OAK RIDGE National Laboratory

Mapping EMT Data Sources Consolidating Inputs for Your First Simulation

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Transmission Planner

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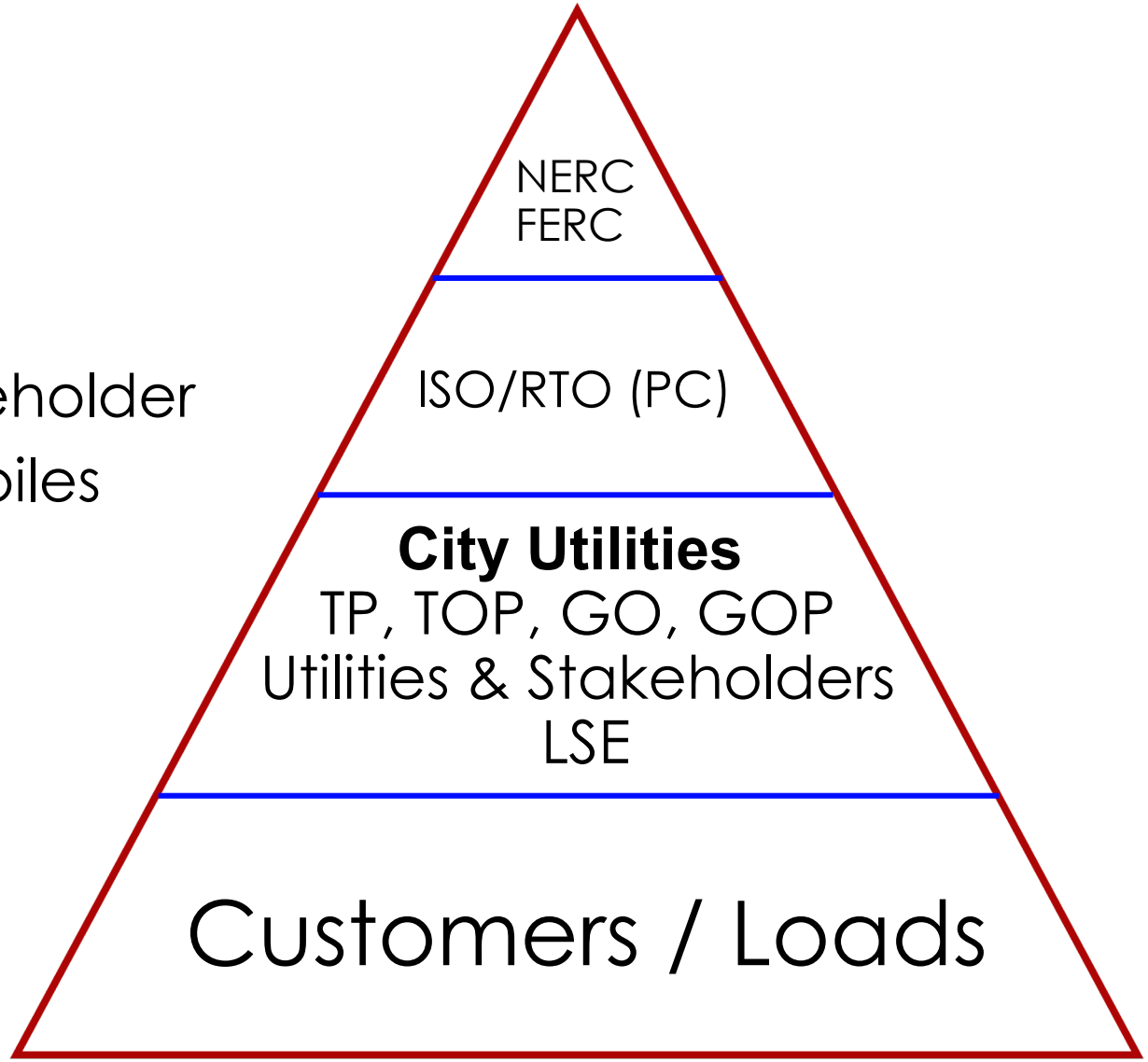
City Utilities and Glen Halley

- City Utilities is a Municipal Utility Serving Springfield, Missouri
  - Gas, Water, Electric, Broadband, Transit
  - Generation: Solar, Natural Gas, Coal, and soon Battery
  - 678 square miles in Greene County
  - ~ 750-800 MW Peak
  - One 345 kV bus, 161 kV ring around the city, 69 kV Dist.
- Background
  - Planning, Design, Construction, and Operations
  - Customers, Distribution, Transmission, Substations, and Broadband
  - Present Project: EMT Analysis for BESS



Regulatory Organization

- Planning Coordinator (PC)
  - Receives quality data from stakeholder
  - Verifies completeness and compiles
- Transmission Planner (TP)
  Generator … Planner (GOP)
  - Verifies and adds to analysis
  - Measure, model, and modify
- Load Serving Entity (LSE)



The Value of Practical Models

- "Military genius is really only the capacity to understand and apply simple principles founded on experience and sound reasoning.“
  - General John J. Pershing

- “All models are wrong, but some are useful.”
  - British statistician, E.P. Box

Executive Roadmap

Modernizing the Utility-to-RTO Pipeline

01 / Foundation

Successful Data Structures

Schemas: Interoperability baselines

Access: Piercing IP shields

Testing: PPC vs. MOD-testing

Scale: Beyond PSCAD silos

02 / Process

Understanding Workflows

Paradigms: Relay vs. IBR validation

Telemetry: PMView quality checks

Alignment: RTO model assessments

Stability: Grid strength inputs

03 / Architecture

Consolidated Data

Umbrella: SysML v2 multi-engine routing

Convergence: Utility-RTO boundary handshake

Corridors: Wideband line models

Apparatus: Empirical transformer curves

Supporting Successful Studies with Input Data by providing:

- Clear criterion to be met
- Confidence to handle the next decade's requirements
  - Known knowns, unknown knowns, unknown unknowns, chaos*
- Timely, relevant, and actionable results

* Cynefin framework as presented by *Observability Engineering*, 2nd Edition

Required Input Data (example files)

- Powerflow(.raw), dynamics(.dyr), sequence(.seq), EMT(P3743)
  - Model quality testing (MQT)
- Models protected by IP such as relays and IBR - verification
- COMTRADE, SCADA - validation
  - High-resolution time-synchronized event logs, DFRs, PMUs
- Simulation, contingency, compliance, and everything else
  - Try to address unknown unknowns, chaos,

Input Data Structure: The Interoperability Baseline

- Proven Sharing Models
  - Legacy snapshots (.raw, .dyr, .seq) prove that multi-vendor data sharing works.
- The Export Mandate
  - True exchange requires native, documented software exports, not just internal capabilities.
- Manual Verification
  - To be documented for export, it must be explicitly detailed in the vendor's manual.

