ENGINEERING SERIES · EC-WP-504

Engineering Studies: Pre- and Post-COD

Pre-COD and post-COD engineering studies for reliability validation.

Pre-COD studies tell you what a project will do. Post-COD studies tell you what it actually does, and the gap between them is where most reliability surprises live. This reference walks through both, the NERC and RTO/ISO requirements that now reach past the commercial operation date, and how a project owner keeps its studies defensible for the life of the plant.

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Foreword

This professional reference is one of a series Energy Compliance, Inc. publishes for registered entities and the people who run their compliance programs.

I've spent more than thirty years on every side of the bulk electric system. I've operated control centers as a Reliability Coordinator, Transmission Operator, and Power System Operator. I've audited grid facilities and signed off on findings as a senior compliance auditor. I've worked enforcement matters from inside the regulator's process. For the last several years I've advised registered entities directly through the firm I founded.

The entities that do reliability well share a common habit. They take the standards seriously without confusing them with reliability itself. They know that a NERC Reliability Standard is a floor, not a ceiling. They know that compliance is something an auditor evaluates, but reliability is something a system either delivers or doesn't. They prepare for audits by building programs that survive real questions, not binders that look thick.

That's the perspective these references try to share. Each one focuses on a single topic: a standard family, an operational function, a regulatory framework, or an emerging industry challenge. Each one walks through how the topic actually works.

These references are written for the compliance manager who wants to understand the system, not just memorize requirements. For the legal counsel who has to brief a board honestly. For the senior operator who's been told that compliance and reliability are the

same thing and suspects they aren't. And for the new compliance hire who got handed a binder and told good luck.

These references aren't marketing material disguised as content. They're the result of three decades of doing this work and watching it succeed and fail. I've written them in the same voice I use in a control room or in front of a Regional Entity audit team: direct, grounded in evidence, and honest about what the standards do and do not require.

Energy Compliance exists because most of the consulting offered to registered entities today is structured for billable hours rather than for outcomes. Every engagement is overseen by a senior practitioner. We don't bring five people to a meeting that needs one. We automate the work that should be automated. We apply senior judgment to the work that requires it. If that approach matches what you're looking for in a compliance partner, the back of this reference has our contact information.

If not, the reference still belongs to you. Take what's useful. Apply it well. And remember the only test that ultimately matters: when the system needs to perform, does it?

Rob Smith

Founder and Principal, Energy Compliance, Inc.

Executive Summary

Pre-COD engineering studies tell you what the system will do. Post-COD studies tell you what it actually does. The gap between them is where most reliability surprises live.

Studies are reliability artifacts. Their conclusions get cited, audited, and acted on for years after the engineer who ran them has moved on. A study without verifiable assumptions, traceable methodology, and documented conclusions isn't a study. It's documentation.

For most of the last decade, a project owner could treat the commercial operation date as the finish line for studies. That is no longer true. NERC's verification and validation standard for dynamic models, MOD-026-2, took effect April 1, 2026, and asks for verified and validated models within 365 days after the commercial operation date once its compliance dates arrive. PRC-030-1 requires the Generator Owner of an inverter-based resource to analyze unexpected changes in output within 90 days and to explain them. BES IBRs comply from October 1, 2026, and applicable non-BES (Category 2) IBRs comply with R1 through R4 by January 1, 2027. ERCOT's Planning Guide already requires as-built models, model quality tests, and plant verification reports before and after commissioning. Post-COD study work is now an obligation with dates on it.

The points that matter most:

- Interconnection studies are forecasts. Once a project comes online, measured behavior often diverges from what was modeled, and that divergence creates compliance scope nobody planned for.
- A pre-COD study that didn't model the actual control settings is a study of the wrong project. NERC's May 2025 Level 3 Alert asks Transmission Planners and Planning Coordinators to make sure model parameters reflect as-built field settings before full commercial operation.
- The project owner is accountable for its own obligations no matter who performed the study. Outsourcing the study doesn't outsource the obligation.
- RTO acceptance and NERC compliance aren't equivalent. A study that satisfies the RTO process but leaves a NERC obligation unaddressed is incomplete.
- Models that don't represent inverter behavior accurately produce studies that don't predict real outcomes. NERC's own analysis says the major IBR events since 2016 were not predicted by planning processes.
- The bar isn't engineering competence. It's enforcement defensibility.

Lifecycle stage	Primary requirement	Who carries it	Timing or trigger
Interconnection study	FAC-002-4 R1, R2	TP and PC study; GO coordinates and provides data	New interconnection or qualified change
Annual planning	TPL-001-5.1 R2; MOD-032-1 R2	TP and PC assess; GO provides modeling data	Annual Planning Assessment
Commissioning (ERCOT)	ERCOT Planning Guide Section 5.5	Interconnecting Entity, then Resource Entity	Before Resource Commissioning Date; within 30 days after
Capability verification	MOD-025-2 Attachment 1	GO	Within 12 calendar months of COD, then at least every five years
Model verification and validation	MOD-026-2 Attachment 2	GO, TO; TP reviews	Within 365 days after COD or by April 1, 2029, whichever is later; then within 10 years
Unexpected IBR event	PRC-030-1 R2, R3	GO of IBR	90 days to analyze; 60 days to CAP or justification
System model validation	MOD-033-3 R1	PC; RC and TOP provide data	At least every 24 calendar months

1 Engineering Studies Within the Reliability Framework

1.1 What a Study Is For

The engineering studies required or expected for generation resources are one of the foundation blocks of the reliability framework for the Bulk Electric System. They are technically complex to prepare, but in the reliability context their job is not to choose the design that must be built. Their job is to show whether a generation resource, new or existing, fits the assumptions and performance criteria the reliability framework is built on.

From the regulator's side of the table, a study is a structured record. It shows what was analyzed, under what conditions, with what data, and when. An auditor reading it is not checking your load flow arithmetic. The auditor is asking whether the scope was right, whether the assumptions were stated and reasonable, and whether the timing fit the decision the study supported.

