June 24, 2025 Virtual Meeting

NERC Milestone 3 Update (~230 attendees)

Presentation recording and slides are available to download here. Figure 1 shows the makeup of attendees by industry sector:

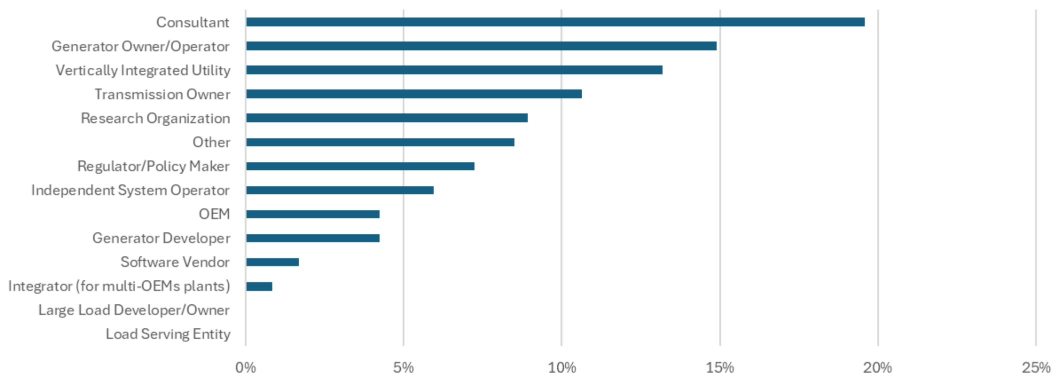

Figure 1: Meeting attendees by industry sector

This second meeting of Season 2 of the DOE i2X FIRST initiative focused on the North American Electric Reliability Corporation (NERC) Milestone 3 standards projects, the current state of IBR modeling in North America, and legacy IBR plant modeling practices. Presentations included the following:

<u>Sandhya Madan, NERC</u>

Sandhya provided an overview of NERC standards revisions underway related to FERC Order 901. NERC has implemented a four-part milestone plan spanning several years (see Figure 2).

Figure 2: NERC Work Plan Milestones for FERC Order 901 [Source: NERC]

Milestone 1 involved NERC submitting its Order 901 work plan to FERC. Milestone 2 included standards development efforts to address IBR disturbance monitoring (PRC-028), disturbance ride-through and performance requirements (PRC-029), and post-event performance validation (PRC-030). Those standards were submitted by NERC to FERC before the November 2024 deadline. In February 2025, FERC approved the new IBR definition (see below) and proposed Reliability Standards PRC-028-1, PRC-002-5 (for synchronous generators), and PRC-030-1.[1] The implementation plans for each standard were also approved.

> ***NERC Definition of Inverter-Based Resource:*** *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. Examples include, but are not limited to, plants/facilities with solar photovoltaic (PV), Type 3 and Type 4 wind, battery energy storage system (BESS), and fuel cell devices.*

Current standards drafting efforts are now focused on Milestone 3 standards revisions, which relate to data sharing and model validation for all applicable IBRs. Figure 3 illustrates the various standards revision efforts underway presently targeting model verification and validation, a uniform modeling framework, and system model validation. The related standards projects include:

- **Project 2020-06 Verifications of Models and Data for Generators:** This project is revising MOD-026 (and consolidating MOD-026 and MOD-027) and has also developed "Model Verification" and "Model Validation" terms for the NERC Glossary of Terms.
- **Project 2021-01 System Model Validation with IBRs:** This project is revising MOD-033 with minor editorial and technical revisions.
- **Project 2022-02 Uniform Modeling Framework for IBR:** This project is revising MOD-032, IRO-010, and TOP-003, as well as developed a definition for "Distributed Energy Resource" for the NERC Glossary of Terms.

