ESIG SUMMER WORKSHOP 2026 • DAY 2 OPENING SESSION

Developer Perspective: Load Modeling & Validation Challenges

Khundmir Syed • Director of Power & Grid Strategy • Diode Ventures, LLC

June 16, 2026

01

SECTION

Who We Are

ABOUT THE PRESENTER

Introduction to Diode Ventures

A wholly owned subsidiary of Black & Veatch

What We Do

01
Site & Resources
De-risks land, power, and water.

02
Site Selection
End-to-end zoning and entitlements.

03
Community
Engagement and incentive structuring.

04
Hyperscale Delivery
Land delivered to major operators.

05
EPC History
Backed by Black & Veatch's century of EPC expertise.

Grid Strategy Focus

1. **Interconnection Requests**
   Active across ERCOT, PJM, MISO, SPP, SERC, WECC.
2. **Load Models**
   Delivered for the interconnection process.
3. **TSP / ISO / OEM Coordination**
   Study scope and data collection.
4. **Standards Engagement**
   NERC, ESIG, and ISO large-load workstreams.
5. **EPC Baseline**
   Standardized B&V design for modeling assumptions.

THE DEVELOPER'S ROLE

We Work Between Three Parties With Different Priorities And Timelines

The end customer

Hyperscale & AI tenants focused on IT load, PUE, and ramp profiles; not historically on grid reliability.

The OEM

UPS, switchgear, VFDs, BESS, cooling from multiple OEMs. Datasheets shared, but firmware is proprietary and can change mid-build.

The TSP / ISO

Verified PSPD & EMT site model, ride-through performance, protection settings, and current model revisions.

What the developer is responsible for

Model quality
Meet ISO/TSP model-quality requirements

Keep model current
Update as design and requirements evolve

OEM coordination
Validate equipment response under operating conditions

Stakeholder alignment
Close coordination from application through commissioning

02

SECTION

Interconnection Process

COMPARING TIMELINES

Interconnection Process Vs. Development Process

Both clocks run in parallel, and delays in one impact progress in the other.

Step	POWER	Duration	DEVELOPMENT	Description
1	Pre-application utility discussions	~1 month	Land Origination & Screening	Site identification, due diligence on land and power availability.
2	Application submission	1-2 months	Site Control & Data Collection	Land control secured, tenant LOI in hand, data collection and other requirements met
3	Engineering studies kick off	3-12 months	Site due diligence	Preliminary design developed, initial model packages submitted, desktop studies, community engagement
4	Engineering study results finalized	~3 months	Planning & Zoning	Study reviews, deposits, other land development efforts.
5	ESA & construction agreements negotiated	3-6 months	Long-lead orders	Offtake secured, Equipment procurement, long-lead orders placed, model updates as design firms.
6	Construction start	Post ESA & CLOA	Build & commission	Site construction, commissioning, model refreshed for as-built and firmware versions

Design Control Across the Interconnection Process

	Pre-App	Application	Study	Build	Commission	Operate
Powered Land Developer Delivers powered land to end user	Full	Full	High	Low	None	None
Powered Shell Developer Builds shell; tenant fits out IT	Full	Full	Full	High	Medium	Low
Hyperscaler / Operator Owns design, build, and ops end-to-end	Full	Full	Full	Full	Full	Full

Design control: Full · High · Medium · Low · None / handed over

DEVELOPER ARCHETYPES

Different Developer Profiles, Different Challenges

Interconnection and modeling challenges for each developer type

DEVELOPER TYPE	INTERCONNECTION CHALLENGES	MODELING CHALLENGES
Powered Land Developer Merchant; delivers powered land to an end user.	‣ **Owns interconnection** up to powered-land delivery. ‣ Tenant and equipment selection still unknown at filing.	‣ **Initial model** built on a standardized EPC reference design. ‣ No “as built” until tenant IT load and OEM choices firm up.
Powered Shell Developer Builds the shell; tenant fits out IT.	‣ **Utility study results** wanted ASAP ‣ Ride-through specs apply to an unknown tenant ‣ Ability to confirm equipment spec. dependent on operator offtake.	‣ **Aggregated site model** evolves as tenants and OEMs come online. ‣ Validation ownership between shell developer and tenant unclear.
Hyperscaler / Operator Owns design, build, and operations end-to-end.	‣ **Strong utility relationships** across regions. ‣ Interconnection limited by capacity constraints and long-lead items.	‣ **Strong in-house modeling teams.** ‣ Rapid AI cluster and firmware churn complicate the energization load profile sharing.

