* Recovery (if manager fails)
  * Manager must periodically broadcast keep-alive
  * All ports restart registration on timeout

Power Request/Grant - TBD

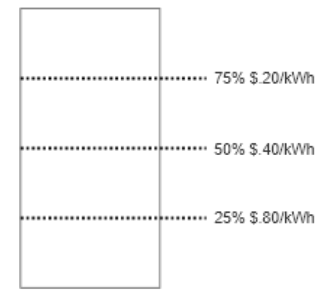
* Power request message includes both sell and buy
  * Sell price ($/Wh), power level (W),
  * Buy price ($/Wh), power level (W)
* Power grant response
  * Grant role (source, load), power level (W)

Protocol Example



Time	L1	L2	PV1	PV2	Gen	Refg	Bat Chrg %	B1->B2(W)
0	Off	Off	Off	Off	Off	Off	50%	0
1	On	Off	Off	Off	Off	Off	40%	-10
2	On	Off	Off	Off	On	Off	25%	200
3	On	Off	Off	Off	Off	Off	50%	-10
4	On	Off	On	On	Off	Off	50%	10
5	On	Off	On	On	Off	Off	100%	10
6	On	On	On	On	Off	On	100%	0
7	On	On	On	On	On	On	25%	200
8	On	On	On	On	Off	On	50%	10

Battery price function of charge



Additional Protocols

* Configuration, monitoring and control
  * Security?
  * Internet routing?
  * OCF? ThingSet?
  * Energy scheduling?
* PAYGO
  * Angaza Nexus (OCF)?
* Utility grid interface
  * IEEE 2030.5?

Related Standards / Industry Developments

* P2030.10
  * Recirculation ballot (D11) in progress – please vote!
* LFEnergy
  * Architecture sprint in progress led by Bruce Nordman
  * Spring summit Apr 14 - Jim/Martin presentation on ODG, Zephyr
* P2030.10.1
  * Getting ready for ballot – no recent activity
* GOGLA Interop activities - ?
* OpenPAYGO Link - ?
* Angaza Nexus Channel / Nexus Channel Core - ?
* Open Connectivity Foundation / IoTivity - ?

Next Meeting / Feedback

* Next Meeting
  * 13 April 2021 – 1400 UTC
  * Zoom – Meeting ID 87518284403 password: opendcgrid
* Sharing Portals
  * Web site: https://open-dc-grid.org/
  * GitHub: https://github.com/open-dc-grid