

NERC Reliability Standards Review

NERC System Planning Impacts from Distributed Energy Resources Working Group (SPIDERWG) White Paper: October 2022

Introduction

The North American bulk power system (BPS) is experiencing a rapid growth of distributed energy resources (DER) in multiple utility footprints and others are expected to have significant additional DER growth in future years. The increasing penetration of DERs is already having an impact on BPS planning, operations, and design, and it is paramount that NERC Reliability Standards remain effective and efficient in ensuring an adequate level of reliability for the BPS.¹ As a result, the NERC SPIDERWG has evaluated the current body of NERC Reliability Standards and the requirements within those standards for their applicability and effectiveness to remain relevant with increasing levels of DERs. This white paper details the findings of the SPIDERWG review and makes recommendations for actions that should be taken to address identified issues. **Appendix A** provides additional details on review approach. A well thought out approach to DER integration is needed to continue to ensure adequate levels of BPS reliability. The growing aggregate DER levels will affect all facets of the operating the BPS—from planning activities to real-time operations to system restoration activities.

The terms "DER" and "aggregate DER" have been used throughout this document and are appropriately based on the context of their specific use. SPIDERWG has a set of definitions² to accurately describe the DER facets in its set of documents that clarify that DERs are distribution-connected sources of power. This standards review paper in its entirety relates to the aggregate impacts of DERs in the context of the reviewed standards. The term "aggregate DERs" simply relates to the aggregated effects that DERs can have. In many cases, the term "DERs" is more appropriate in specific contexts for this review.

SPIDERWG Background and Purpose

SPIDERWG was formed in 2018 as a follow-up to the NERC Distributed Energy Resources Task Force (DERTF) and Essential Reliability Services Working Group (ERSWG).³ SPIDERWG's goal is to analyze the increasing DER penetrations many areas across North America and develop recommended practices to manage the BPS under these situations. SPIDERWG has published multiple reliability guidelines related to BPS planning aspects with increasing DER levels.

In December 2021, SPIDERWG submitted standard authorization requests (SARs) for revisions to NERC MOD-032-1 and TPL-001-5 to address gaps in these standards related to the consideration of DERs. The NERC RSTC endorsed both SARs, and these SARs are being presented to the NERC Standards Committee in

¹ This effort is tied to the RISC report that identifies the "Changing Resource Mix" as a high priority. The work here supports mitigation and monitoring strategies that tie into the report's findings. For more information the report can be found here: https://www.nerc.com/comm/RISC/Documents/RISC%20ERO%20Priorities%20Report_Final_RISC_Approved_July_8_2021_Board_Submitted_Copy.pdf

² Available here: <https://www.nerc.com/comm/RSTC/SPIDERWG/SPIDERWG%20Terms%20and%20Definitions%20Working%20Document.pdf>

³ [https://www.nerc.com/comm/Other/Pages/Essential-Reliability-Services-Task-Force-\(ERSTF\).aspx](https://www.nerc.com/comm/Other/Pages/Essential-Reliability-Services-Task-Force-(ERSTF).aspx)

Q1 2022. These two standards were therefore omitted from the standards review as they were recently reviewed in depth by SPIDERWG.

SPIDERWG found that it would be beneficial to perform a comprehensive technical review of all NERC Reliability Standards to determine if there are any potential gaps or improvements beyond what was identified for its work plan in 2018. This white paper provides the results of the review conducted by SPIDERWG and covers the majority of currently enforceable standards for potential gaps or improvements. The review is intended to be technical and may not be limited by, nor intends to comment on, existing jurisdictional boundaries between NERC registered entities and those under state or other jurisdictions. Where appropriate, the recommendations from this review should be further discussed with applicable regulatory bodies and the associations representing them, e.g., National Association of Regulatory Utility Commissioners (NARUC).

Because of NERC jurisdictional limitations, the identified reliability concerns that potentially arise from increased DER deployment could be addressed through other means to achieve the same objective of maintaining BPS reliability. One of such means may be IEEE Standards Association (IEEE-SA) projects that complement NERC Reliability Standards with industry consensus standards, recommended practices, and guidelines that often have a higher degree of technical specificity. Examples include IEEE 1547-2018 (Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces), IEEE P1547.2 (Application Guide to IEEE 1547-2018), and P2030.11 (Guide for Distributed Energy Resources Management Systems Functional Specification).⁴ IEEE-SA documents are voluntary in their nature and would require adoption and enforcement by applicable regulatory bodies (e.g., state authorities).

