AI OPEN
DATA CENTER:
Power Distribution



Interface Specification Between Hyperscalers and Utility Grid for Disturbance Performance



Ashish Upreti *Google*

Mike Della Penna *Google*

The Catalyst Event

1,500MW

SIMULTANEOUS LOAD LOSS

July 2024 Northern VA Grid Event

- A July 2024 lightning strike and subsequent protection system clearing attempts drove six voltage depressions and the subsequent loss of approximately 1,500 MW of voltage-sensitive load that was not anticipated by the grid operators.
- This has prompted utilities to investigate stricter interconnection protocols.

Evolving Utility Requirements

Past Interconnection Specs

Past DC development did not have massive scale and utility requirements were limited

Upcoming Stringent Mandates

Future scale of DCs (often 100s of MW upto GW+) paired with ML workload power fluctuations are drawing significant utility scrutiny and a whole new class of requirements

Current state features significant regional variation

While requirements are still finalizing, initial engagements suggest mitigation development efforts are likely needed to comply across software, firmware, hardware

Utility Requirements and Grid Stability - Requirements distilling into key subcategories

Utility requirements at a glance

Reqs. not driven by ML load profile

- **System capacity**
  Transmission and generation
- **Fault ride through behavior**
  (Voltage Ride Through, Frequency Ride Through)
- **Post-fault active power recovery (PFAPR)**

Fault ride through and PFAPR

Loads to hold on through expanded fault ride through curves, including deep LVRT reqs.

and

Loads to ramp back to 90% of pre-fault load within 0.5-1s of voltage at connection point restoring to 0.9 per unit

Reqs. driven by ML load profile

- **Ramp rate**
- **Intra-minute fluctuations**
- **Forced oscillations**
  1) inter-area and 2) subsynchronous torsional effects (SSTI)

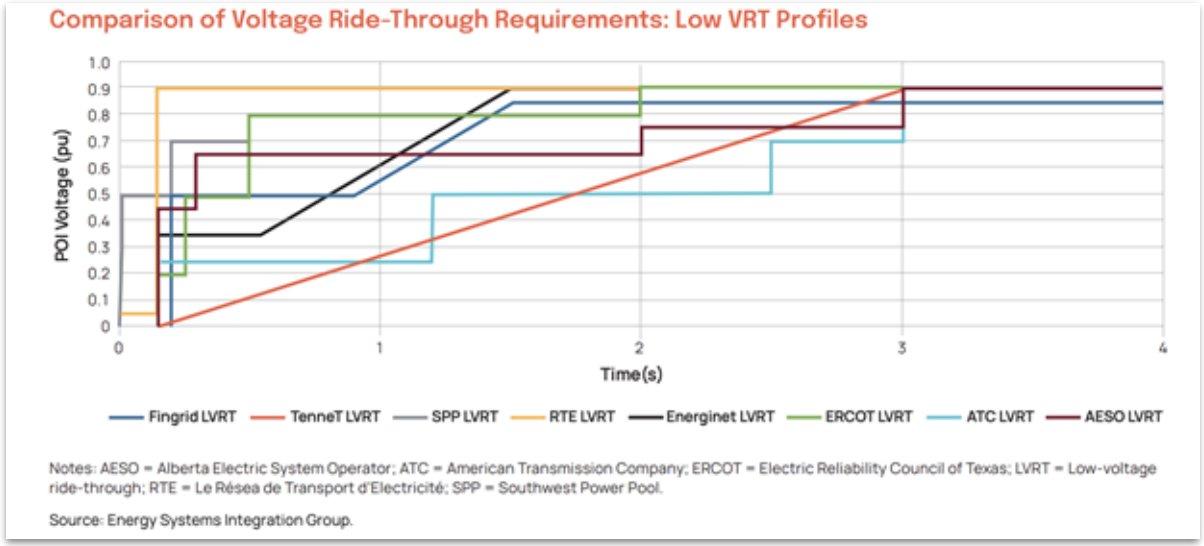
Ramp rate, fluctuations, and forced oscillations

- Reqs. in tens of MWs/min limit given gas CT/CCGT dominated contingency reserve fleet
- Not to exceed [10-25] MWs every 5-10 seconds so as not to impact system frequency
- Concerns both on low end (inter-area) and high end (SSTI) of frequency spectrum

Time domain | Minutes to hours | Seconds to sub-seconds

Low Voltage Ride Through and Post Fault Active Recovery

To support system frequency stability, utilities driving large loads to ride through a window well beyond the ITI curve (fka CBEMA), and after disconnecting or going to battery/UPS backup, be able to restore pre-fault load quickly



Region / Grid Operator	Required Timeframe
FinGrid (Finland)	90% within 1 second
ERCOT (Texas, USA)	90% within 2s
AESO (Alberta, Canada)	100% within 1.0 to 10.0 seconds (configurable)
Energinet (Denmark)	80% within 5 seconds, then 90% within 30 seconds

Implications : Meet Performance Requirement beyond ITIC Specification for interconnection requirement. Considerations for backup power transfer logic and load management.