Studies are part of the engineering process, but they differ from design. Design specifies equipment. A study examines how a resource behaves inside the interconnected system: its impact on neighbors, its response to faults and frequency events, and its effect on transfer capability and stability margins. Reliability review cares whether those questions were answered, not which software package answered them.

1.2 Where NERC Asks for Studies

NERC's standards are mostly outcome-based. They rarely prescribe a tool or a study format. They do, however, say who studies what.

FAC-002-4, Facility Interconnection Studies, requires each Transmission Planner and Planning Coordinator to study the reliability impact of interconnecting new generation, transmission, or end-user Facilities, and of existing interconnections seeking a qualified change as the Planning Coordinator defines it. Requirement R1 lists what must be studied: the impact on affected systems; adherence to NERC standards, regional and Transmission Owner planning criteria, and interconnection requirements; steady-state, short-circuit, and dynamics studies as necessary under normal and contingency conditions; and, in Part 1.4, the study assumptions, system performance, alternatives considered, and coordinated recommendations. Requirement R2 puts the Generator Owner on the hook to coordinate and cooperate on those studies, including providing the data.

TPL-001-5.1 requires each Transmission Planner and Planning Coordinator to prepare an annual Planning Assessment that uses current or qualified past studies and documents its assumptions. MOD-032-1 requires Generator Owners and others to provide steady-state,

dynamics, and short-circuit modeling data to their Transmission Planners and Planning Coordinators under the data requirements those planners publish.

Conforming revisions, FAC-001-5 and FAC-002-5, passed final ballot with the Project 2026-02 computational load standards, as NERC announced on October 15, 2026, and now go to the NERC Board of Trustees for adoption. Until a revised version is approved and effective, FAC-002-4 governs.

Read those three together and the point is plain. NERC does not care what your study looks like. It cares that the right entity studied the right questions, wrote down its assumptions, and used data that represents the equipment.

1.3 Where the RTO or ISO Comes In

The regional interconnection process turns those outcome requirements into specific studies. The details differ by region because system design, generation mix, and operating practice differ.

In ERCOT, Section 5 of the Planning Guide governs generator interconnection or modification. It states that its requirements are designed to make sure new or modified generation interconnects in a way that maintains ERCOT System reliability and complies with NERC Reliability Standards, the Protocols, the Planning Guide, and the Operating Guides. A large generator goes through a Security Screening Study and then a Full Interconnection Study made up of steady-state analysis, system protection (short-circuit) analysis, dynamic and transient stability analysis, and a facility study.

In the FERC-jurisdictional RTOs and ISOs, the interconnection procedures sit in each tariff. FERC Order No. 2023 reformed the pro forma Large and Small Generator Interconnection Procedures and Agreements to address queue backlogs and improve certainty. Those procedures decide how the study is run. They do not relieve any registered entity of its own NERC obligations.

1.4 Assumptions Do the Real Work

Every engineering analysis rests on assumptions: hypothetical system states, assumed operating modes, assumed resource performance. Assumptions make the analysis tractable. They also decide its conclusions. That is why FAC-002-4 names study assumptions as something the study must address, and why TPL-001-5.1 requires the Planning Assessment to document them. A reliability review has to look at the results and at the assumptions behind them, and ask what happens to reliability if an assumption turns out wrong.

1.5 Coordination Across Boundaries

Studies cross organizational lines. The Generator Owner, the Transmission Owner, the Transmission Planner, the Planning Coordinator, and the operators who will run the system all need a consistent picture of how the resource behaves. The reliability consequences of one resource can reach far beyond its fence line. FAC-002-4 recognizes this directly: studies may be performed independently, but the results must be evaluated and coordinated by the entities involved.

1.6 Studies Are Time-Bound

A study describes the system, the methods, and the reliability questions of a particular time. The system keeps moving. New lines, retirements, new resources, and changed settings can make an earlier study stale. Updating a study when that happens is normal system management, not a failure. TPL-001-5.1 builds this in: a past study can support a Planning Assessment only if it is five calendar years old or less (unless a technical rationale shows the older results are still valid) and no material changes have occurred to the system it represents.

End-of-Chapter Summary

Engineering studies are the analytical tools the reliability framework uses to understand how generation resources interact with the BES across planning and operating conditions. NERC standards such as FAC-002-4, TPL-001-5.1, and MOD-032-1 assign who studies what and who supplies the data. RTO and ISO processes decide how the studies are run. Neither prescribes how the plant must be designed. The rest of this reference follows a study from pre-COD forecast through post-COD verification.

> **From the Field**
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> An engineering study is not a check-the-box exercise. It is a reliability artifact. The study's conclusions get cited, audited, and acted on for years.

2 Pre-Commercial Operation Studies and Reliability Validation

2.1 What Pre-COD Studies Evaluate

Pre-commercial operation studies are carried out during planning and interconnection, while the resource exists only on paper. Their purpose is not to verify the plant's design. It is to make sure reliability questions are answered before the resource begins operating.

These studies simulate expected system behavior under a range of conditions: forecast load and generation, network topology and operating states, and credible contingencies. They are where potential interactions, stability limits, and short-circuit impacts first show up. Under FAC-002-4 R1, the Transmission Planner and Planning Coordinator perform steady-state, short-circuit, and dynamics studies as necessary to evaluate performance under normal and contingency conditions. The standard does not tell them which tools to use, but the scope has to reach the reliability consequences that matter.

The regional process adds detail and consistency. In ERCOT, for example, the stability portion of the Full Interconnection Study must dispatch operational and planned generators in the study area at full net output in at least one scenario, unless the report gives a technical rationale for doing otherwise. If the lead TSP decides a stability study is not required, it must provide a written justification in place of the study report.

2.2 The Model Is Only as Good as the Data

Resource modeling in pre-COD studies depends on a long list of assumptions about capability and control behavior: expected operating modes, voltage and frequency control, ride-through, and plant controller response during both normal operation and faults. When the interconnection study is run, the final inverter firmware, plant controller tuning, and protection settings are often not yet fixed.