03

SECTION

Regulatory Landscape

REGULATORY LANDSCAPE

The Regulatory Landscape – Alerts to Standards

Sep 2025
NERC Level 2 Alert
Recommended Practices

Feb 2026
ESIG Performance
Requirements Report

Apr 2026
Draft Registry Criteria
+ SAR posted

May 2026
Level 3 Alert
Seven Essential Actions

Q2 2026
Data Center Load
Modeling TRD (PERC1)

2026–2027
Phased SARs
→ Reliability Standards

ON THE SYSTEM TODAY

What we're seeing

- **Sudden load reductions and oscillations** observed across multiple interconnections.
- **Summer peak demand projected to grow significantly** over the next 10 years with data centers driving most of it.

NERC L3 ACTION AREAS

Seven Essential Actions

Modeling · Studies · Instrumentation · Commissioning · Operations · Protection · Control

NERC L3 Alert: 7 Essential Actions for Computational Loads

REPORT Aug 3, 2026

EA 1 · TP / PC + TO (shared)
Modeling data set (PERC1)

EA 2 · TP / PC
System SOL & contingency studies

EA 3 · PC
Update qualified change rule

EA 5 · TP / PC + TO (shared)
Ride-through & protection coordination

NERC L3 ALERT
7 Essential Actions
≥20 MW · ≥60 kV

EA 4 · TO
Commissioning & model verification

EA 6 · TO (+ RC coord.)
Dynamic fault recording

EA 7 · TOP / RC / BA
Operator & load communications

BASELINE MODEL · PERC1

RIDE-THROUGH BEHAVIOR — THE CENTRAL RELIABILITY ISSUE

L3 Alert's Seven Actions Relate to Disturbance Performance

DISTURBANCE EVENT SEQUENCE

FAULT
Voltage or frequency excursion conventional loads ride through.

→

TRIP
1–3 GW load lost – Similar to unplanned generation addition.

→

RECONNECT
How and when UPS comes back matters as much as the trip.

→

OSCILLATE
Swings too fast for operator response.

WORK TO CONFIRM, IMPLEMENT & VERIFY RIDE-THROUGH

CONFIRM

Characterize the load
Server PSU, PDU, and UPS trip and reconnect behavior captured accurately

IMPLEMENT

Tune settings & specs
Tune within the allowable range of the equipment and understand UPS reconnect timing in relation to grid recovery.

VERIFY

Commission & record
On-site commissioning plus dynamic fault recording to confirm modeled ride-through performance matches response under real events.

04

SECTION

Modeling & Validation Challenges

MODELING AT A GLANCE

RMS / PSPD And EMT Answer Different Questions

	RMS / PSPD PSS®E · PowerWorld · TSAT	EMT PSCAD/EMTDC · EMTP
DOMAIN	**Positive-sequence,** Fundamental frequency · Δt ~ 1–10 ms	**Three-phase instantaneous values** Δt ~ 5–50 μs
USE CASES	**Bulk system planning** Transient & voltage stability, regional cases	**Converter stability & harmonics** Fault response · sub-synchronous interaction
STRENGTHS	**Scales to thousands of buses** Standard models actively improving and being tested Primarily utilized by planners for studies today	**Captures UPS / VFD / BESS converter physics** Better at capturing data center load behavior
WATCH-OUTS	**Cannot resolve converter-driven dynamics** UPS ride-through approximated · standard library models immature	**Time-consuming to build and run** Black-box IP models · generic models need validation

BOTH ARE REQUIRED · **RMS / PSPD for system-wide scale · EMT for converter-driven dynamics**

Three Activities Make A Large Load Model Trustworthy

Parameter verification

- **Match as-built.** Control gains, time constants, protection settings vs. installed equipment.
- **1:1 parameters first.** Trip thresholds matched to HMI data and OEM documentation.
- **OEM attestation** where direct checks are not feasible.

Model validation

- **Simulated vs. measured.** Staged tests and disturbance recordings.
- **Realistic behavior** across operating conditions and disturbances.
- **High-resolution data** at the point of interconnection.

Model quality testing

- **Structured test set.** Voltage steps, frequency changes, ride-through.
- **Numerical stability** and control response before acceptance.
- **Early-stage** interconnection requirement.

Well established for generators through the interconnection process, but still largely undefined for large loads.

Source: ESIG, Large Load Modeling for Dynamic Studies (2026)

VALIDATION HURDLES

Validating Large Load Models

⚠

PRE-ENERGIZATION

Greenfield Challenges

- **No field data** exists pre-energization.
- **Bench tests cover converters** in isolation, not the whole site.
- **Few events available** for benchmarking
- **HIL provides higher value** with as-built design and OEMs confirmed.

✓

THE BENCHMARK

What "Validated" Means

- **Documented lab-test match** for each major piece of equipment.
- **Reproduces benchmark events** within ±5% P, ±5ms timing.
- **Playback** vs. real grid data once energized.
- **Versioned models** tied to firmware and equipment.
- **Written scope statement** of what the model does NOT cover.