EMT Interoperability: Overcoming Proprietary Silos

- CIM Stagnation – structurally standard but operationally stalled
- EULA Roadblocks
  - Restrictive End User License Agreements prohibit programmatic parameter extraction.
- The Legal Symptom
  - Current EULAs act as a direct description and symptom of a broken, protective data ecosystem.
- The Path Forward
  - Utilities must push software and OEM vendors to natively support IEEE Standard P3743

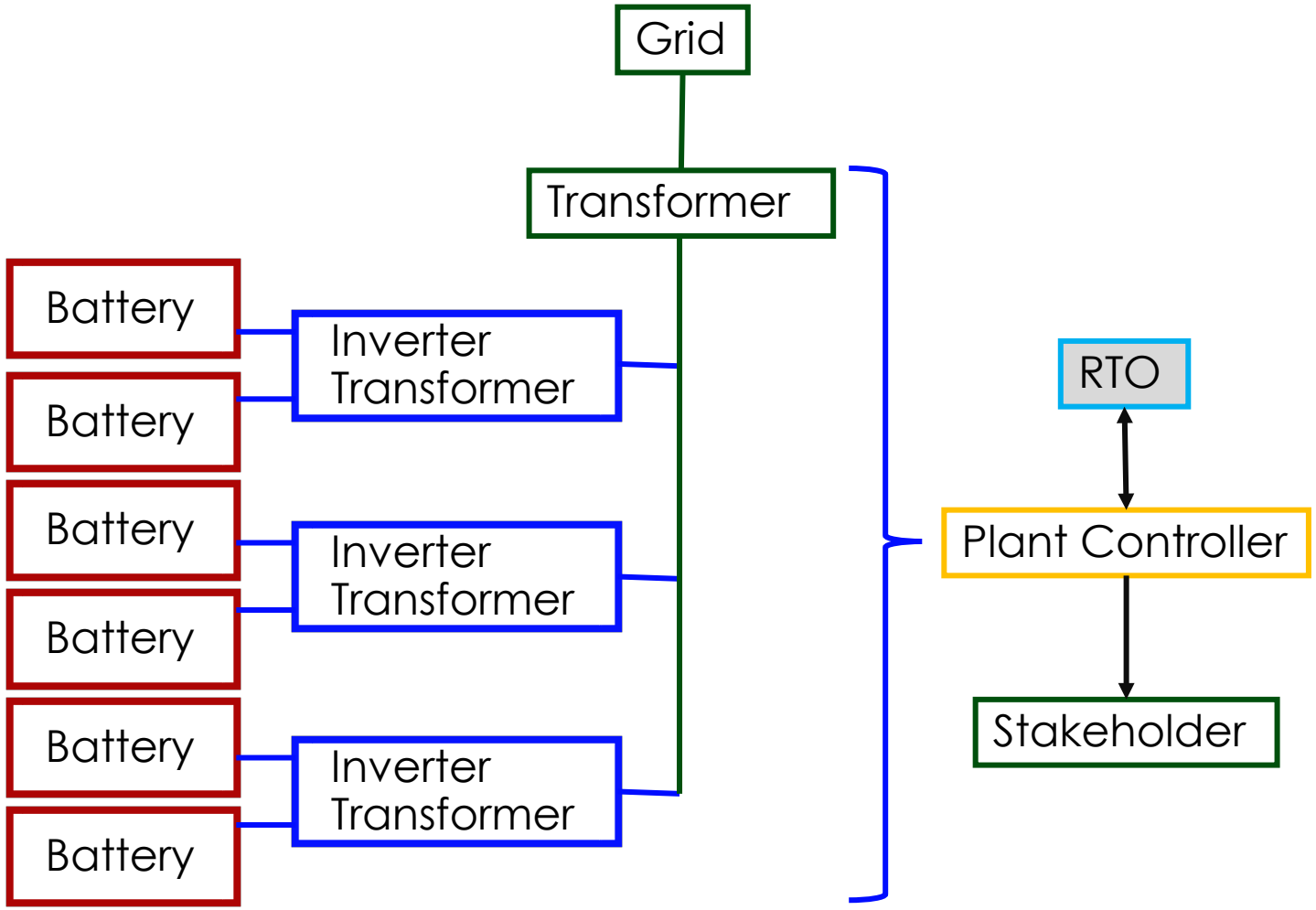
OEM Vendor Files: Overcoming the IP Shield

- NDAs legally protect Intellectual Property (IP)
  - Frequently used as a defensive shield to avoid model sharing.
  - Protects source code and the "secret sauce"
- Standards physically protect IP
  - Formats include CIGRE/IEEE "real code", IEEE P3743, Modelica Functional Mock-up Units (FMUs), Compiled Black-box DLLs
- Interoperability Baseline
  - Providing operational models without sharing IP is solved
  - Multi-vendor model exchangeability remains stalled

Shifting the Burden: The NRTL Liability Framework

- The Core Blocker: Model Liability
  - Vendors fear financial and legal liability for model inaccuracies
  - Current process forces validation retroactively during late-stage commissioning under utility direction
- Certified Equipment and Models to Grid Code
  - Verified by 3rd party Nationally Recognized Testing Laboratory (NRTL)
- The Interoperability Outcome
  - Shifting burden of proof allows vendors to share exchangeable models

Field Verification: PPC Vendor vs. MOD-testing



- As left commissioning
- Opt. A: Power Plant Control
- Opt. B: MOD-testing via consultants

Extending PSCAD: Inoperability Path Forward

- Bottleneck: Policy vs. Reality
  - NERC Policy: software agnostic (cares about mathematical accuracy)
  - RTOs Reality: exclusively PSCAD … a single proprietary format
- Catalyst: Solving Model Liability
  - Clear "as-left" validation boundaries + data standards = less vendor risk
  - Moves toward IP protected, exchangeable data
- Unlock Advanced System Analysis
  - Seamless Multi-domain (EMT + RMS (phasor))
  - Robust verification for mathematical cross-checking
  - Massively parallel cloud execution (hours not weeks)