That is where the risk sits. The joint NERC and Texas RE report on the 2021 Odessa disturbances found that the performance issues it identified, and those in past NERC disturbance reports involving solar PV, should have been identified during interconnection studies. The report also found that conventional positive sequence simulations do not model inverter-based resources with enough resolution to show every control and protection function that could trip a plant, and recommended EMT models and studies for all newly interconnecting IBRs.

NERC's May 20, 2025 Level 3 Alert on IBR Performance and Modeling went further. It asks Transmission Planners and Planning Coordinators to enhance their modeling and study practices, including model quality and accuracy criteria and performance testing that confirms

model parameters reflect as-built field settings and that model performance matches field performance before the resource reaches full commercial operation.

2.3 The Baseline for Everything That Follows

A pre-COD study does one more job that is easy to overlook. It sets the baseline. Once the plant is running, the pre-COD results are the yardstick for asking whether actual performance matches what was expected. If the assumptions behind that baseline were never written down, nobody can tell later whether a deviation is a plant problem or a study problem.

Pre-COD studies are not guarantees of future performance. They are best-effort analyses based on the data and assumptions available when they were run. The reliability question is whether their scope and analysis were sufficient and whether the planning and interconnection process actually used them.

2.4 The Commissioning Gate

ERCOT makes the pre-COD to post-COD handoff explicit. Under Planning Guide Section 5.5, before the Resource Commissioning Date of an IBR, the Interconnecting Entity must submit dynamic models for the as-built data alongside the data submitted for the quarterly stability assessment, documentation of any differences, and model quality test results for the as-built data overlaid with the earlier results. No later than 30 days after the Resource Commissioning Date, the Resource Entity must submit updated dynamic planning and operations models based on as-built data, with model quality tests and a plant verification report.

That sequence is the whole argument of this chapter in procedural form. The study model and the built plant have to be compared, and the differences documented, before the plant is treated as the plant that was studied.

End-of-Chapter Summary

Pre-commercial operation studies are a disciplined way to determine, before commissioning, how a new resource will interact with the BES. NERC planning standards and RTO/ISO processes require them, and they let a reliability conclusion be reached before the plant runs. They document assumptions about system interaction and resource behavior, but they do not guarantee later performance or impose a design. Their weakest point is model data that does not match the equipment and settings actually installed.

> **From the Field**
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> Pre-COD studies model the project's expected interaction with the system. The model is only as good as the input data, and the data sources matter.
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> A pre-COD study that didn't model the actual control settings of the inverter is a study modeling the wrong project. NERC's 2025 Level 3 Alert targets exactly this gap.

3 Post-Commercial Operation Studies and Ongoing Reliability Alignment

3.1 A Different Purpose

Post-COD studies serve a different reliability purpose than pre-COD studies. Pre-COD work rests on assumptions about future operation. Post-COD work tests those assumptions against measured behavior and real system conditions. It keeps planning assumptions aligned with how the plant and the system actually operate.

3.2 What Triggers Post-COD Work

Post-COD analysis typically follows a change or a surprise:

- A change in system configuration, such as new transmission, retirements, or a change in topology near the plant.
- Plant performance that differs from what the pre-COD studies predicted, often revealed by a disturbance.
- A change to the plant itself, such as new firmware, plant controller tuning, or protection settings.
- A change in reliability criteria or in the standards that apply.

Each one raises the same question: do the interactions assessed earlier still hold for the system and the plant as they exist today?

3.3 The Requirements That Now Reach Past COD

Post-COD study work used to be mostly good practice. Several requirements now put dates on it.

MOD-025-2 requires each new applicable Facility's Real and Reactive Power capability to be verified within 12 calendar months of its commercial operation date, and then at least every five years, with no more than 66 calendar months between verifications. A change that affects capability by more than 10 percent and is expected to last more than six months triggers verification within 12 calendar months of its discovery.

MOD-026-2, Verification and Validation of Dynamic Models and Data, took effect April 1, 2026 and retired MOD-026-1 and MOD-027-1. It applies to Generator Owners, Transmission Owners, Transmission Planners, and Planning Coordinators. The model-submittal obligations (R2 through R4, and R6) sit with Generator Owners and Transmission Owners, including owners of BES and qualifying non-BES inverter-based resources. The Transmission Planner and Planning Coordinator carry the model requirements and reviews (R1 and R5). Requirement R2 calls for a

positive sequence dynamic model representing the in-service equipment, documentation of Model Verification against the design and settings of that equipment, and documentation of Model Validation comparing model behavior to measured behavior during a staged test or system disturbance. Attachment 2 requires a newly commissioned facility to transmit those models within 365 calendar days after its commercial operation date, and every facility to repeat the process within 10 calendar years of its most recent transmittal. The implementation plan gives entities 36 months from the effective date, until April 1, 2029, to comply with Requirements R2 through R6. Plants reaching COD now should build to the new standard from day one.

PRC-030-1, Unexpected Inverter-Based Resource Event Mitigation, took effect October 1, 2026. BES IBRs must comply from that date; applicable non-BES (Category 2) IBRs must comply with R1 through R4 by January 1, 2027. It requires the Generator Owner of an applicable IBR to maintain a documented process for identifying a complete loss of output, or a Real Power change of at least 20 MW and at least 10 percent of gross nameplate within four seconds, excluding listed causes such as resource variability and dispatch. Within 90 calendar days of such an event, or of a request from its Reliability Coordinator, Balancing Authority, or Transmission Operator, the Generator Owner must determine root cause, document ride-through performance, assess whether corrective action is needed, and determine whether the root cause applies to its other IBR facilities. If corrective action is needed, a Corrective Action Plan or a technical justification is due within 60 days after the analysis.

PRC-028-1, effective April 1, 2025, sets disturbance monitoring and reporting requirements for IBRs, and PRC-029-2, effective October 1, 2026 in place of PRC-029-1, sets their frequency and voltage ride-through requirements. Together they define both the performance a post-COD analysis is measured against and the data it is measured with.

In ERCOT, the Planning Guide requires a plant verification report no later than 30 days after a settings change, again between 12 and 24 months after the later of the Resource Commissioning Date or March 1, 2021, and at least every ten years.