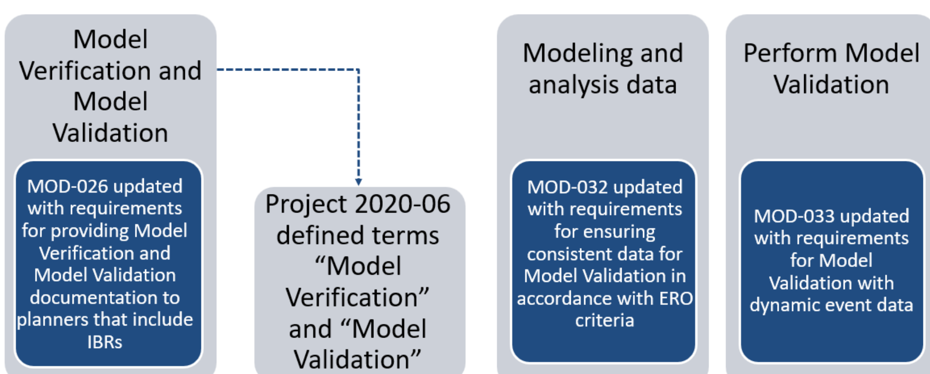

Figure 3: NERC Milestone 3 Summary [Source: NERC]

[1] At the time of writing, FERC has not made any statement regarding PRC-029-1 approval.

All three standards projects have now completed their initial ballots. Table 1 provides an overview of the results of those initial ballots. The drafting teams are currently responding to industry comments and feedback provided, making revisions to the standards and implementation plans, and will be re-posting the standards for a next round of balloting in July/August timeframe. The standards must be submitted to FERC by the November 2025 deadline.

Table 1: Initial Ballots for Milestone 3 Standards

Project	Standard	Standard Ballot Results	Implementation Plan Ballot Results
Project 2020-06	MOD-026-2	32.47% (Fail)	40.22% (Fail)
Project 2021-01	MOD-033-2	57.06% (Fail)	59.43% (Fail)
Project 2022-02	MOD-032-2	39.05% (Fail)	39.46% (Fail)
	IRO-010-6	41.62% (Fail)	
	TOP-003-8	34.70% (Fail)	

NERC is also ramping up initial efforts related to Milestone 4 activities. The Milestone 4 SARs will be published around August timeframe for industry comment. NERC is seeking nominations for Milestone 4 drafting team members – specifically looking for individuals from utilities, Regional Entities, and vendors with expertise in planning and operational studies with IBRs. These projects will focus on the NERC TOP, IRO, FAC, PRC, and TPL standards as well as revise the definitions for Real-Time Assessment, Operational Planning Analysis, and Balancing Contingency Event to include IBR performance and sudden IBR output reduction.

Miguel Cova Acosta, Vestas

Miguel presented on the current state of IBR modeling in North America, particularly from Vestas' perspective. Accurate IBR modeling is essential for grid reliability, project stability, and long-term success throughout the lifecycle of the asset. Standard library models are widespread due to their simplicity, ease of use, and ease of review; they are mandated across many regions and used widely in both interconnection studies and planning cases. This can pose a challenge because these models may give the illusion of compliance. The models may appear to provide a smooth and compliant response; however, they may not reflect the dynamic characteristics of the asset under varying system operating conditions, curtailments, etc. This can result in misleading study results that introduce reliability risks. Miguel emphasized the need for IBR developers to raise internal standards in terms of model quality and fidelity, particularly with the use of user-defined models (UDMs).

During the interconnection process, IBR plant design evolves as equipment is selected, plant and protection systems are designed, and site controls are tuned. After the interconnection process, an IBR plant may have further changes due to firmware updates, plant upgrades, and further parameter tuning. Thus, the models must also evolve and refine as the site specifications change. However, current requirements and practices tend to discourage model updates because they may result in interconnection delays and restudies. Up through energization, industry needs a framework that encourages model updates to reflect latest changes rather than punishing entities for making improvements to the models. Additionally, once the resource enters commercial operation, it is imperative that the models reflect the actual installed equipment to support accurate reliability studies.

Use of standard library models, instead of OEM-validated UDMs, may create a false sense of grid code compliance for the IBR developer. Where available, OEM-supplied UDMs with verified site-specific model parameters should be used during interconnection studies and IBR plant performance conformity tests since they are the most accurate representation of the actual controls, protections, and overall representation of the asset. Use of models that do not have all the key controls features of the physical asset may lead to a disconnect between the model and actual performance, introducing reliability risks. Leaning towards model simplicity rather than model accuracy is a prevalent issue across various systems in North America, relying on standard library model representations and not considering UDMs.