Relay versus Inverter-based Resource (IBR)

IBR

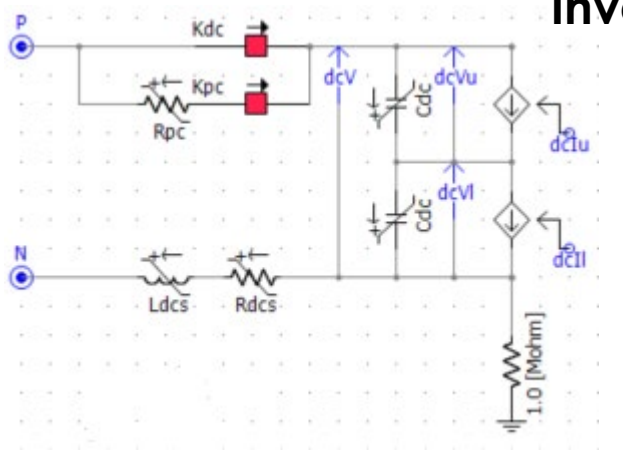
Sensors

- **Relay**
- **Controller / Model**

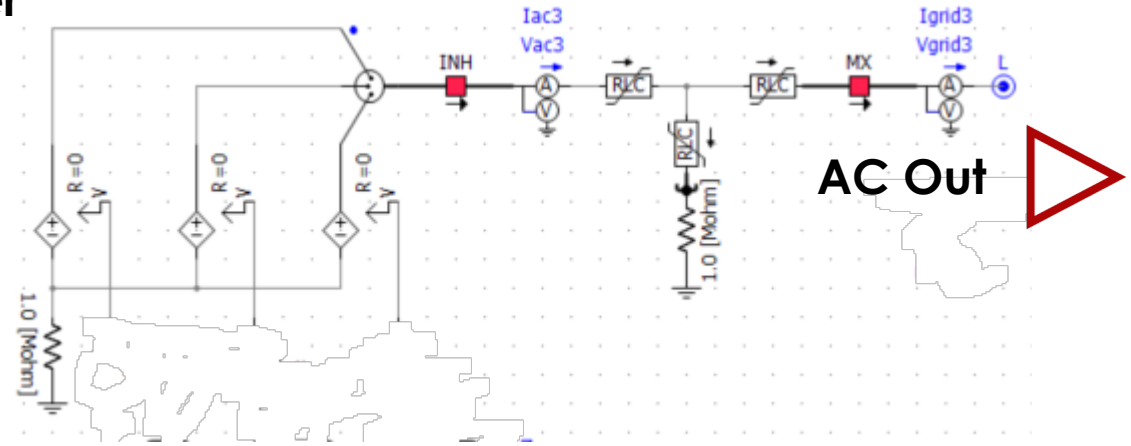
Specialized microcomputer that monitors current and voltage signals to execute logic.

- **Passive Power Components / Passive Filters**
- **Electrical Balance of Plant (eBOP)**
- **Plant-side Passive Infrastructure**

