GridStrong

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AUTOMATED MODEL VERIFICATION FOR IBR DYNAMIC MODELS

A deterministic approach to bridging the model-to-field gap

GRIDSTRONG / 2026

THE MODEL-TO-FIELD GAP

WHY IBR MODELS CAN'T BE TRUSTED

- 2,600+ GW in interconnection queues (LBNL Queued Up 2025)
- IBR behavior is software-defined, not physics-governed
- Dynamic models frequently don't match installed settings
- Default params submitted, never reconciled after commissioning
- OEM firmware updates change behavior without model updates
- PSCAD to PSS/E translation introduces mapping errors

REAL-WORLD CONSEQUENCES

Odessa I (May 2021)
1,100 MW solar tripped during routine 345 kV fault

Odessa II (June 2022)
1,700 MW solar reduction, despite NERC alert

Blue Cut Fire (Aug 2016)
1,200 MW solar tripped in Southern California

Root cause: models did not match installed settings

SOURCES: NERC / WECC JOINT STAFF DISTURBANCE REPORTS (BLUE CUT 2016; ODESSA 2021, 2022); LBNL QUEUED UP 2025 (QUEUE VOLUME)

REGULATORY CONTEXT

THE STANDARDS GAP

- MOD-032-1: requires data submission, not verification
- MOD-033-2: system-level validation, not plant-level
- FAC-001/002: one-time interconnection model review
- A Generator Owner (GO) can submit default params and be 'compliant'
- System validation masks individual plant errors
- ISO/RTO supplements (ERCOT's model quality tests (MQTs), PJM) are manual

MANUAL REVIEW: UNSUSTAINABLE

- 4-16 hours per plant for manual review
- Requires PSS/E + PSCAD + OEM expertise
- 50-200 interconnections per year per planner
- NERC's IBR Performance Subcommittee (IRPS) recommends all IBR models be reviewed
- = Thousands of engineer-hours annually per entity

HOUR AND VOLUME FIGURES: GRIDSTRONG ENGINEERING ESTIMATES FROM INTERCONNECTION STUDY PRACTICE; REVIEW RECOMMENDATION PER NERC IRPS

BACKGROUND

IBR MODEL ARCHITECTURE

THE TWO-PLATFORM REALITY

EVERY PLANT NEEDS BOTH MODELS

PSCAD (ELECTROMAGNETIC TRANSIENT)

- Full 3-phase instantaneous modeling
- Sub-millisecond time steps
- Captures switching, PLL, harmonics
- OEM-provided, often encrypted DLLs
- XML-structured .pscx project files

PSS/E (POSITIVE-SEQUENCE PHASOR)

- Positive-sequence equivalent model
- Few-millisecond time steps
- Workhorse of transmission planning
- WECC generic model blocks (standardized)
- Positional .dyr files with no param names

The challenge: ensuring these two representations are parametrically consistent, and that both match the actual installed equipment settings.

WECC GENERIC MODEL BLOCKS

THE STANDARD FOR POSITIVE-SEQUENCE IBR MODELING

MODEL BLOCK	FUNCTION	FIELDS	VARIANTS
REGCAU1	Generator/Converter	14	REGCA1
REECAU1	Electrical Control	35	REECA1, REECBU1, REECCU1
PLNTBU1	Plant Controller	23	REPCA1, REPCAU1
REAX4BU1	Auxiliary Control	6	n/a
VTGTPAT	Voltage Trip	14	n/a
FRQTPAT	Frequency Trip	6	n/a

98 mapped positional fields across 6 blocks + 4 power flow params = 102 total per plant. 12 model name strings resolve to 6 field arrays via variant aliasing (REGCA1 → REGCAU1, etc.)

OEM-PROPRIETARY PSCAD ARCHITECTURES

THREE DISTINCT PATTERNS ACROSS 12 OEMS + GENERIC WECC

A: ENCRYPTED DLL

- Minimal exposed params
- 8-18% parameter accessibility
- Binary compiled components

B: WECC-EQUIVALENT NAMING

- Near-1:1 mapping to REGCA/REECA/PLNTBU
- Straightforward canonical translation
- 36-163 mapped parameters

C: VENDOR-SPECIFIC NAMING

- Requires full translation layer
- 90-418 mapped parameters
- Custom naming per subsystem

Internal component identifiers serve as OEM detection signatures for automated adapter selection.