Miguel also described the efficacy of different types of supplemental modeling documentation to aid in ensuring model quality. Figure 4 illustrates effective and less effective options. Parameter verification reports, model quality test results and reports, and site-specific verification and validation reports are all effective options; however, OEM attestations, model compliance checklists, and generic requests for information (RFIs) can result in complications or generic information provided if not issued or delivered with clear instructions and understanding of their use.

Figure 4: Effective and Less Effective Supplemental Documentation to Ensure IBR Model Quality [Source: Vestas]

Miguel recommended that the model development process should always follow a source code integration concept, which should mirror parameterization and performance of the IBR plant as built in the field. Industry standards should focus on interfacing source code-integrated models rather than standardizing control structures for IBR plant models generically.

Andrew Isaacs, Electranix

Andrew presented on legacy (i.e., existing) IBR plant modeling practices and challenges, primarily focused on EMT modeling. When an IBR plant model is needed for a legacy asset for the purposes of conducting a study, there is often no satisfactory solution. Hence, this is why it is very important to ask for high-quality models prior to interconnection whether or not those models will be used immediately in a study. Sufficiently detailed and specific modeling requirements are important, if not necessary to ensure that the right questions are asked, appropriate tests/model reviews are conducted, and that accurate models are supplied. These concepts apply to both IBR plants and power electronic loads such as data centers, and should be a major priority for all regions across North America.

If an EMT model is needed for an existing asset, there are a few guiding questions that can be asked:

- Is the model needed for posterity/requirements, or is there a study being conducted?
- If a study is being conducted, how impactful is the plant to the study area?
  - Is it the main device being studied?
  - Is it electrically very close or impactful under key contingencies?
  - What phenomena are the key areas of focus (e.g., subsynchronous control interactions (SSCI), fault ride-through (FRT), voltage impacts, other transients, etc.)?
- Is the plant large or small relative to the other plants and study area?

These questions help determine the level of effort needed to ensure accuracy of the missing model. If an EMT model is not available and cannot be acquired through requirements, regulations, or other mandatory and enforceable ways, there are a few options that can be considered (from best to worst):

- Best approaches:
  - Collect a model from the interconnection customer/GO that meets the requirements established.
  - Find engineers involved from the original OEM and ask (or pay) them to create a model using their best information.
- Proxy model approach:

  - Learn as much as possible about the equipment, and configure a proxy model using a similar vintage and type of model from the *same* OEM.
  - If possible, test the hardware in a lab and configure an appropriately parameterized generic model to match the performance.
  - Learn as much as possible about the equipment, and configure a proxy model using a similar vintage and type of model from a *different* OEM.
- Generic model approach (not recommended):
  - Learn as much as possible about the equipment and configure a generic model to match key settings to the extent possible.
  - Use a completely generic model.

Deviations from accurate implementation of phase lock loop (PLL), protection circuits, and inner controls will cause misrepresentations of SSCI damping, ride-through performance, and voltage control response. Deviations from accurate implementation of delays, power plant controllers (PPCs), outer loop controls, etc., can cause important errors depending on the study being performed. If a device is important to the study, proxy modeling is not recommended and it may be best not to conduct a study at all.

Anything other than a fully-tested, verified, and validated EMT model will degrade the benefit obtained from the EMT study in terms of accuracy and the ability to make business decisions using the results obtained (i.e., accuracy requirements exist for a reason). If the model quality is degraded too far, and the plant is critical in the study being performed, it may not be possible to drive useful results from the EMT study.

Additionally, all models will require maintenance and updating throughout the lifecycle of a plant. Effective data organization procedures, documentation, and change management practices help ensure the model remains accurate as compared with the actual equipment. Furthermore, as requirements change, older models may become noncompliant and require updates; thus, it is important to have robust requirements to start with and also for IBR developers to have strong contract language for ongoing support from OEMs.

Dynamic link library (DLL) wrapper real code model writing processes are helpful to maintain compatibility across tool and compiler revisions. Models should be written to support these techniques.[2]

Q&A and Interactive Group Discussion

[2] Cigre B4.82 "Guidelines for Use of Real-Code in EMT Models for HVDC, FACTS and Inverter based generators in Power Systems Analysis" Available here.

What are the initial ballot results for MOD-026-2 and what is the current status for Project 2020-06?