Battery



Inverter

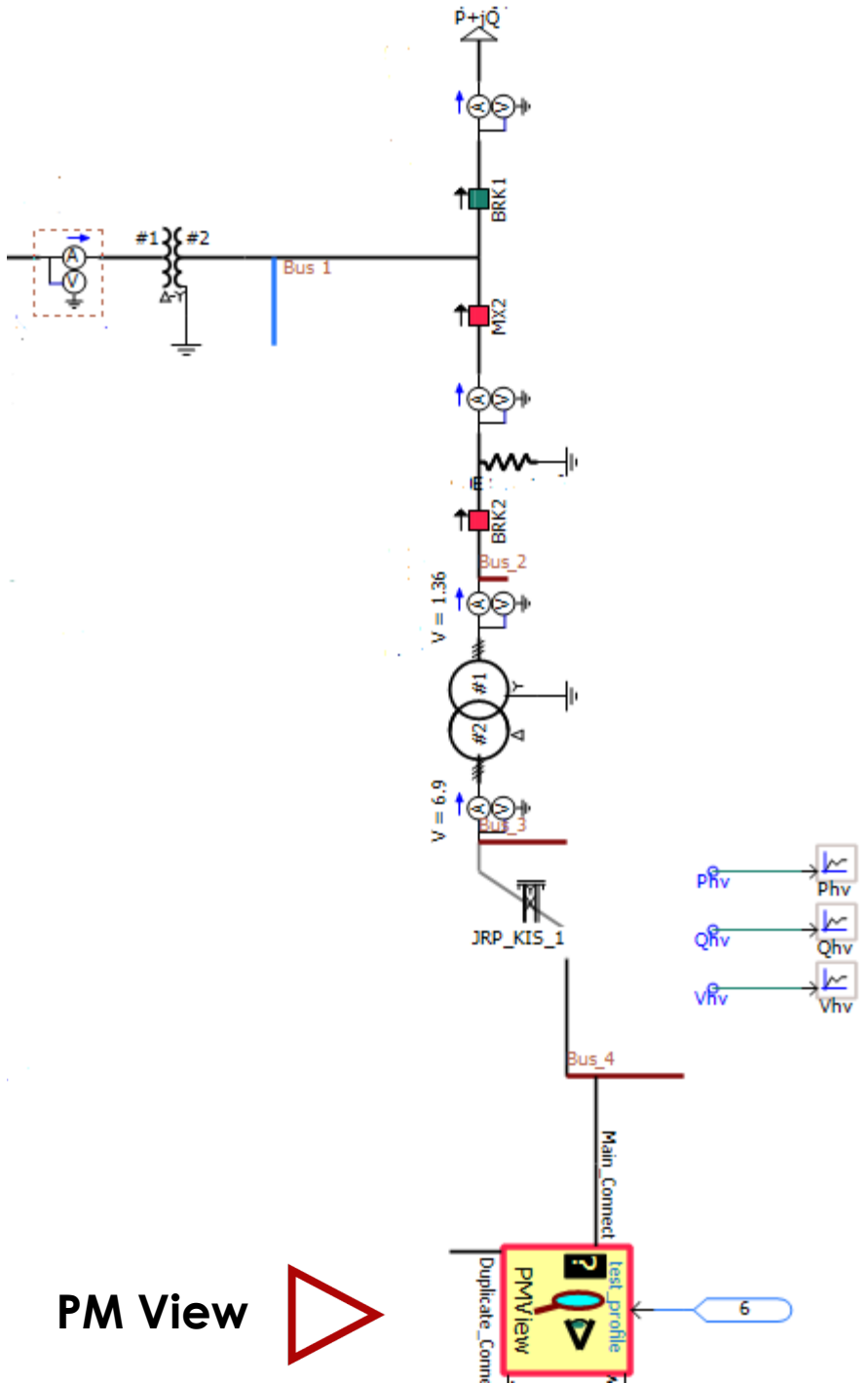


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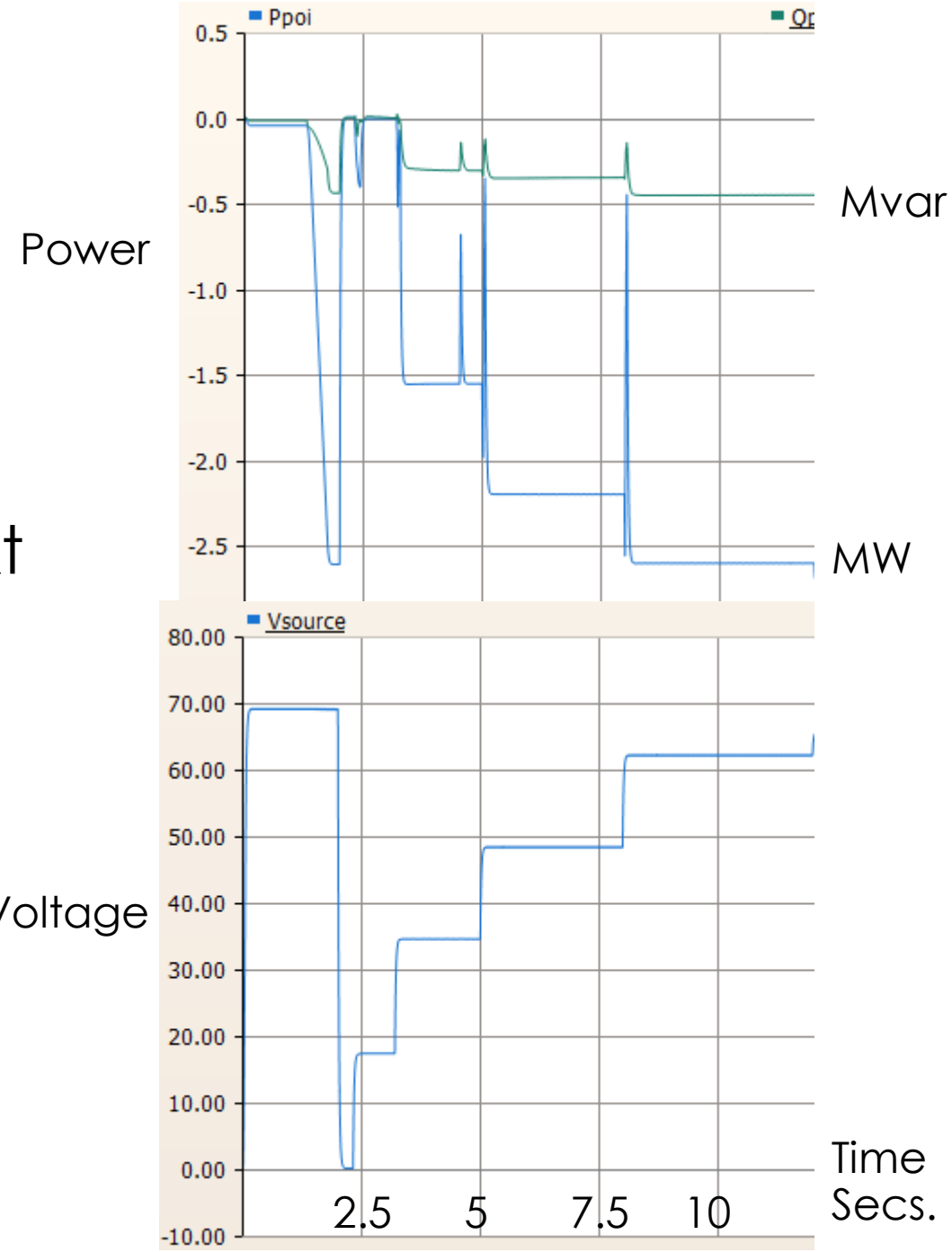
Model Quality and Verification Tool

- ERCOT provides PMView
  - **Applies** automated synthetic disturbances to a vendor's PSCAD model.
  - **Verifies** that the model *is built correctly according to ERCOT guidelines*.
- Prove model compliance
  - Risk mitigation
  - Cost of failure
- Prerequisite to Interconnection Study



PMView Time-series (ERCOT)

- PRC-029-1 Frequency/Voltage Ride-through
- PMView_profile_2800_LVRT_PVGR.txt
- IBR to ride through the required low-voltage boundary steps
  - No disconnect from 0s to 18s (+ 2s)
  - Intentionally trip from 18s to 24s
    - Verify that its protective relaying functions correctly
    - Voltage drops to 0.10 p.u. for 6 seconds