SPIDERWG acknowledges that the findings in this white paper are limited to the knowledge and experience of its members and that other issues may be discovered as industry and technology continues to evolve and grow. Any such issues may be addressed through the NERC RSTC or NERC Standards Committee processes, accordingly. In particular, SPIDERWG acknowledges that it lacks subject matter expertise in the areas of the CIP and NUC standards and did not review those standards as part of this activity.

Recommendations: Standards and Guidelines

This section will talk about standards and guidelines with their needed updates and time frames.

Standards for Revision

SPIDERWG identified potential gaps and areas for improvements in the standards listed in **Table 1**. The table provides a brief description of the improvement needed. Refer to **Appendix A** for more details on the review of each specific standard. SPIDERWG assigned a priority to each recommended standard revision based on the impact that these gaps may have on reliable operation of the BPS with increasing levels of DERs.

⁴ Other industry activities include the following:

DER Group Management for Coordinated Operations across the T–D Interface. EPRI. Palo Alto, CA: December 2019. 3002016174. [Online] <https://www.epri.com/#/pages/product/000000003002016174/>

TSO/DSO Coordination for DER Management Working Group. EPRI. Ongoing and public working group. Latest materials available at URL <https://epri.box.com/v/TSODSOCoordinationWG> (password: EPRITSODSOWG)

Prioritization is intended to help support the NERC Standards Committee in the development of possible standard drafting teams. The high, medium, and low categories are based on the prioritization of two parallel elements constituting importance and a feasible development timeline. Prioritization is based on the following:

- **High:** These standard revisions should be completed as soon as possible or on a very near-term horizon. As short-term DER penetrations increase across North America, the issues identified are likely to lead to a potential reliability issue.
- **Medium:** These standard revisions should be completed on a mid-term horizon (i.e., within a two-year window). As DER penetrations increase, entities may experience potential reliability issues if the standards identified are not revised to address the issues.
- **Low:** These standard revisions should be completed on a longer-term horizon (i.e., within a three-year window). Gaps and areas for improvement relate to clarity and consistency issues regarding how DERs impact the BPS or are accounted for in the standard requirements.

SPIDERWG recommends that a Standard Authorization Request (SAR) be developed for each project, and SPIDERWG will add work plan items to begin development⁵ of SARs upon Reliability and Security Technical Committee (RSTC) approval of this white paper. SPIDERWG recognizes that the development of SARs will require coordination with other RSTC groups and will take the initiative to coordinate with those groups as needed.

Table 1: Consider Standards Revisions

Standard	High-Level Description of Outcome	Priority
BAL-003-2*	Revise the standard to ensure consistent accounting of DERs in balancing calculations	Low
EOP-004-4*	Revise the standard to ensure proper reporting of the loss of aggregate DERs to NERC with defined thresholds. ⁶	Medium
EOP-005-3*	Revise the standard to establish telemetry requirements for DERs and/or distribution providers (DP)	Medium
FAC-001-3	Revise the standard to include the DP in the Applicability section	High
FAC-002-2	Revise the standard to ensure responsible entities perform study when aggregate DERs cause material modifications to electricity end-user facilities	High

⁵ Any revisions to standards need to follow the processes outlined in the NERC *Standards Processes Manual*. Available here: https://www.nerc.com/comm/SC/Documents/Appendix_3A_StandardsProcessesManual.pdf

⁶ A draft SAR has been proposed by the IRPS to incorporate Inverter-Based Resources (IBR) above a defined threshold for bulk-connected inverter-based resources. DERs are distribution-connected and would not be covered by revisions to include bulk-connected IBR.

Table 1: Consider Standards Revisions

Standard	High-Level Description of Outcome	Priority
MOD-031-2	Revise the standard to ensure that existing and forecasted DER data is provided by DPs or Transmission Planners (TPs) to the Planning Coordinator (PC) upon request ⁷ Allow TPs to be an intermediary to provide data from DPs to the PC	High
PRC-006-3	Revise R3 of the standard to specify whether net or gross load is required for underfrequency load shedding (UFLS) studies	Low
TOP-001-4	Revise the operational planning analysis (OPA) and real-time analysis (RTA) definitions to explicitly enumerate aggregate DER or non-Bulk Electric System (BES) generation output levels	Low
TOP-002-4	Revise the OPA definition to include aggregate DER or non-BES generation output levels	Low
TOP-003-3	Revise the OPA and RTA definitions to include aggregate DER or non-BES generation output levels	Low
TOP-010-1(i)	Revise the RTA definition to include aggregate DER or non-BES generation output levels	Low

* Indicates that the review team also identified the need for a reliability guideline on the general subject.