The initial ballot for MOD-026-2 recently closed as of late June 2025. The standard and implementation plan received a 32.5% and 40.2% weighted ballot score, respectively. The drafting team is currently reviewing comments received and working on addressing those comments in a revised version that is planned for another ballot in late July or August.

With the next ballots for the Milestone 3 projects scheduled for late July (and subsequent review in August/September), how is NERC expecting to meet the November 4 FERC deadline particularly given that the NERC Board meeting is scheduled for October? Will NERC expect to leverage its Rules of Procedure Section 321 process again for these standards?

NERC and the drafting teams are working towards revised standards that meet the concerns raised by industry commenters as part of the ballot process. NERC is conducting informational webinars to share updates along the way. However, the deadlines are fast-approaching, and NERC may need to take alternate paths (e.g., NERC Section 321 process) to expedite meeting the November deadlines set by FERC if the standards do not pass the next ballot.

What are the pertinent updates regarding approval and effective dates for NERC Milestone 2 projects including PRC-028-1, PRC-029-1, and PRC-030-1?

FERC approved both NERC PRC-028-1 and NERC PRC-030-1. FERC also issued a Notice of Proposed Rulemaking (NOPR) to gather additional information and industry feedback on NERC PRC-029-1 and has not yet ruled on this standard as of June 2025. With the NOPR, FERC sought comments on all aspects of the proposed PRC-029-1, but was particularly interested in comments and supporting materials on concerns regarding: "(1) the IBR performance requirement set forth in Requirement R1; (2) the absolute RoCoF in Requirement R3; and (3) the adequacy of NERC's proposed exemption provision in Requirement R4 as it pertains to both projects in service and those under contract, but not yet in-service as of the effective date of Reliability Standard PRC-029-1."[3]

Regarding effective dates, NERC PRC-028 became effective on April 1, 2025. FERC did not establish an effective date for PRC-030-1 since it relies on NERC PRC-029-1. Thus, industry expects that once FERC rules on PRC-029-1, it will also include an effective date for PRC-030-1 in that ruling.

The proposed NERC MOD-026-2 leaves establishing a model verification and validation procedure up to each Transmission Planner (TP) and Planning Coordinator (PC). This may lead to widely disparate requirements and lack of harmonization across North

[3] https://www.ferc.gov/media/e-10-rm25-3-000

America, creating additional obstacles and barriers for IBR asset owners. What is NERC doing to address this concern, which has been raised in industry stakeholders numerous times?

Sandhya stated that NERC Reliability Standards explicitly do not define how a standard must be implemented and only focus on what must be implemented. Thus, to handle the need for regional or transmission entity-specific differences, the NERC Project 2020-06 drafting team has left these considerations up to the TP and PC to determine. It was acknowledged that this could lead to disparity across TPs and PCs, which could create complications for GOs.

How can entities effectively commission an IBR plant when the OEM does not have a mapping between PSCAD and their actual equipment settings, parameters, and controls?

IBR commissioning has been identified by the NERC Inverter-Based Resource Performance Subcommittee and other organizations as an area for improvement for IBR integration. IBR plants may be commissioning in a way that does not match the modeling and studies conducted during the interconnection process. This is further exacerbated when the IBR plant model parameters are obfuscated by the OEM and thus the Generator Owner is unable to discern whether what is being commissioned matches expectations. Improvements in IBR model transparency, regardless of model type, are needed to map actual equipment to models and their respective parameters.

ISOs may emphasize overlaying simulation plots and lack attention to how controls, protections, etc., are implemented in the IBR plant. Any recommendations for this can change?

Much of the interaction between the interconnection customer and the TP/PC is related to ensuring that the models are verified to match the actual equipment, meet certain model quality test requirements, and are suitable for transmission system impact studies. Transmission entities should adopt modeling requirements that ensure model verification – the model matches the proposed and actual equipment – as well as model quality and performance tests that ensure the IBR plant meets a certain performance, and the models are adequate for use in studies.

The concepts of 1) "the IBR plant passes the model quality tests" and 2) "the IBR plant operates reliably under all credible contingencies" are almost entirely orthogonal to each other; yet, almost all simulation time and effort between the IBR developer/owner and TP/PC is devoted to the former. How can this be overcome?