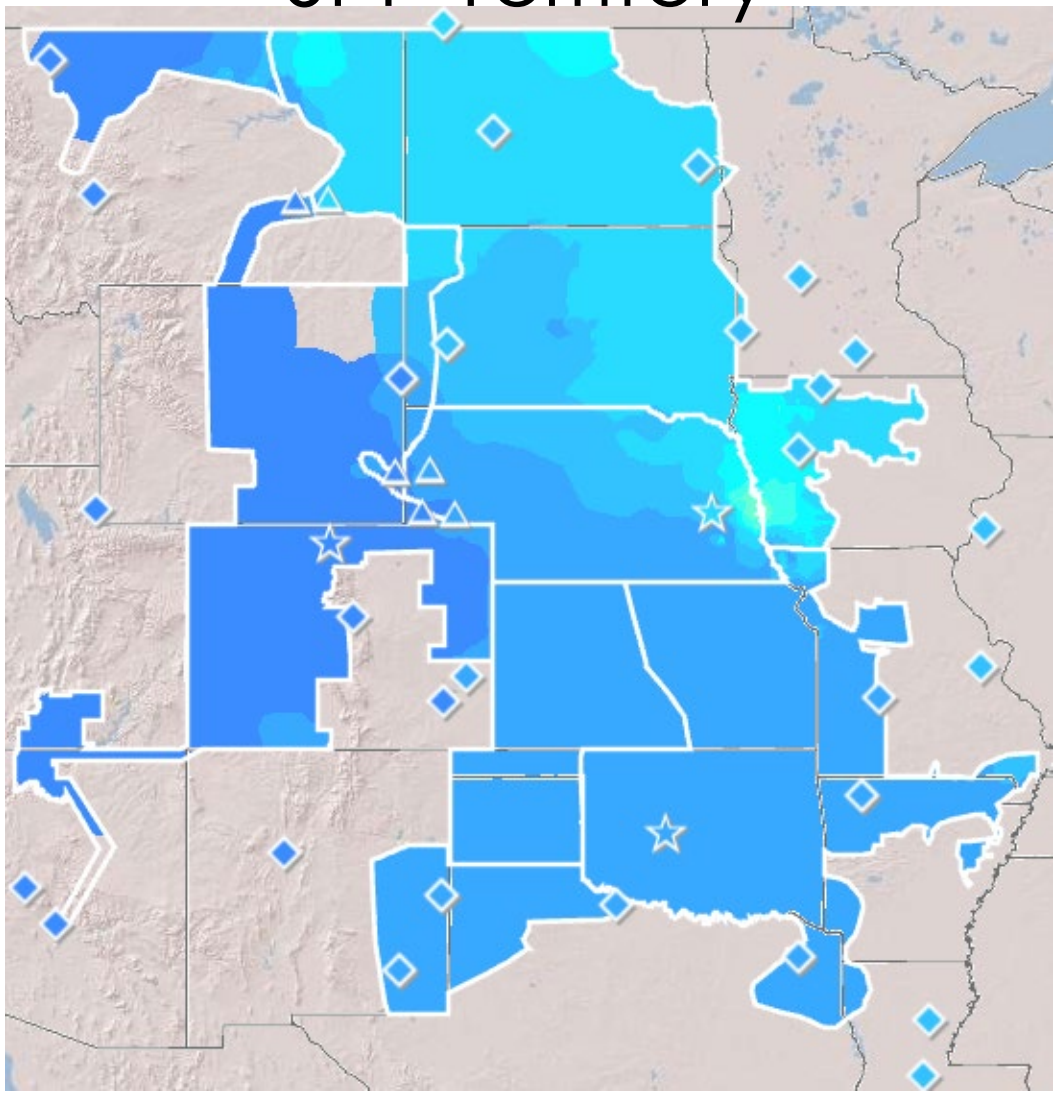
Verification Relay and IBR Plant Comparisons

- Relay
  - Clearance times, zone configurations, backup tripping mechanisms remain independent of plant's active control schemes.
  - Protection settings and coordination studies
- IBR Plant
  - No unexpected trips, instability, or control interactions under weak grid conditions.
  - Update dynamic simulation models.

Summary of RTO Model Assessments (SPP)

- Common Assessment
  - Perform weak-grid analysis
  - Receive
    - certified model quality assessment
    - "As-built" HIL validation if not "real firmware code" IBR
- Fast-track LL don't negatively interact with nearby IBR
- Future Grid-forming (GFM) Performance & Capability Testing

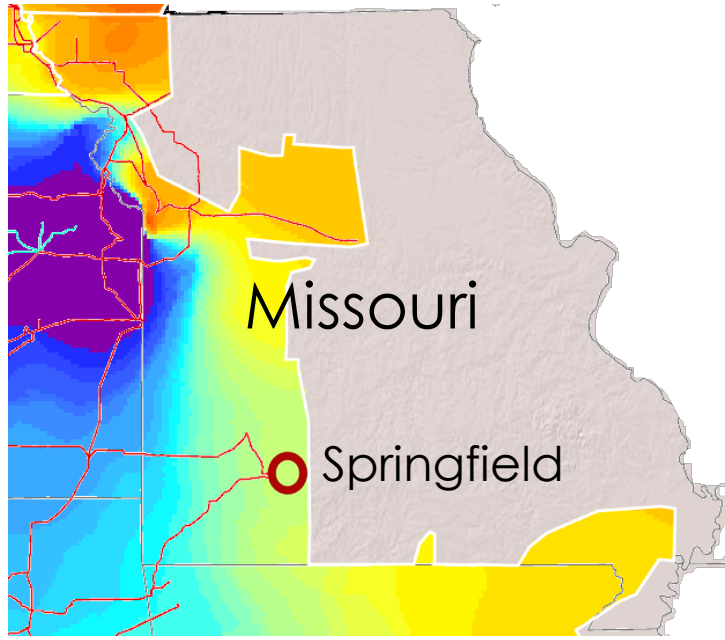
SPP Territory



Grid Strength Input Data Example

- Gatekeeping checkpoint for grid strength is insufficient
- Requires verifying grid strength after local generation additions
- Links power system data and regulations together
  - Requirement: If SCR < 2.0, a full EMT study is mandatory.
  - Power System Data: coordinate of POI, architecture, measured MVA, Size, etc.
- Save conversation for Consolidated Data