3.4 Disturbances as Study Inputs

Disturbances are the post-COD study nobody schedules. When a plant fails to ride through an event, the investigation usually starts with the question of why the pre-COD study did not predict it. NERC's 2025 Level 3 Alert states that since 2016 NERC has analyzed major events totaling more than 15,000 MW of unexpected generation reduction, that these events were not predicted through current planning processes, and that NERC studies could not replicate the behavior that occurred. PRC-030-1 turns the plant-level version of that investigation into a requirement.

3.5 Shared Awareness

Post-COD results matter beyond the plant fence. Planners, operators, and the Reliability Coordinator all work from models. When post-COD analysis shows that a plant behaves differently from its model, the fix only helps reliability if the corrected model reaches the people who use it. Otherwise outdated assumptions stay embedded in operating procedures and planning cases. The grid these plants operate in changes every year, with load growth, a

shifting resource mix, and new operating practices. Post-COD studies are how the record keeps up.

End-of-Chapter Summary

Post-commercial operation studies re-validate the relationship between an operating resource and the BES in its current configuration. MOD-025-2, MOD-026-2, and PRC-030-1 now attach specific post-COD deadlines to that work, and ERCOT's Planning Guide adds its own commissioning and verification requirements. The core of post-COD analysis is the comparison of assumed versus observed behavior, and it is how reliability validation continues after the interconnection approval.

From the Field

Post-COD studies verify what the project is actually doing. The verification matters because operating performance often diverges from the planning assumption.

Disturbance reports become a major input to post-COD analysis. A disturbance that the project didn't ride through gets investigated, and the investigation often reveals that the pre-COD study didn't predict the actual behavior.

4 Interfaces Between NERC Standards and RTO and ISO Study Requirements

4.1 Two Layers, Both With Authority

Engineering studies for generation resources sit where national reliability requirements meet regional planning practice. NERC sets the reliability requirements through its standards. The RTO or ISO administers the study process that supports interconnection and operations. Know which layer asks for what, and you know which gaps are yours.

NERC standards say what must be achieved and who is responsible. They seldom prescribe tools, methods, or report formats. What they require is that the necessary analyses exist and show that the applicable performance criteria were considered. TPL-001-5.1, for instance, sets the planning events and performance requirements a Planning Assessment must meet, and FAC-002-4 sets what an interconnection study must address.

4.2 Coordination, Not Duplication

RTO and ISO study processes translate those objectives into studies that fit local topology, operating procedures, and planning horizons. The relationship is meant to be coordination, not duplication, as the ERCOT Planning Guide purpose statement in Section 1.3 shows.

Differences between regions do not mean different reliability expectations. They reflect different systems. What matters from a reliability perspective is whether each region's process addresses the material reliability implications of the resource, with scope adequate to the question and assumptions transparent enough to check.

4.3 Where the Gaps Show Up

The trouble starts when a project owner treats the regional process as the whole job. The RTO study may be complete for the RTO's purposes while a NERC obligation that belongs to the Generator Owner goes unaddressed. Common examples:

- FAC-002-4 R2: the Generator Owner's duty to coordinate and provide data is its own requirement, separate from the planner's study obligation.
- MOD-032-1 R2: modeling data must follow the data requirements and reporting procedures the Planning Coordinator and Transmission Planner publish, which may differ from what the interconnection application asked for.
- MOD-025-2 and MOD-026-2: capability verification and model verification and validation run on their own clocks from the commercial operation date.

- PRC-024-4 or PRC-029-2: settings and ride-through capability that must hold in operation, not just in the study.

A single study can serve several purposes and several reviewers. That is efficient, but only if the assumptions, limits, and conditions of the study are documented well enough for each reviewer to see how its results connect to the requirement in front of them.

End-of-Chapter Summary

The scope of engineering studies for generation resources falls at the boundary between NERC Reliability Standards and RTO/ISO study requirements. NERC sets outcome-based requirements and assigns responsibility; regional processes reflect each system's configuration and practices. Reliability review asks whether the two layers together cover the material risks, whether the methods are transparent, and whether each entity has met the obligations that are its own.

> **From the Field**
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> NERC sets the reliability requirements. The RTO/ISO administers the study process. Both have authority. The project owner has to satisfy both.
>
> A study that meets RTO requirements but misses NERC requirements is not a complete study. The owner is accountable for the gap, even when the RTO didn't flag it.

5 Study Assumptions, Modeling Boundaries, and Reliability Risk

5.1 Assumptions Set the Conclusions

Assumptions and boundaries are the foundation of every study of a generation resource. They shape how the system is modeled and how the resource's capability is assessed. That is why reliability oversight focuses on how assumptions are formed, documented, and interpreted, more than on the analytical method.

Assumptions are the conditions under which a study's conclusions stay valid. They cover system topology, dispatch, load, available resources, and operating conditions. They are necessary to analyze a very complex system. They are also a standing source of uncertainty, because the real system will eventually operate in conditions the model did not contemplate.

TPL-001-5.1 treats that uncertainty as something to be measured, not ignored. For the near-term steady-state portion of the Planning Assessment, Requirement R2, Part 2.1.3 requires sensitivity cases that vary one or more conditions, including forecast load, expected transfers, in-service dates of new Transmission Facilities, reactive resource capability, and generation additions, retirements, or dispatch, enough to show a measurable change in System response.

5.2 Boundaries Define What Was Studied

Boundaries delimit the study. They define which parts of the system, which interactions, and which time frames are in or out. They are set by planning jurisdiction, study objective, and practical limits. A study does not need to model every possible interface, but its boundaries must be wide enough to catch the material reliability issues for the resource. A model bounded too narrowly can miss exactly the contingency that matters.

5.3 When Assumptions Meet Reality

The most common source of study risk is a mismatch between assumption and reality. A study is valid only as long as the assumptions it was built on remain valid. When enough time passes, or when operating practice or plant settings change, the assumptions can quietly expire, giving a misleading picture of reliability or hiding a new concern.