These different types of tests are intended to analyze the IBR plant models in different ways. Model quality tests are intended to check that the model is suitable for studies and is a reasonable reflection of the actual equipment planned or installed at the facility. These test may consider varying system conditions such as voltage and frequency fault ride-through or system strength. Once the models pass the necessary single machine infinite bus (SMIB) type modeling tests, then they are integrated into the system model for system-level performance evaluations. Significant time between the IBR developer/owner and the TP/PC needs to be devoted to ensuring models are accurate and of high quality to help aid in preparations for effective systems studies, which are the responsibility of the TP/PC.

For the current state of IBR modeling, why was the option for OEMs to more actively participate in the standard library model building process not included?

OEMs should still engage in standard library model building processes, particularly since the use of these models is mandated by FERC for use in interconnection-wide base cases. Industry cannot simply forego these efforts as they are mandated by federal law presently. Thus, as observed by the NERC modeling recommendations and other guidelines, both types of models are needed and OEMs need to actively be engaged in creating high-quality UDMs as well as sufficiently reflective standard library models for their equipment.

If models across simulation domains are to only be real code models, does industry thus have to trust the OEMs if a model cannot accurately represent a feature in the actual equipment? This may introduce significant reliance on OEMs on intellectual property concerns regarding information sharing.

Focus needs to turn toward effective collaboration between the interconnection customer/GO and the OEM to ensure that the currently-used models are reflective of the actual product (make, model, version, etc.), rather than artificially tuning standard library models which are not reflective of the actual equipment. OEMs will need to be transparent about what is and is not modeled, and should provide IBR unit (single inverter or wind turbine) model validation reports to demonstrate that the model adequately reflects actual product across a range of operating conditions. Note that "real code" models remain black boxed models (i.e., the real code is not accessible to the end user of the model).[4,5]

What is the difference between UDMs and standard library models regarding IBR plant commissioning? Intuition is that UDMs would also be subject to "manual tuning, patchwork fixes, and late-stage overrides" to reflect as-built conditions but the slides implied otherwise.

Regardless of model type, it is important to ensure that the commissioned IBR matches the models used during study, and that any discrepancies are identified, updated in the models, and shared with the transmission provider for evaluation. Commissioning tests may subject the site to small disturbance events that can then be used to conduct post-commissioning model validation. It should be noted that these tests likely will not subject the site to large disturbance events that

[4] https://www.e-cigre.org/publications/detail/gb-16-power-system-dynamic-modelling-and-analysis-in-evolving-networks.html
[5] https://www.e-cigre.org/publications/detail/881-electromagnetic-transient-simulation-models-for-large-scale-system-impact-studies-in-power-systems-having-a-high-penetration-of-inverter-connected-generation.html

initiate ride-through modes of operation. Hence, post-conditioning event monitoring and model validation is important to also ensure accuracy of the models upon commissioning.

It was mentioned that EMT modeling concerns raised regarding IBRs may also apply to data center load modeling efforts – can you elaborate on those issues and give some examples?

Many of the issues pertaining to IBR modeling today – model transparency, model verification versus actual equipment, model quality testing, and post-event model validates – all translate to large power electronic load (e.g., data center) modeling. Ensuring that the models used to represent data centers are adequate representations of the actual facility, particularly for rather large load sites, is imperative to ensure reliability of the bulk power system.

Why do so many organizations push for creating and running generic models in studies? Seems like a lot of research effort is going into creating generic models for use in real world studies and this may not be the recommended approach. Thoughts?

Generic model may have a place for exploratory studies or research and development activities; however, these models are not adequate for making utility decisions such as determining reliability impacts of a specific IBR plant seeking interconnection, establishing operating limits, or determining the need for transmission network upgrades. This is particularly relevant for those conditions that invoke instability risks. Further, the generic models may inappropriately show stable operating conditions whereas the more detailed UDMs in phasor domain or EMT studies may uncover reliability risks. Thus, general industry consensus, as recommended by NERC and required in FERC Order 2023, is to gather both UDMs for local reliability studies and appropriately parameterized standard library models for interconnection-wide base case development.