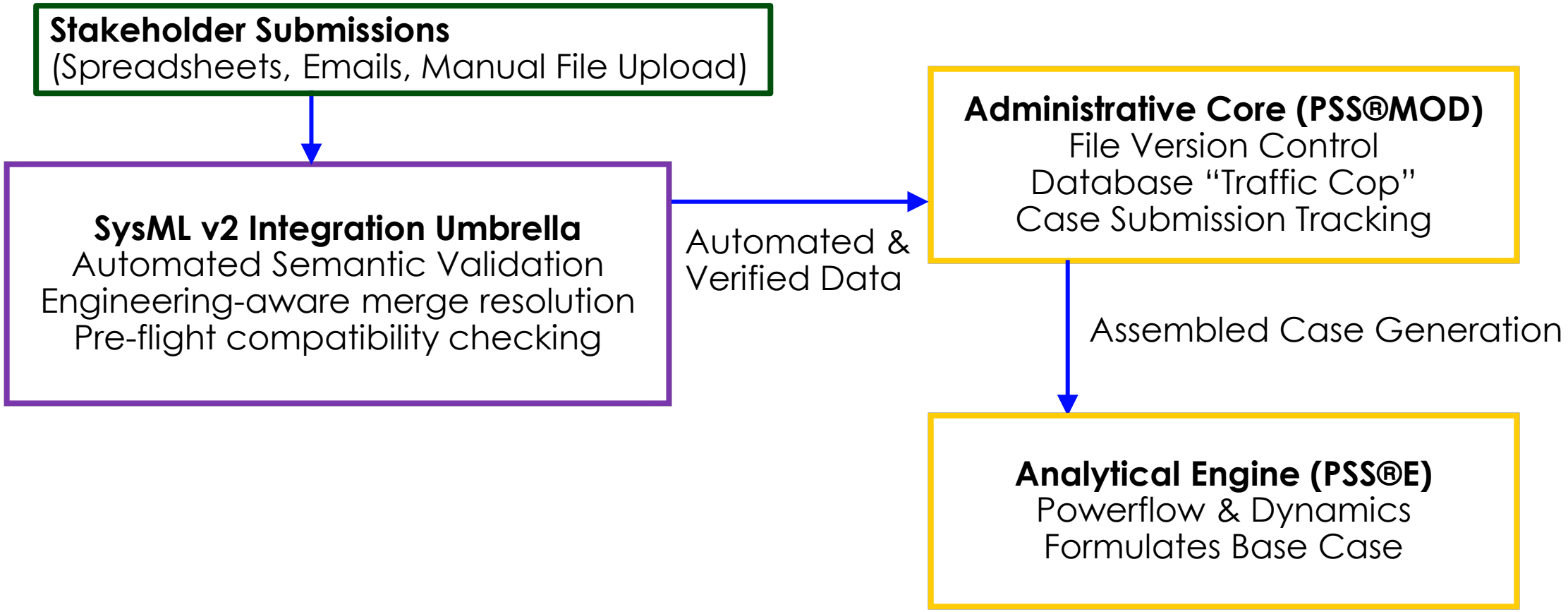
Summary of Stakeholder Analysis (CU)



EMT requirements beyond compliance:

- Generator Operator (GOP/GO)
  - Firmware logic, current limits, and network
- Transmission Operator (TOP/TP)
  - FAC-002-4 Facility Interconnection Studies
  - MOD-032-1 Data for Power System Modeling and Analysis
  - Catch Complex Anomalies
    - Sub-synchronous Control Interaction (SSCI)
    - Transient Overvoltage (TOV)
    - Weak-grid instabilities

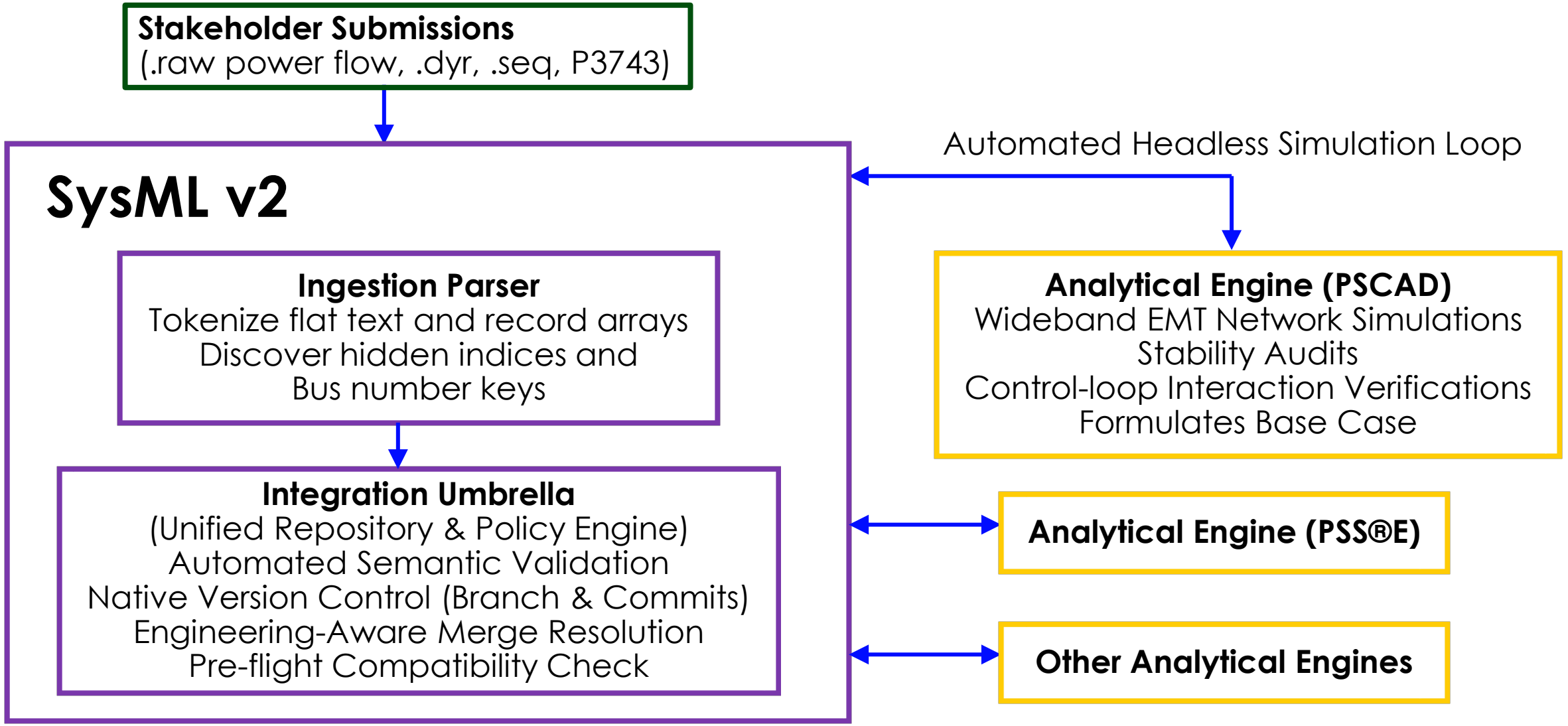
RMS submissions by the Utility to the RTO



[**1. Baseline RMS (SysML)**] ➔ [2. Multi-Engine Routing] ➔ [3. RTO/Utility Convergence] ➔ [4. Utility Input: Wideband Lines] ➔ [5. Utility Input: Transformers]