Mitigations

- Firmware Updates to the the Power Supply (Rectifiers, LV UPS firmware Updates)
- Energy Storage (e.g., Super Capacitors, BESS) for ride through and Load Mimicking
- Expansion of Equipment Capabilities for ride through
- Considerations for Mechanical Equipments.

Proposed VRT and PFAPR Characteristics

Line to neutral or line to line voltage as measured at POI (p.u. of nominal voltage "V")	Minimum Ride-Through Time Before Transfer to Backup Allowed (seconds)	Load Behavior During Ride Through	Operational commitment once POI voltage returns to 0.90 ≤ V ≤ 1.10 "PFAPR"
V > 1.20	May transfer to backup instantaneously	N/A	N/A
1.10 < V ≤ 1.20	1	Maintain constant power	N/A
0.90 ≤ V ≤ 1.10	Normal range, continuous operation	Maintain constant power	N/A
0.80 ≤ V < 0.90	2	Continue consuming active power from the grid. May reduce power in proportion to V.	restore to 90% of pre-fault load within 2 seconds
0.50 ≤ V < 0.80	0.5	Continue consuming active power from the grid. May reduce power in proportion to V.	restore to 90% of pre-fault load within 2 seconds
0.35 ≤ V < 0.50	0.25	May reduce power to any value	restore to 90% of pre-fault load within 2 seconds
V < 0.35	0.15	May reduce power to any value	restore to 90% of pre-fault load within 2 seconds

Mitigation Options

Firmware Updates

Concept: Modify rack-level low-voltage (LV) rectifier/PSU firmware to utilize capacitor stored energy during disturbances.

OEM Specific: Highly dependent on original equipment manufacturers. Each OEM has unique designs, making global feasibility timelines impossible to define.

Consideration: Grid grandfathering schemes should account for varying models across hyperscaler fleets based on workload demands.

MV-UPS Deployments

Alternative: Explore in-line double conversion medium-voltage UPS (MVUPS) schemes instead of rack-mounted LV PSUs.

Stored Energy: Custom firmware can allow MVUPS energy storage to ride through voltage anomalies.

Retrofit Limits: Adding MVUPS to existing facilities is highly space-dependent and usually too costly/disruptive to be practical.

Grid-Side Mitigations

Strategy: Utilities deploy dynamic reactive power support equipment in high data center density zones.

Goal: Reduces severity of voltage sag/swell at the facility Point of Interconnection (POI) to stabilize the overall grid.

Equipment: SVCs and E-STATCOMs inject reactive power instantaneously. E-STATCOMs excel in weak-grid conditions by maintaining current injection.

Implementation Plan Considerations & Outline

Because enabling LVRT and PFAPR cannot be assumed to be a straightforward software or firmware update in all cases, the OCP hyperscalers propose the following outline for a workable implementation plan:

01 **Specific Effective Date:** A specific effective date is established for the disturbance performance requirement.

02 **Grandfathered Facilities:** Facilities that are already operational or that have executed interconnection agreements as of the effective date would not be required to comply for the lifetime of the facilities.

03 **Site Growth Limits:** Growth at an already operational site above and beyond already executed interconnection agreement volume as of the effective date would be subject to the requirements, but *only for the incremental volume (i.e. incremental growth at an existing site doesn't trigger retroactive application of the requirements for previously grandfathered facilities).*

04 **Voluntary Compliance:** Best-effort voluntary compliance pathways are established for grandfathered facilities and supported by utility engagement and possible incentives.

05 **New Facilities:** Facilities entering load study and contracting after the effective date would be expected to comply upon commencing operations.

Next Steps & Call to Action

Oct 2026

Step 1: Publication Goal

“VRT and PFAFPR” Version 1.0

Q4 2026

Step 2: Drafting and Alignment

“Power Ramp and Fluctuations” Version 1.0

Q1 2027

Step 3: Publication Goal

“Power Ramp and Fluctuations” Version 1.0

Call to Action

Participate and Support from broader industry

Utility Partners

Industry Partners

Research Institutions

OEM vendors

- PSU for IT Infrastructure
- LV / MV UPS Manufacturer
- Cooling Infrastructure Providers
- Grid Stability Solution Providers

Open Discussion