Key Themes

- **NERC Milestone 3 Standards Development and Balloting Challenges:** The current NERC Milestone 3 efforts are addressing data sharing, model verification, and system model validation including IBRs. Initial ballots for the three Milestone 3 projects did not reach passing scores; current drafting team efforts are focused on addressing industry concerns. NERC is aiming for re-ballots by late summer to meet a tight FERC submission deadline in November 2025. If needed, NERC may need to use its Section 321 procedures to meet the FERC timelines. The challenges underscore ongoing industry tension between compliance needs and implementation feasibility.
- **Upcoming Milestone 4 Work and Expanding IBR Reliability Focus:** NERC is preparing to launch Milestone 4 projects, which will examine broader reliability standards including TOP, IRO, PRC, and TPL, and revise key definitions. Draft SARs will be released in August 2025, and NERC is actively seeking drafting team members

with experience in planning and operational studies involving IBRs. The goal is to integrate IBR-specific considerations into operational and planning assessments.

- **Legacy Modeling Practices and the Importance of Accurate EMT Models:** Modeling legacy IBR plants presents unique challenges, especially when EMT models are needed post-interconnection and were never initially required. Without high-fidelity models, studies may yield unreliable or misleading decisions. Proxy models and generic models offer limited accuracy and should only be used when absolutely necessary. Upfront modeling requirements and OEM-supplied, validated models are essential, particularly for high-impact assets. Ongoing model maintenance, including change management and source code compatibility, is equally critical over a plant's lifecycle.
- **UDMs vs. Standard Library Models:** Standard library models, though easy to use and review, often present a simplified and misleading picture of IBR performance. Reliance on these models may give a false sense of compliance with applicable interconnection requirements, as they often omit the nuanced dynamics of actual equipment. UDMs provided and validated by OEMs offer a more faithful representation and should be preferred, especially during interconnection studies and plant commissioning. Industry's current tendency toward simplicity over accuracy introduces reliability risks that grow as grid complexity increases. More OEM collaboration, transparency, and use of supplemental documentation can help ensure IBR model quality.
- **Commissioning Gaps and Model Fidelity Concerns:** The commissioning process for IBR plants often lacks alignment with the models used during interconnection studies. Discrepancies between installed equipment and model parameters—especially when OEMs obscure model details—can result in mismatches that degrade reliability. While commissioning tests help validate models through small-signal disturbances, they may miss crucial behaviors activated during grid faults or instability events. This highlights the need for robust model validation post-commissioning, and for utilities to require transparency and ongoing model support from OEMs. Accurate commissioning models are essential to uphold both compliance and operational integrity.
- **Model Quality and Use in Planning vs. Operational Studies:** The industry tends to over-emphasize verifying model quality while under-investing in ensuring reliable system-level performance of IBRs under real-world contingencies. While SMIB-type tests verify models against equipment, they do not guarantee that a plant will behave reliably under stressed grid conditions. Transmission planners must adopt dual objectives: ensuring models are technically valid and conforming with applicable interconnection requirements, while also verifying actual plant performance through contingency simulations as part of system impact studies.
- **Modeling Challenges Shared by IBRs and Data Centers:** The challenges with IBR modeling—model transparency, verification, lifecycle accuracy, and event-driven

validation—are now also surfacing in modeling large data center loads. As with IBRs, inaccurate or generic data center models can misrepresent impacts on the grid. Industry must recognize that reliability risks are not limited to generation but also apply to increasingly complex, inverter-dominated loads. Robust model requirements and validation protocols for both generation and load are essential for ensuring bulk power system reliability.

- **Limitations of Generic Models in Decision-Making:** Generic models may be useful for early-stage research or exploratory studies, but they are generally not sufficient for decision-making such as setting operating limits or approving transmission upgrades. These models often miss critical OEM-specific control behaviors, potentially masking underlying reliability risks. As such, NERC, FERC, and OEMs all stress the need for UDMs in phasor domain and EMT for reliability-critical studies. Interconnection-wide base cases may still require standard library models, but local reliability studies should rely on detailed, OEM-supplied, site-specific models to ensure accuracy. The industry must evolve from a generic-first mindset toward a precision-first approach to grid modeling.

Disclaimers

This is a work in progress and is not yet finalized and published. The content is provided as a summary for the convenience of the public participating in the Interconnection Innovation e-Xchange (i2X) Forum for the Implementation of Reliability Standards for Transmission webinar series. The U.S. Department of Energy (DOE) makes no representations or warranties as to the accuracy, completeness, or timeliness of the information contained in this document. DOE shall not be liable for any loss or damage arising from any use of or reliance on the information contained in this document.

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