Standards for Future Revisions

SPIDERWG identified potential gaps and areas for improvement in the standards listed in [Table 2](#). However, these issues are much lower priority than those mentioned above in [Table 1](#), so SPIDERWG has not recommended a standards project at this time to address the issues identified. SPIDERWG is documenting these considerations and issues that may warrant possible standards projects as the integration of DERs continues. The issues identified in [Table 2](#) should be reviewed again after completion of items in [Table 1](#) or if these standards are revised in other projects. Refer to [Appendix A](#) for more details on specific standards review outcomes.

Table 2: Consider Standards Future Revisions

Standard	High-Level Description of Outcome
FAC-011-3	Revise the standard to address potential system operating limit (SOL) inaccuracies caused by the variability or uncertainty of DERs and the change of power flows at the transmission–distribution interface
IRO-001-4	Revise the standard requirements focused on managing reliability impacts from aggregate DERs

⁷ NERC Reliability Guideline: DER Forecasting Practices and Relationship to DER Modeling for BPS Planning Studies, to be published 2022.

Reliability Guidelines Needed

SPIDERWG identified multiple standards where industry guidance is needed in the areas related to implementation of specific standards. The team considered both NERC reliability guidelines as well as NERC compliance implementation guidance options. The issues identified are general in nature, so broader guidance (i.e., reliability guidelines) is more suitable than compliance implementation guidance for the identified topics. **Table 3** provides a list of standards where reliability guidelines would be useful.

Upon RSTC approval of this white paper, SPIDERWG will add each of the guidelines identified in **Table 3** to its work plan. SPIDERWG will prioritize these guidelines as needed and develop suitable time lines that align with current work plan activities.

Table 3: Recommended Reliability Guidelines	
Standard	Description of Guidance Needed
BAL-002-3	Reliability guideline on approaches to DER accounting in reserve management
BAL-003-2*	Reliability guideline on managing adequate levels of frequency response with increasing levels of DERs
BAL-005-1	Reliability guideline on approaches to DER accounting in reserve management
EOP-004-4*	Reliability guideline on detection and calculation of aggregate DER loss during and after an event to facilitate accurate reporting
EOP-005-3*	Reliability guideline on coordination and data exchange between the Transmission Operator (TOP) and DP for development of restoration plans, including information regarding aggregate DER levels and expected operating characteristics
EOP-011-1	Reliability guideline on how load shedding schemes may need to consider the amount of DERs impacted by such load shedding practices to ensure minimal power system impact and that load can be effectively shed without the loss of considerable levels of generation
IRO-018-1(i)	Reliability guideline for telemetry, communication, data handling capability coupled with data quality issues associated with increasing DERs
MOD-033-1	Reliability guideline providing industry recommended practices for collection and validation of DER and distribution level characteristics should be developed
PRC-010-2	SPIDERWG is presently working on a white paper emphasizing that under-voltage load shedding (UVLS) programs should be coordinated with DER ride-through capabilities
PRC-012-2	Reliability guideline discussing the impact of DERs on Remedial Action Scheme (RAS) design and performance
PRC-027-1	Reliability guideline discussing the impact of “nuisance” trips of aggregate amounts of DER for BPS faults due to miscoordination of DP-owned protection systems

* Indicates that the review team also identified the need to revise the standard in addition to developing a guideline.

No Action Needed

SPIDERWG did not identify any actions needed for those standards listed in [Table 4](#).

Table 4: Standards with No Action Needed					
BAL-001-2	FAC-013-2**	IRO-014-3	MOD-029-2a	PRC-008-0	PRC-026-1
COM-001-3	INT-004-3.1**	IRO-017-1	MOD-030-3	PRC-011-0	TPL-007-3
COM-002-4	INT-006-4	MOD-001-1a	PER-003-2	PRC-015-1	VAR-001-5
EOP-006-3	INT-009-2.1	MOD-004-1	PER-005-2	PRC-016-1	VAR-002-4.1
EOP-008-2	INT-010-2.1**	MOD-008-1	PER-006-1	PRC-017-1	
EOP-010-1	IRO-002-6	MOD-020-0**	PRC-001-1.1(ii)	PRC-018-1	
FAC-003-5	IRO-006-5	MOD-025-2	PRC-002-2	PRC-019-2	
FAC-008-3	IRO-008-2	MOD-026-1	PRC-004-5(i)	PRC-023-4	
FAC-010-3	IRO-009-2	MOD-027-1	PRC-005-1.1b	PRC-024-2	
FAC-014-2	IRO-010-2	MOD-028-2	PRC-005-6	PRC-025-2	

** Indicates that this standard was retired.

Discussions: Standards and Guidelines

This section will talk about the following body of standards: BAL, CIP, COM, EOP, FAC, INT, IRO, MOD, NUC, PER, PRC, TOP TPL, and VAR.