↻

POST-ENERGIZATION

Ongoing Cycle

- **High-resolution recording** with PMU / DFR.
- **Simulated vs. measured** across test bed and real events.
- **Tolerance bands;** re-engage OEM on persistent errors.
- **Periodic review** at utility defined intervals.
- **Mandated updates** per validation outcomes.
- **Benchmark PSPD vs. EMT** when both submitted; document differences.

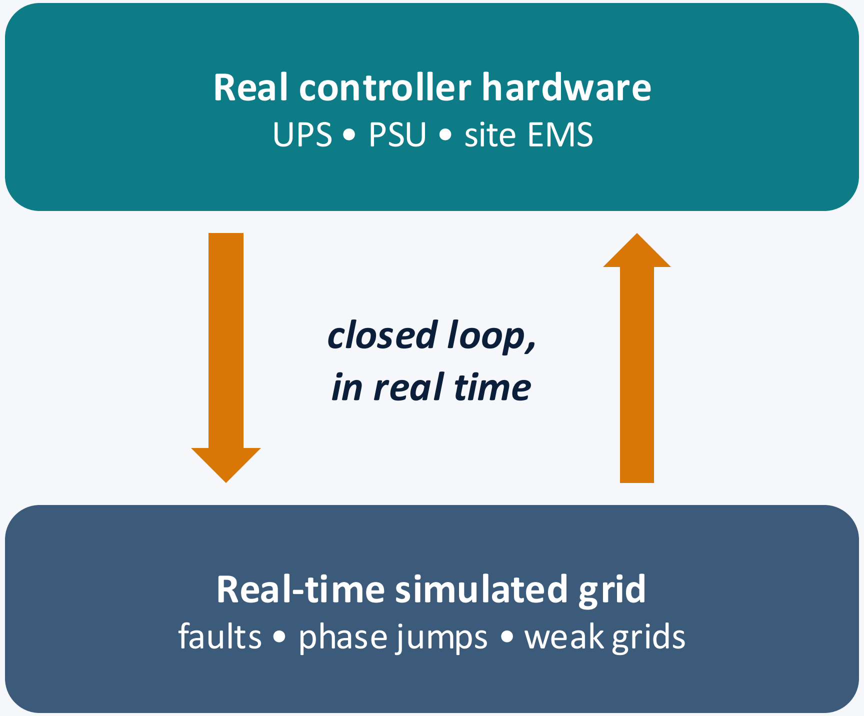
05

SECTION

Solutions

SOLUTIONS — HARDWARE-IN-THE-LOOP

Testing The Facility Before It Exists



- **Evaluate dynamic load behavior before construction.** Simulating different grid conditions, such as faults, phase jumps, and weak-grid cases.
- **Control & Protection Validation.** Tune and validate the parameters without exposing vendor IP or tenant data.
- **Observe control interactions early.** UPS, BESS, and site controls can be tested together under disturbance conditions before any installation.
- **Inverter-based resources (IBR).** Megawatt-scale lab testing of data center equipment, including on-site storage and generators with grid-forming / following converters.

Examples: NLR Agora LL Grid Integration Test Bed • EdgeTunePower AI Load Simulator

It is the most practical way to learn how a facility behaves before it is energized.

A STAGED VALIDATION FRAMEWORK

How Developers Can Credibly Build and Maintain the Compliance Record

1	**1. HIL Test bed**	OEM/HIL lab tests of UPS, VFD, and BESS converters against published ride-through and other reliability standards.
2	**2. Site simulation**	RMS and EMT modeling, benchmarking, and simulations to represent onsite equipment performance under various conditions.
3	**3. Commissioning**	On-site staged tests: block load pickup, transfer scheme exercises, and intentional UPS mode transitions under monitoring.
4	**4. Measure, Study, & Address**	Replay actual grid disturbances through the model post-energization; benchmark model response against site data and address any shortcomings.
5	**5. Ongoing Model Updates**	Versioned model updates and studies triggered by firmware changes, capacity additions, load profile changes, or observed events. Tied to the ISO model update process.

THE MINDSET SHIFT

Reframing The Modeling Conversation

FROM	TO
“The developer knows everything, and we need that information.”	**“Let’s define what is known, and when.”**
“I know what to expect from the data center because I have conducted the studies up front.”	**Data center design, load profile, and other characteristics will change.**
Exact values requested before design decisions are made.	**Ensure that the interconnection process, including material modification, is well-defined to support the restudy of dynamic behavior.**
“I will wait for the utility industry to tell me what they need via process updates and standards.”	**Get involved early in process/standards development. Review draft proposals and actively engage in learning grid reliability concerns.**

“Standards written without developer input still apply to developers.”

THANK YOU

Questions & Discussion

Khundmir Syed • Director of Power & Grid Strategy • Diode Ventures, LLC • syedk@diodeventures.com