THREE-WAY VERIFICATION MODEL

COMPARING EQUIPMENT, EMT MODEL, AND PLANNING MODEL

AS-LEFT

GROUND TRUTH

Actual equipment settings from commissioning

PSCAD MODEL

EMT SIMULATION

What the OEM model thinks is configured

PSS/E MODEL

PLANNING STUDIES

What planners assume in stability analysis

All agree
MATCH (verified)

Any disagree
CONFLICT (reliability risk)

PSCAD ≠ PSS/E
Translation error

As-left ≠ PSCAD
Model never updated

As-left ≠ PSS/E (even if PSCAD = PSS/E)
Both models wrong; the most dangerous case

Simulation-only params (gains, filters)
Two-way comparison only

METHODOLOGY

AUTOMATED EXTRACTION PIPELINE

PIPELINE ARCHITECTURE

DETERMINISTIC: NO ML, NO HEURISTICS

1 FILE DISCOVERY → **2 EXTRACTION** → **3 OEM MAPPING** → **4 VERIFICATION**

1. **FILE DISCOVERY** — ZIP → identify .pscx .dyr .raw
2. **EXTRACTION** — PSCAD 3-tier + PSS/E positional
3. **OEM MAPPING** — Vendor → canonical taxonomy (1,302)
4. **VERIFICATION** — 3-way compare: match / conflict

12 OEM ADAPTERS + GENERIC FALLBACK = 13 FIXTURES

Covering PV, wind (WTG), BESS, and hybrid plant architectures across all major inverter manufacturers

PSS/E: positional parsing of .dyr + .raw power flow

OEM PARAMETER MAPPING

CANONICAL TAXONOMY WITH EXHAUSTIVE ACCOUNTABILITY

PARAM_MAP DESIGN

- WECC-standard: direct PSS/E comparison fields
- Cross-vendor: unified canonical symbols across OEMs
- Vendor-specific: unique features per architecture
- Every parameter either mapped or explicitly excluded
- No silent gaps; structural completeness enforced

BY THE NUMBERS

1,302	total PARAM_MAP entries across 13 fixtures
456	explicitly excluded with documented reasons
1,119	unique canonical symbols
52	structural completeness checks (4 × 13)

EXHAUSTIVE ACCOUNTABILITY

52 STRUCTURAL CHECKS (4 ASSERTIONS × 13 FIXTURES)

1 — EVERY PARAM ACCOUNTED → **2 — NO STALE MAP ENTRIES** → **3 — NO STALE EXCLUSIONS** → **4 — NO OVERLAP**

1 — EVERY PARAM ACCOUNTED

Fixture param not in MAP or EXCLUDED → test fails

2 — NO STALE MAP ENTRIES

MAP key references removed param → test fails

3 — NO STALE EXCLUSIONS

EXCLUDED key references nonexistent param → test fails

4 — NO OVERLAP

Param in both MAP and EXCLUDED → test fails

Structurally impossible to add a parameter without classifying it. Scales to new OEMs: fixture + PARAM_MAP + EXCLUDED_PARAMS + 4 passing tests.

OEM COVERAGE SUMMARY

12 OEM ADAPTERS + GENERIC FALLBACK: MAPPED, EXCLUDED, VERIFIED

ADAPTER	MAPPED	EXCLUDED	ARCHITECTURE
PV OEM 1	335	83	Vendor-specific (hybrid PV+BESS)
PV OEM 2	203	13	Vendor-specific
PV OEM 3	163	11	Vendor-specific
PV OEM 4	137	62	Vendor-specific (dual-block)
BESS OEM 1	130	12	Vendor-specific
BESS OEM 2	90	13	Vendor-specific (tiered)
PV OEM 5	59	13	Encrypted DLL
PV OEM 6	59	14	Vendor-specific
WTG OEM 1	41	26	Vendor-specific
Generic WECC	36	1	WECC-equivalent
WTG OEM 2	23	0	Encrypted DLL
WTG OEM 3	18	207	Encrypted DLL (8% accessible)
PV OEM 7	8	1	Vendor-specific

456 total exclusions, every one documented with reason (signal routing, internal opaque, config flags, curve breakpoints). Zero silent gaps.