The gap is sharpest for generation resources. Pre-COD studies rest on assumed conditions and expected resource behavior. Post-COD studies rest on revised and measured data. The two are complements. No single study can analyze every operating scenario.

5.4 Transparency and Reuse

Assumptions and boundaries have to be visible for anyone else to interpret the results. Transparency does not mean every study uses the same assumptions. It means the

assumptions are stated clearly enough that a reviewer can judge whether they fit the question. MOD-026-2 makes this concrete: where a Generator Owner cannot verify a model parameter, Part 2.2.1 requires a written statement to the Transmission Planner identifying the unverifiable parameters and why they cannot be verified.

Reuse deserves its own attention. Assumptions carried from one study into the next without review are a quiet risk in a system that keeps changing. A disciplined program records where each key assumption came from, when it was last checked, and which later studies relied on it.

End-of-Chapter Summary

Study assumptions and modeling boundaries are central to the reliability conclusions drawn for generation resources. Assumptions make analysis possible but introduce risk when they no longer reflect the real system. Reliability review concentrates on whether assumptions and boundaries are valid, documented, and still current, rather than on the methods that use them.

> **From the Field**
>
> The assumptions that go into a study determine its conclusions. Wrong assumptions produce wrong conclusions, and the wrong conclusions live in the program until the next disturbance reveals them.
>
> Boundary conditions matter. A study that bounded the model too narrowly missed the contingencies that mattered.
>
> Risk assessment is part of the study, not a footnote. Programs that treat risk as an afterthought have not done the assessment the framework expects.

6 Timing, Triggers, and Study Lifecycle Considerations

6.1 Timing Changes the Value of a Study

When a study is performed, and what triggers it, has a direct effect on its reliability value. A study is not a one-time deliverable. It is a function that runs across the life of the resource, and oversight cares about when studies are done and under what conditions.

Pre-COD studies are triggered by proposed changes to the system, most often new or modified generation. Their value depends on timing relative to key milestones such as interconnection approval and initial synchronization. A study run too early rests on design assumptions that have not matured. A study run too late leaves no time to deal with what it finds.

ERCOT's quarterly stability assessment shows how tightly that timing can be managed. ERCOT studies planned large generators every three months, and a generator that has not met the prerequisites by the deadline is not eligible for Initial Synchronization in that quarter. For a planned Initial Synchronization in January through March, for example, prerequisites are due by the prior August 1 and the assessment is completed by the end of October.

6.2 What Triggers a Fresh Look After COD

Post-COD studies are undertaken for several reasons: a change in system configuration, observed performance that departs from expected performance, a change in operating constraints, or re-evaluation of long-term development. Not every change needs a full study. What oversight looks for is a defined way of deciding when a review is necessary.

Some of those triggers are now written into the rules:

- ERCOT Planning Guide Section 5.5(6): before an IBR modifies control settings or equipment in a way that affects dynamic response at the Point of Interconnection, the Resource Entity submits the revised model and overlaid model quality tests for ERCOT and TSP review. ERCOT may recommend a limited dynamic stability study, require a new Generator Interconnection or Modification request, accept the change, or reject it.
- MOD-025-2: the capability-change trigger described in Section 3.3.
- MOD-026-2 (compliance from April 1, 2029): R4 requires updated models within 180 calendar days after a change that alters dynamic response; R6 requires a response within 120 days of an unacceptability notice or 180 days of a review request.
- PRC-030-1: a qualifying unexpected output change starts a 90-day analysis clock.

6.3 The Age of a Study

Engineering studies are a snapshot of the system at a point in time. As conditions change, the snapshot stops depicting reality. So the question is not whether a program "adhered" to a prior

study. The questions are how old the study is, what scope and conditions it covered, and whether it is still valid for the current situation.

TPL-001-5.1's limit on reusing past studies, set out in Section 1.6, gives a useful benchmark. That rule binds planners, not Generator Owners, but it is a fair test for any study a compliance position leans on.

Periodic obligation	Requirement	Interval
Real and Reactive Power capability verification	MOD-025-2 Attachment 1	At least every five years, no more than 66 calendar months apart
Dynamic model verification and validation	MOD-026-2 Attachment 2, Row 3	Within 10 calendar years of most recent transmittal
Use of past studies in a Planning Assessment	TPL-001-5.1 R2, Part 2.6	Five calendar years or less, absent technical rationale
System model validation against actual behavior	MOD-033-3 R1	At least once every 24 calendar months
ERCOT plant verification report	Planning Guide Section 5.5(6)(c)	30 days after a settings change; 12 to 24 months after the later of the Resource Commissioning Date or March 1, 2021; then at least every ten years

6.4 Lifecycle Continuity

Old studies often get reused for new evaluations of the same project. That is fine if the continuity is managed: changes in assumptions and model parameters over time are recognized and addressed, and the record shows which study supported which decision. Studies aligned with established planning cycles, seasonal assessments, and known maintenance or system modifications tend to produce information people can actually use.

End-of-Chapter Summary

The reliability value of a study depends on its timing and its triggers as well as its quality. Pre-COD studies evaluate a change before it is made; post-COD studies re-evaluate reliability as the plant and the system change. Engineering studies need continuing currency, tracking, and adaptation, and the standards now set specific intervals for several of them.

> **From the Field**
>
> Verification: do the model's structure and parameters represent the equipment design and settings? Validation: did the model match reality? NERC now defines both terms, MOD-026-2 requires both, and both have to be evidenced.
>
> A model validated against real performance is the discipline that distinguishes reliability work from engineering exercises.

7 Reliability Oversight Use of Engineering Study Outputs

7.1 What Oversight Does With a Study

Engineering studies of generation resources give reliability analysts a structured view of system-level risk. Running the study is technical work. Oversight is concerned with how the study was planned, how its results were used, and whether they identify reliability risks. The aim is to keep the reliability model non-prescriptive while still evaluating performance properly.