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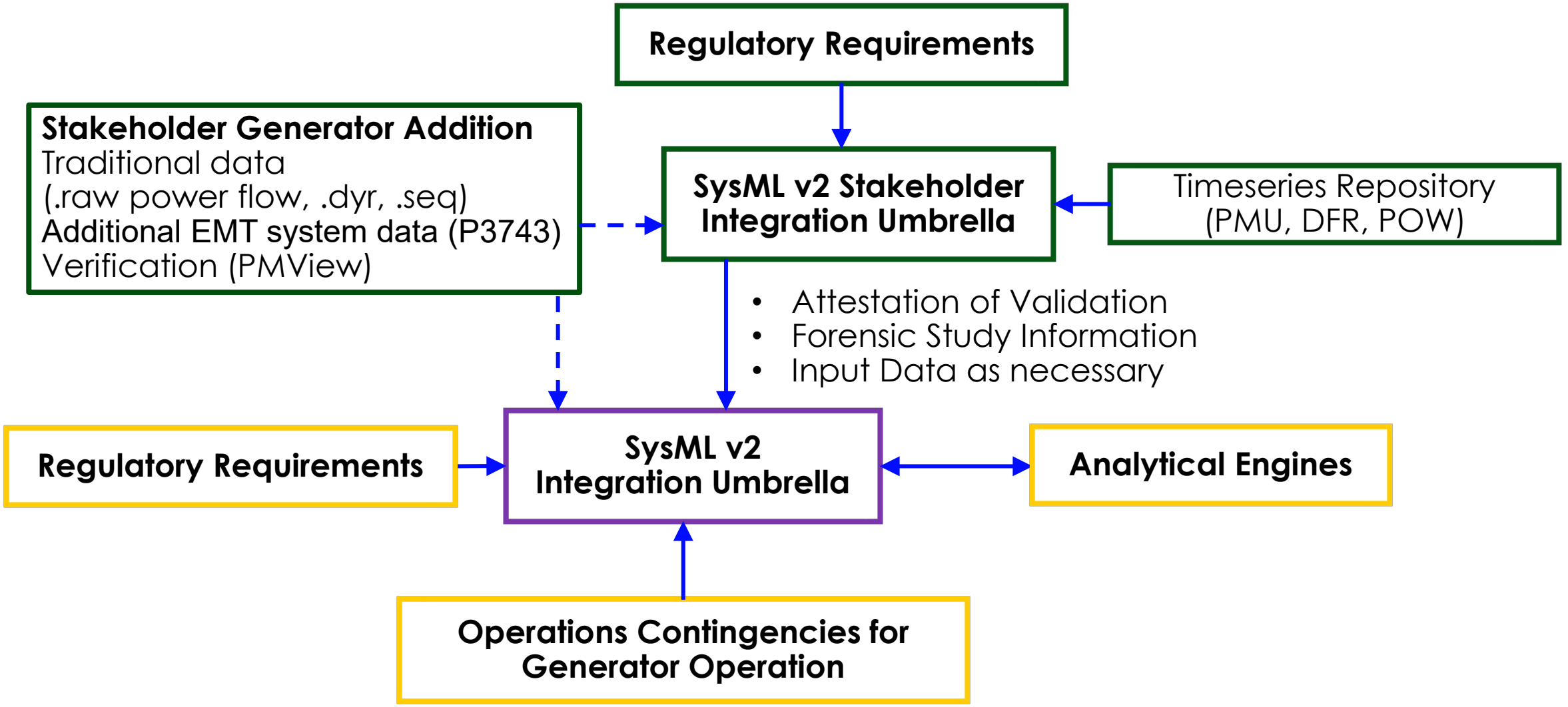
Broader Consolidated Data



[1. Baseline RMS (SysML)] ➔ [**2. Multi-Engine Routing**] ➔ [3. RTO/Utility Convergence] ➔
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Grid Strength With New Local Generation Example



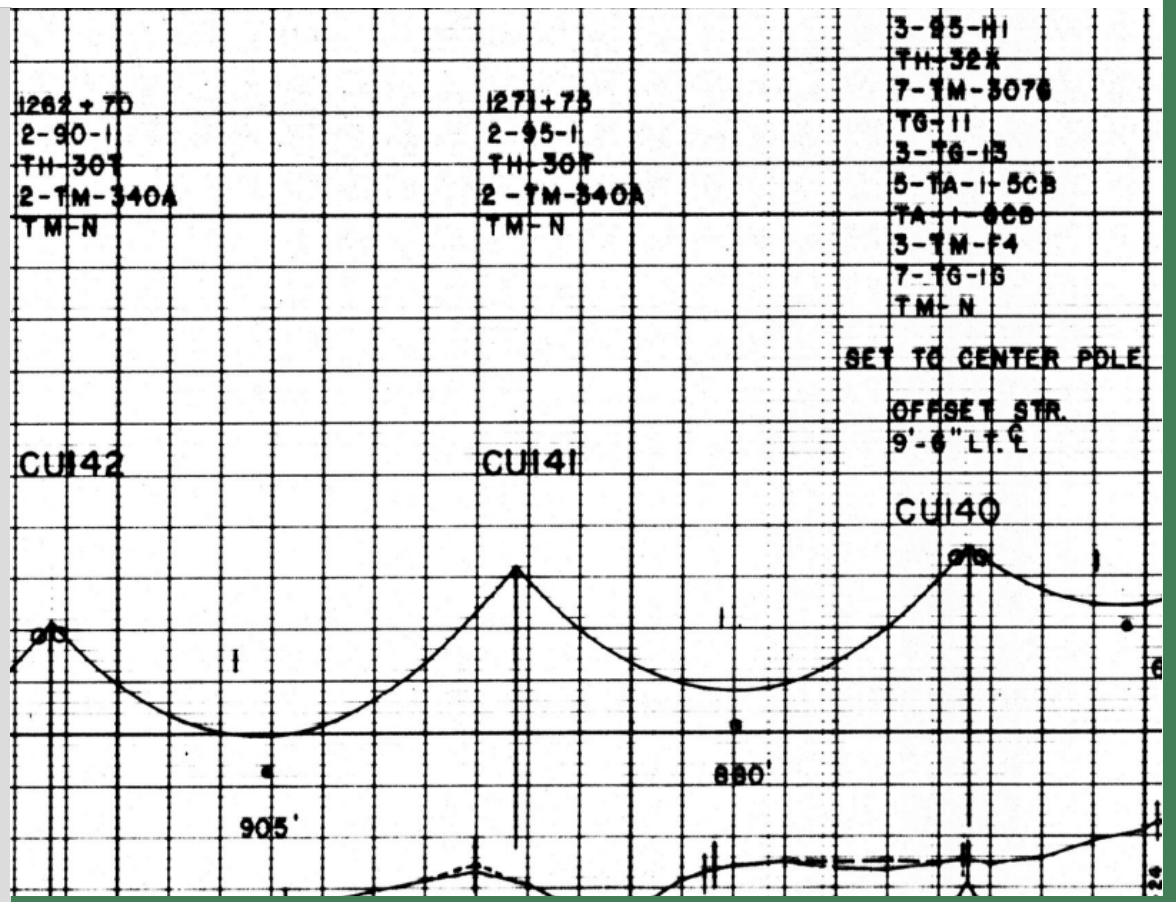
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Building Wideband Transmission Line Models: Field-to-RTO Pipeline