BAL Standards

The following is a summary of findings and recommended actions (see [Table 5](#)) for this body of standards:

- A reliability guideline should be developed or an existing one expanded to cover the consistent treatment of DERs across the various BAL standards.
- The NERC Glossary of Terms should be changed to resolve the identified issues across multiple standards.

Table 5: BAL Standards Review Outcome	
Standard	Result of SPIDERWG Review
BAL-001-2	No Action Needed
BAL-002-3	Reliability Guideline
BAL-003-1.1	Revise Standard and Reliability Guideline

Table 5: BAL Standards Review Outcome

Standard	Result of SPIDERWG Review
BAL-005-1	Reliability Guideline

The following outcomes were identified by SPIDERWG:

- **BAL-002-3 and BAL-005-1: Reliability Guideline**

The placement of DERs in the various balancing equations (e.g., accounting of impact of DER in the most severe single contingency or the gathering of data for reporting in area control error) cut across a number of standards, so compliance implementation guidance is not the best vehicle to use. The standards themselves do not need revision for DERs, but a consistent approach regarding DERs (e.g., counting DERs either explicitly as resources or implicitly as load modifiers) is needed that would be applicable across all standards. New reliability guidelines or revisions to existing guidelines (e.g., reserves management) would be helpful. NERC Glossary of Terms⁸ changes or additions may also be an effective way to implement consistent treatment across multiple standards in the future.

- **BAL-003-2: Revise Standard and Reliability Guideline**

The standard is currently under revision but not necessarily focused on aggregate DER concerns. The reporting of net generation and net load will be affected by how DERs are counted and the resultant apportionment of interconnection frequency response obligation to each Balancing Authority (BA). The calculation of the interconnection frequency response obligation mentions “load”; however, the language when calculating the bias setting uses load, so clarity is needed for how DER play into that calculation. Standard language would need to address the reporting of net generation and net load, which indicates a need for standard revisions.

A reliability guideline (not specific to BAL-003) on how DER should be counted (a reduction in load or explicit inclusion as resource capacity) should be written. The existing reliability guidelines focused on balancing should also be reviewed to address counting of DERs consistently. One of those guidelines is currently under triannual revision by the NERC Resources Subcommittee, so input should be directed to its originating group, the Resources Subcommittee.

CIP Standards

The NERC CIP Standards were not reviewed.

COM Standards

The following is a summary of findings and recommended actions (see [Table 6](#)) for this body of standards:

- COM-001-3 and COM-002-4 standards were reviewed, and no actions are needed because the increase in DERs will not affect applicability or implementation of these standards.

The addition of a DER aggregator may require further analysis and possible modifications to the COM standards at a later time should such an entity receive operating instructions or other dispatch signals.

⁸ The NERC Glossary of Terms is available here: https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary_of_Terms.pdf

Table 6: COM Standards Review Outcome

Standard	Result of SPIDERWG Review
COM-001-3	No Action Needed
COM-002-4	No Action Needed

EOP Standards

The following is a summary of findings and recommended actions (see [Table 7](#)) for this body of standards:

- A reliability guideline should be developed for EOP-004-4 regarding how to detect and calculate aggregate DER loss during and after an event.
- A reliability guideline should be developed for EOP-005-3 regarding the coordination and data exchange between the TOP and DP in the development of restoration plans.
- A reliability guideline should be developed for EOP-011-1 regarding how to coordinate manual or automatic load shedding schemes with DERs.
- EOP-004 should be revised to include thresholds for reporting of aggregate DER loss during and after an event.
- EOP-005 should be revised to include data and monitoring requirements on the DP and/or DERs for inclusion of DER into system restoration plans.