Oversight does not re-check each calculation. It tests whether a study's conclusions are internally consistent, reasonable, and tied to the applicable reliability requirements. Part of that is comparison. If studies of similar resources under similar assumptions reach materially different results, something in the assumptions, boundaries, or system characteristics needs explaining.

7.2 Cumulative Effects

Taken together, individual study results show how new generation is changing system dynamics over time, and Section 9.2 looks at that cumulative effect with the Odessa data.

7.3 The Operational Link

Study outputs are not usually used for real-time decisions, but operating models and practices rest on assumptions that pre-COD and post-COD studies validate. MOD-033-3, effective April 1, 2026, requires each Planning Coordinator to implement a documented process comparing its planning models to actual system behavior, both steady-state and dynamic, at least once every 24 calendar months, with guidelines for identifying and resolving unacceptable differences, including those for generating facilities. Reliability Coordinators and Transmission Operators must provide actual system behavior data within 30 calendar days of a written request. That is the planning side of the same loop a Generator Owner runs at the plant level.

7.4 Industry Learning

Oversight bodies use study and event findings to drive learning across the industry. NERC's disturbance reports, Level 2 Alerts, and Level 3 Alerts on inverter-based resources are examples. They identify trends and emerging concerns. A Level 3 Alert's Essential Actions are actions NERC has determined are essential to reliability and to which registered entities must respond, but the alert itself does not change the requirements of any approved Reliability Standard.

7.5 Transparency and Traceability

From an oversight perspective, the two characteristics of study output that matter most are transparency and traceability. Transparency lets a reviewer see the reasoning, assumptions, and scope behind the findings, and keeps anyone from stretching the results past what the study supports. Traceability lets a reviewer follow a conclusion back to the data, model version, and settings it came from. A study without both may be sound engineering and still be impossible to defend.

End-of-Chapter Summary

Reliability oversight uses study results as evidence of how design and operating factors affect system-wide risk. It compares results, tests consistency, and checks whether study conclusions actually feed operational planning. Transparency, traceability, and alignment with reliability objectives are what let study outputs serve industry learning and situational awareness without dictating technical solutions.

> **From the Field**
>
> The most common study issue: the input data didn't reflect the as-built configuration. Design data and as-built data diverge, and the study based on design data overestimates performance.
>
> Settings drift. The settings used during commissioning often differ from settings in operation. Studies based on commissioning settings don't predict operating reality.
>
> Vendor data isn't always accurate. The standards expect the project owner to verify, not just to accept.

8 Distinguishing Reliability Validation from Engineering Approval

8.1 Two Different Questions

A sound reliability program understands the difference between a study used for reliability validation and a study used for project approval or design validation. The same document can serve planning, interconnection, and operations. What changes is the question being asked of it.

Reliability validation asks whether a resource has been modeled and analyzed in a way that supports BES reliability. It is a functional analysis of system interactions, assumptions, and impacts. Engineering approval in an RTO or ISO interconnection process asks different questions: feasibility, cost responsibility, and readiness to build. A reliability analysis may ride along with the studies used for those approvals, but the reliability question is its own question.

8.2 Verification, Validation, Certification, Guarantee

The distinctions between verification and validation, and between certification and guarantee, explain what studies can and cannot do. The NERC Glossary now defines Model Verification as confirming that model structure and parameter values represent the equipment or facility design and settings, and Model Validation as comparing simulation results with measurements to assess how closely the model matches measured behavior.

No study can guarantee that a resource will perform exactly as predicted under every plausible future condition. A study assesses reliability questions under stated assumptions, using the data available at the time. Verification and validation are how those assumptions get tested.

8.3 When Approval Is Mistaken for Validation

Trouble starts when the two are confused. If an interconnection approval is treated as permanent reliability validation, accountability lands in the wrong place, and real changes in system conditions or plant behavior go unexamined. Treating studies as tools for reliability awareness keeps the framework flexible. A project approved on studies done in one year may interact with the system differently five years later. Post-COD validation can re-examine those interactions while recognizing that the original approval was sound for the conditions that existed then.

Keeping that boundary clear also makes for better conversations between owners, planners, and auditors. Nobody has to defend the original approval in order to admit that the plant or the system has changed.

8.4 What the Enforcement Data Says

NERC's 2025 ORCP and CMEP Annual Report, published February 11, 2026, shows why this matters. In 2025, MOD-025 was among the three most frequently reported Operations and Planning noncompliance areas, and MOD-026, MOD-027, PRC-019, and PRC-024 were also in the top ten. The report attributes MOD-025 noncompliance mainly to lack of understanding or compliance awareness and to missing or deficient procedures. The same report says registered entities self-identified approximately 85 percent of reported noncompliance in 2025, and that the ERO Enterprise reads high self-reporting as a sign of good detective controls.

End-of-Chapter Summary

Engineering studies serve different purposes in planning, interconnection, and operations. Reliability review looks at them as validation, not as approval or certification. Misreading a completed study as a permanent answer leads to wrong assumptions about system performance. Keeping validation and approval separate preserves the ability to re-validate, keeps oversight objective, and keeps the plant's record aligned with the system it actually operates in.

> **From the Field**
>
> The project owner is accountable for the studies regardless of who performed them. Outsourcing the study doesn't outsource the obligation.
>
> A study that becomes the basis for a compliance argument has to hold up under audit-level scrutiny. The bar isn't engineering competence; it's enforcement defensibility.
>
> Programs that surface their own study gaps have a different enforcement experience than programs that wait for the auditor. Most reported noncompliance is already self-identified; make sure yours is.

9 System Evolution, Generation Characteristics, and Study Relevance

9.1 The System Keeps Changing

The relevance of any engineering study changes as the BES changes. New generation technologies and operating practices alter how generation and the transmission system interact, and that can undermine the assumptions a study was built on. Inverter-based resources respond to faults and frequency events through control logic, not physics alone. Their behavior during disturbances does not match what traditional models of synchronous machines assumed, and it can change with a firmware update.

FERC recognized the scale of the problem in Order No. 901, issued October 19, 2023, which directed NERC to develop new or modified Reliability Standards addressing IBR reliability gaps in four areas: data sharing, model validation, planning and operational studies, and performance requirements. MOD-026-2, PRC-028-1, PRC-029-2, and PRC-030-1 are part of the response.