RAW STORAGE AND AUDIT TRAIL

COMPLETE DATA PRESERVATION FOR COMPLIANCE

POSTGRESQL + JSONB	Full parameter set from every source file preserved
PSCAD RAW	Every component, definition, instance name, complete param hash + OEM detection
PSS/E RAW	Every model block including unrecognized blocks; future-proof
RE-EXTRACTION WITHOUT RE-UPLOAD	Update mapping logic → reprocess raw data
REGULATORY AUDIT TRAIL	Inspect exactly what was in original files, independent of mapping
TRAINING CORPUS ANALYSIS	Aggregate across plants to prioritize mapping expansion

VERIFICATION VIEWS

ADAPTIVE WEB INTERFACE BY FUNCTIONAL CATEGORY

Profile-backed: 3-way (as-left / PSCAD / PSS/E)
Ratings, ramp rates, deadbands, capability flags

Equipment simulation: 3-way where as-left available
REECAU1, PLNTBU1, VTGTPAT, FRQTPAT, power flow

Simulation-only: 2-way (PSCAD vs PSS/E)
Controller gains, filter constants, V-I curves

OEM-specific: 2-way 14 adaptive categories
Per-manufacturer parameter organization

MATCH STATUS

MATCH	All sources agree
CONFLICT	Any source disagrees; risk
INCOMPLETE	One or more values missing

BigDecimal normalization: '0.020' and '0.02' → same value

RESULTS AND DISCUSSION

COVERAGE ANALYSIS

QUANTIFIABLE COVERAGE ACROSS THE ENTIRE PARAMETER SPACE

1,302	1,119	102	13	52
PARAM_MAP entries	Canonical symbols	PSS/E fields per plant	Fixtures (12 OEM adapters + generic)	Structural checks

Accountability enforcement has caught: stale mappings for renamed params, missing exclusions for newly discovered params, accidental MAP/EXCLUDED overlap.

Test-first development: write the completeness assertion before implementing the mapping. Essential for maintaining discipline at this scale.

AUTOMATED VS. MANUAL

VERIFICATION AT SCALE

MANUAL PROCESS

- 4-16 hours per plant
- 10-20 critical params reviewed
- Subset-based; may miss subtle issues
- Requires PSS/E + PSCAD + OEM expertise
- No structural completeness guarantee
- Doesn't scale to fleet portfolios

AUTOMATED PIPELINE

- < 1 second per plant
- ALL params examined (e.g., 418 for one OEM)
- Deterministic; identical results every time
- 12 OEM architectures + generic fallback, automatic
- Exhaustive accountability enforcement
- Scales to 2,600 GW in queues

CAPABILITIES AND POSSIBILITIES

CAPABILITIES

- 12 OEM adapters + generic fallback (13 fixtures)
- 3-way verification (as-left / PSCAD / PSS/E)
- Exhaustive accountability (52 structural checks)
- Automated PSS/E .dyr generation from PSCAD
- Complete raw data preservation for audit
- Sub-second per-plant processing

POSSIBILITIES

- PSCAD variable resolution across all OEMs
- Automated per-unit base conversion
- Model topology inference (OEM → WECC blocks)
- Expand trip coverage to encrypted DLLs
- From verification → full model construction

CONCLUSION

1

AUTOMATED EXTRACTION

12 OEM adapters + generic fallback for PSCAD + positional PSS/E parsing

2

OEM PARAMETER MAPPING

12 vendor conventions + generic WECC → unified canonical taxonomy (1,302 mappings)

3

EXHAUSTIVE ACCOUNTABILITY

Every parameter classified, 52 automated spec tests

- The model-to-field gap persists because verification has been treated as a manual process at industrial scale
- A 'conflict' on a voltage ride-through threshold = same class of error that caused Odessa
- Complements MOD-032 (submission) and MOD-033 (system validation) with plant-level verification
- 2,600 GW in queues → thousands of plants needing verified models. Automated verification is an operational necessity.

THANK YOU

QUESTIONS?

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