- **Spatial Geometry (OpenDSS)**
  - Map tower coordinates, phase spacing, and conductor sag
- **Mutual Coupling (IEEE P3743)**
  - Captures electromagnetic coupling across parallel corridors
- **Earth-Return Path (2-Layer Soil)**
  - Converts geological borings into frequency-dependent resistivity
- **Boundary Equipments (ASPEN)**
  - Integrates validated short-circuit fault parameters
- **RTO Deliverable**
  - Compiles all layers into a single, unified Wideband Line Model

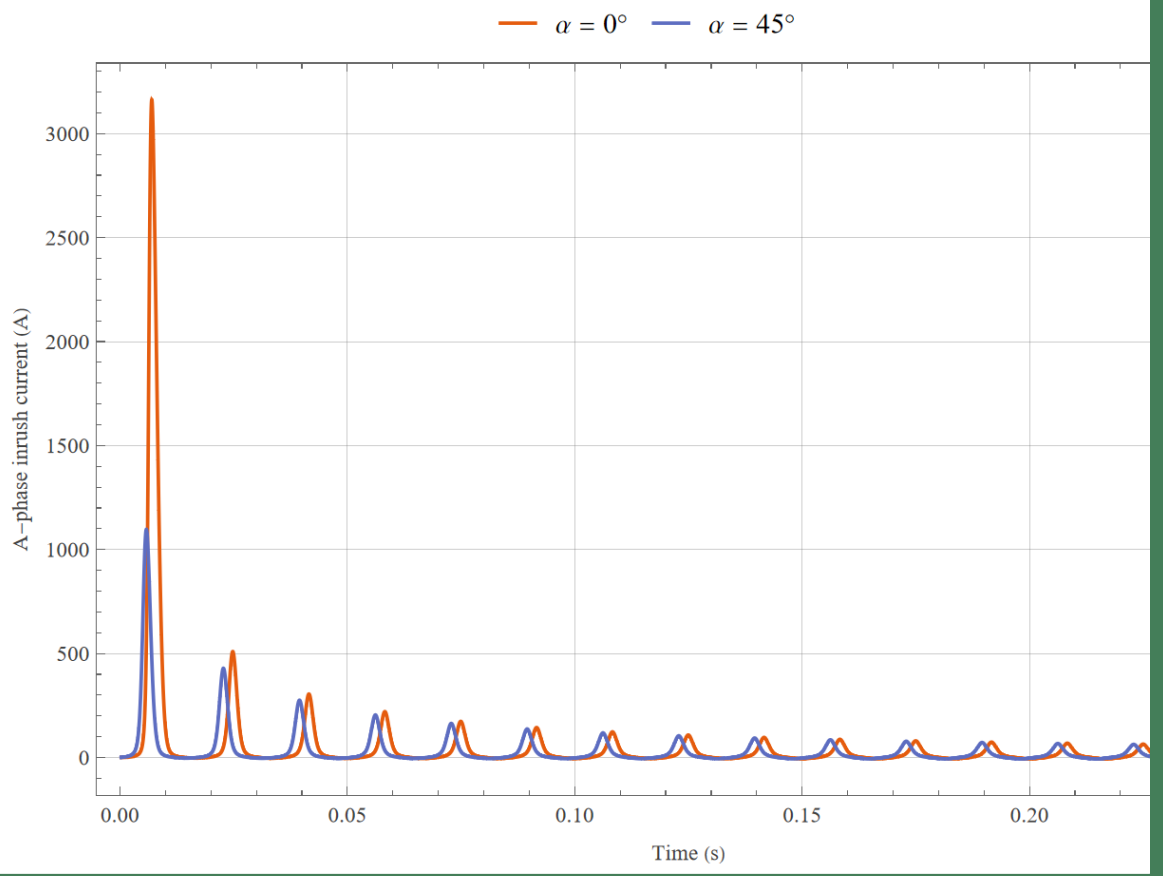


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Field-Validated Transformer Modeling: Low & High Frequency Dynamics

- **Why Field Data?** OEM factory curves fall short in deep core saturation.
- **Low-Frequency (Switching & Inrush):**
  - Layers **POW / DFR + PMU + SOE** time-series data.
  - Uses natural switching as a **High-Side Open-Circuit Test** to map true saturation.
- **High-Frequency (Lightning Dynamics):**
  - Combines off-line **SFRA** sweeps with real-world **DFR lightning captures**.
- **Result:** A single, empirically validated wideband transformer model.



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SYNTHESIS & PATH FORWARD

An Unbroken Chain: Field Physics to RTO Planning

Defensible Structures

MOD-testing resolves OEM liability for cross-solver interoperability.

Aligned Workflows

Relay-grade rigor via PMView validates weak-grid IBR stability.

Consolidated Architecture

SysML v2 routes wideband line and transformer physics to RTO solvers.

Core Takeaway: Automate semantic validation upstream without replacing legacy RTO solvers.

QUESTIONS?

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Summary of Data

- Powerflow such as .raw
- Dynamic such as .dyr
- Sequence such as .seq
- IEEE Std
  - C37.111 (COMTRADE) – transient waveform data
  - C37.232 (COMNAME) – naming for time-sequence data and event files
  - C37.239 (COMFEDE) – event data (sequence of events)
  - P3743 EMT Data and encapsulates vendor models
- OpenDSS – physical layout