9.2 Cumulative Effects of a Changing Mix

As the resource mix changes, the combined effect of many similar resources can become a material reliability issue even when each project looked fine on its own. The Odessa report illustrates the pace. At the time of the May 2021 event, the ERCOT footprint included about 7,200 MW of solar PV with nearly 790 MW more in commissioning. By the end of August 2021 there were 8,900 MW in service and another 1,000 MW in commissioning. Study assumptions about neighboring resources can expire as fast as the queue clears.

9.3 Topology and Operations

Transmission projects, retirements, and changes in operating conditions such as voltage and reactive limits can change how the system performs after a study's base case was set. A study can lose its relevance when the transmission system around it changes, or when the standards change. TPL-001-5.1's limits on reusing past studies exist for that reason, and TPL-001-6 is already pending regulatory filing at NERC.

9.4 Studies Are Not a Crystal Ball

Engineering studies cannot foresee every interaction or behavior. Work done before commercial operation can do no more than form a hypothesis about how the plant will perform. Operation then supplies the data to test it. A good study should not become worthless the moment an assumption changes; it should be documented well enough that someone can see which conclusions still stand and which need rework. Continuing monitoring of the plant and steady accumulation of measured data are what keep it useful.

Oversight does not set a fixed interval between studies for every case. It expects the program to know when results have become outdated and to treat old findings in their context, so that nobody keeps citing a conclusion whose conditions have passed.

End-of-Chapter Summary

The relevance of engineering studies is shifting as generation characteristics, system configuration, and operating practices evolve. The changing BES is eroding long-standing assumptions behind many studies. Reliability oversight focuses on knowing when a study still applies and when design or operating changes require a fresh look.

From the Field

"It's the same plant. We only updated the firmware." Inverter behavior can change with a firmware update, and MOD-026-2 R4 treats a firmware change that alters dynamic response as a reason to update the model. The study that cleared the plant may describe equipment that is no longer in service.

"Studies are engineering deliverables, not compliance ones." They are both. The compliance dimension is real: MOD-025 was among the three most frequently reported O&P noncompliance areas in 2025.

10 Synthesis and Reliability Perspective on Engineering Studies for Generation Resources

10.1 A Layer of Evidence

Engineering studies required or expected by NERC and by RTOs and ISOs are a layer of evidence under the reliability of the BES. They give a structured analysis of how generation resources and the grid interact, before and after commercial operation. Taken together, they support a reliability approach built on validation, situational awareness, and adaptability, rather than on a one-time approval.

The common thread through every stage is that studies validate reliability assumptions. With assumptions that fit the period studied, they turn reliability criteria into a test of how the system will actually perform. Oversight is then mostly a matter of knowing what was studied, when, with what coverage, and under what assumptions, more than how the method worked. That keeps the approach technology-neutral, which is exactly what is needed as new generation technologies arrive.

10.2 Pre-COD and Post-COD as One Process

The split between pre-COD and post-COD studies is what keeps validation dynamic. Pre-COD studies rest on forecasts and proposed characteristics. Post-COD studies test those assumptions against actual performance and real conditions. The goal is a continuous process that keeps assumptions and conditions consistent over time. It is not a guarantee of future performance. With MOD-026-2, PRC-030-1, and ERCOT's commissioning and verification requirements, that continuous process now has deadlines.

10.3 Two Layers, One Obligation

NERC sets the reliability criteria and assigns responsibility. RTOs and ISOs shape the studies to their systems. Oversight looks at whether the whole is coherent, transparent, and comprehensive enough, not whether every region does it the same way. The project owner has to meet both layers.

10.4 What Stays Constant

Assumptions, modeling boundaries, time frames, and triggers decide how long a study stays valid. Reliability risk lives in the analysis and in those surrounding conditions, and in any misalignment that develops as the system or the plant changes. Engineering assessments are not approvals, certifications, or instructions. They are inputs that help everyone understand

system performance. Keeping that separation clear preserves engineering judgment and planning discretion while giving oversight the visibility it needs.

10.5 A Working Checklist for Project Owners

- Keep a study register for each facility: every study, its date, its model versions, its key assumptions, and the decision it supported.
- Compare the as-built model and settings to the studied model before COD, and document every difference.
- Put the MOD-025-2 12-month deadline and the MOD-026-2 deadline (365 days after COD or April 1, 2029, whichever is later) on the project schedule before COD.
- Stand up the PRC-030-1 event identification process and the PRC-028-1 monitoring data it depends on before the first event, not after it.
- Route every firmware, plant controller, and protection setting change through a model-impact check, and in ERCOT through the Planning Guide Section 5.5(6) review.
- Treat vendor models and data as inputs to verify, and document parameters you cannot verify.
- Re-check any study older than five years, or any study whose surrounding system has materially changed, before relying on it in a compliance position.

End-of-Chapter Summary

The engineering studies required or expected by NERC, RTOs, and ISOs give the reliability basis for understanding how generation resources interact with the BES across time scales, from long-term planning to real-time operations. They are meant to be used together for alignment, revision, and interpretation, not as a one-time design approval.

Glossary

NERC-defined terms below are quoted or closely paraphrased from the NERC Glossary of Terms. Terms marked as used in this publication are working definitions for this reference only. This glossary does not supersede or modify the official NERC Glossary of Terms.

Term	Meaning in this paper
Bulk Electric System (BES)	Unless modified by the inclusion and exclusion lists in the NERC definition, all Transmission Elements operated at 100 kV or higher and Real Power and Reactive Power resources connected at 100 kV or higher. This does not include facilities used in the local distribution of electric energy.
Commercial Operation Date (COD)	As used in this publication, the date a generating facility is declared in commercial operation under its interconnection agreement or market rules. NERC has no continent-wide Glossary definition of the term; individual standards and regional rules use their own triggers, such as ERCOT's Resource Commissioning Date.
Generator Owner (GO)	The entity that owns and maintains generating Facility(ies) (Category 1 GO), or owns and maintains non-BES Inverter-Based Resource(s) that either have or contribute to an aggregate nameplate capacity of greater than or equal to 20 MVA, connected through a system designed primarily for delivering such capacity to a common point of connection at a voltage greater than or equal to 60 kV (Category 2 GO).
Generator Operator (GOP)	The entity that operates generating Facility(ies) and performs the functions of supplying energy and Interconnected Operations Services (Category 1 GOP), or operates non-BES Inverter-Based Resources meeting the same 20 MVA and 60 kV criteria (Category 2 GOP).
Interconnection	A geographic area in which the operation of Bulk Power System components is synchronized such that the failure of one or more of such components may adversely affect the ability of the operators of other components within the system to maintain Reliable Operation of the Facilities within their control. When capitalized, any one of the four major electric system networks in North America: Eastern, Western, ERCOT and Quebec.
Inverter-Based Resource (IBR)	A plant/facility consisting of individual devices that are capable of exporting Real Power through a power electronic interface(s) such as an inverter or converter, and that are operated together as a single resource at a common point of interconnection to the electric system.
Model Validation	The process of comparing simulation results with measurements to assess how closely a model's behavior matches the measured behavior.

Term	Meaning in this paper
Model Verification	The process of confirming that model structure and parameter values are representative of the equipment or facility design and settings by reviewing equipment or facility design and settings documentation.
Planning Assessment	Documented evaluation of future Transmission System performance and Corrective Action Plans to remedy identified deficiencies.
Planning Authority (Planning Coordinator, PC)	The responsible entity that coordinates and integrates transmission Facilities and service plans, resource plans, and Protection Systems.
Post-COD study	As used in this publication, any study, verification, validation, or event analysis performed after the commercial operation date to test earlier assumptions against measured behavior.
Pre-COD study	As used in this publication, any study performed before the commercial operation date to evaluate a resource's expected interaction with the system, including interconnection studies.
Transmission Planner (TP)	The entity that develops a long-term (generally one year and beyond) plan for the reliability (adequacy) of the interconnected bulk electric transmission systems within its portion of the Planning Authority area.

How Energy Compliance Can Help

Every Energy Compliance engagement is overseen by a senior practitioner. Here is where that helps most on studies.

Operational and engineering reliability alignment

EC reviews a facility's study record against its NERC obligations: whether the pre-COD study modeled the plant that was built, whether the MOD-025-2, MOD-026-2, and PRC-030-1 clocks are scheduled, and whether settings changes reach the models. Regulator-perspective program reviews and reliability governance and program assessments ask the same questions at the program level, and compliance program design and improvement follows from what they find. For new and Category 2 Generator Owners, EC provides registration and applicability analysis before COD, along with NERC reliability and compliance advisory support, senior advisory on complex reliability questions, and NERC compliance program support, interpretation, and audit preparation.

Audit defense and enforcement

When a study gap becomes a finding, the response has to be built from the record. EC provides audit and enforcement support (non-advocacy), audit defense with Notice of Penalty response and settlement posture, mitigation planning and Self-Report development, RSAW production, and data request strategy. EC also offers training and executive briefings on reliability frameworks and industry engagement in standards development and working-group participation. Each engagement is scoped to the entity's role, function, and bulk system impact.

WattOps Compliance

MOD-025, MOD-026, and PRC-030 evidence lives in test reports, model submittals, and event analyses. WattOps Compliance is EC's NERC compliance evidence platform (wattopscompliance.com). EC will run one standard at one facility through WattOps at no cost (CIP standards excluded).

RenewOps

Post-COD validation runs on operations data. RenewOps is EC's renewable operations monitoring and analytics platform, with a Data Center module.

If your last study predates the plant you are running, let's look at it before an auditor or a disturbance does.

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About the Author

Rob Smith is the Founder and Principal of Energy Compliance, Inc., with more than thirty years in the industry on every side of the system. He began in control-room operations as a Reliability Coordinator, Transmission Operator, and Power System Operator across RTO/ISO and utility control centers. On the regulator side, he was a senior compliance auditor and subject matter expert for NERC Reliability Standards. He audited grid facilities, evaluated mitigation adequacy, participated in risk-based oversight of utility mitigation activities, and supported the development of violation notifications and settlements in FERC-directed enforcement actions. He conducted a regulatory audit in the Sultanate of Oman against the Sultanate's Sector Law and Grid Code.

He founded Energy Compliance, Inc. to deliver senior regulator-side compliance authority without the layered staffing and billable-hour overhead of larger firms.

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- MSL, Compliance Law, Fordham Law University
- BAS, Energy Management, Bismarck State College
- BAS, Mechanical Engineering, Metallurgy minor, University of Florida
- BAS, Criminology, St. Petersburg College (State Law Enforcement Certification)
- AAS, Power Plant Technology, Bismarck State College
- AAS, Electrical Transmission System Technology, Bismarck State College

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About Energy Compliance, Inc.

Energy Compliance, Inc. is an independent consulting and advisory firm based in Bloomington, Minnesota, focused exclusively on electric reliability, cybersecurity reliability, and regulatory compliance for organizations connected to the North American Bulk Electric System.

We support registered entities, including Generator Owners and Operators, Transmission Owners and Operators, Reliability Coordinators, Balancing Authorities, and Distribution Providers. Our work spans NERC Reliability Standards, FERC orders, RTO/ISO market participation rules, Regional Entity oversight, and state regulatory frameworks.

We do this work differently than larger consulting firms. A senior practitioner with regulator-side experience oversees every engagement. We staff for outcomes, not billable hours. Our deliverables are written to be operationally executable and audit-defensible, structured for the auditor's question rather than the consultant's binder. Where automation can replace manual work, we build the automation. Where senior judgment is required, the senior is in the room.

Energy Compliance is not affiliated with, sponsored by, or endorsed by the North American Electric Reliability Corporation, the Federal Energy Regulatory Commission, or any Regional Entity.

Learn more at energycomplianceinc.com.

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