Table 7: EOP Standards Review Outcome

Standard	Result of SPIDERWG Review
EOP-004-4	Revise Standard and Reliability Guideline
EOP-005-3	Revise Standard and Reliability Guideline
EOP-006-3	No Action Needed
EOP-008-2	No Action Needed
EOP-010-1	No Action Needed
EOP-011-1	Reliability Guideline

The following outcomes were identified by SPIDERWG:

- **EOP-004-4: Revise Standard and Reliability Guideline**
Recent large-scale disturbances (e.g., the August 2019 disturbance in the United Kingdom)⁹ have demonstrated that unexpected loss of DERs during BPS faults can compromise reliable operation of the BPS. Despite potential impact to reliable operation, EOP-004-4 does not currently require reporting by BAs and Reliability Coordinators (RC) of the loss of aggregate DERs to NERC. As the resource is distribution connected, it is sometimes netted with load and can impact both generation

⁹ [Investigation into 9 August 2019 power outage | Ofgem](#)

loss and firm load shedding categories of Attachment 1 of EOP-004, so clarity is needed to account for DER in the reporting form. SPIDERWG recommends that a standard drafting team review and revise EOP-004-4 to require reporting, including the threshold for reporting, of the loss of aggregate DERs to NERC. Additionally, a reliability guideline addressing detection and calculation of aggregate DER losses should be developed to help support accurate reporting; the guideline could leverage materials from NERC disturbance reports and other industry efforts, such as the Northeast Power Coordinating Council (NPCC) DER BES Impact Reporting Form¹⁰.

- **EOP-005-3: Revise Standard and Reliability Guideline**

Under the current applicability section of EOP-005-3, the requirements for resource integration into the plan, in most cases, fall to the TOP or the TO. Typically these entities receive only load data from the DP, not the operating characteristics of underlying resource control systems. The TOP or TO are therefore frequently unable to confidently predict resource response to system conditions.

If DERs are to be accepted to participate as blackstart resources in a system restoration plan, there will be a need to study the switching path from the DER to the BPS system restoration plan objective that is being supported. As such, future standard revisions should provide flexibility to ensure reliability is maintained during system restoration should DERs be accepted as blackstart resources to participate in restoration plans. Regardless of whether DERs are blackstart resources, DERs will respond to energization of distribution substations in load pickup, potentially creating adverse conditions. Without access to modeling data and operating characteristics for modeling the DERs in these instances, the studies required under EOP-005-3 would provide only a weak estimate of the distribution system response to an event, such as steady-state and dynamic simulations. This brings into question the accuracy of the studies. As referenced by other standard DER review teams, historical events have shown that the lack of data and modeling from distribution systems has resulted in inaccurate assessments of transmission system performance and contingency responses. Some contributing factors to events were a lack of visibility and understanding of the distribution system resource controls responses to transmission system contingencies.

With the integration of DER as a blackstart resource in a system restoration plan—consideration of inverter-based technologies or an aggregate of resources that include a mix of inverter-based technologies and traditional capacity resources—makes it critical to evaluate the transmission system contingency response prior to accepting the resource into the system restoration plan. Understanding the resource’s expected response is particularly important in the early stages of restoration (when the transmission system is considered weak and frequency control as well as voltage control can be challenging for system operations) with frequency and voltage excursions beyond the normal range being typical.

EOP-005-3 requirements R1.4, R6, R7, and R11 all require data to successfully comply with the standard. The ability to obtain this information in a vertically integrated environment may not present challenges, but Regional Trade Organizations/Independent System Operators (ISO)/TOP’s

¹⁰ This form is available for download here: <https://www.npcc.org/content/docs/public/program-areas/standards-and-criteria/der-forum/distributed-energy-resource-reporting-form-6-29-2018.docx>

past experience has shown difficulty in obtaining new technology or resource mix data and operating characteristics when not enforceable under a standard in market environments. Integration of demand response (DR) in the forward capacity market is an example. DR resides on the distribution system and causes data concerns for the Regional Trade Organization/ISO/TOP around potential real-time dispatch of DR on the wrong side of a constraint.

The creation of a reliability guideline was discussed during the SPIDERWG review. Restoration is too critical to encounter data/operating characteristic issues during plan analysis and implementation to ensure reliability. As shown above, the data concerns for DR are likely to be encountered with DERs. Thus, the onus must be placed on the DP to provide data/operating characteristics of the resources within its distribution system¹¹ to the TOP and TO in the development of a system restoration plan. The reliability guideline for the topic in this standard is related to the practices in sharing that information and not addressing the critical need for such information to be shared for DER participating and responding to a system restoration plan.

- **EOP-011-1: Reliability Guideline**

SPIDERWG recommends the development of a reliability guideline to develop and disseminate recommended practices related to EOP-011-1 emergency plans that include DER operations and considerations. Increasing penetrations of DERs will require modifications to previously used TOP and RC operating practices. Regarding the development of emergency operation plans, the expectation of considerable levels of DERs within the impacted power system requires consideration. The operational state of aggregate levels of DERs, particularly the level of controlled real power curtailment during an emergency, need to be clarified as to leverage all available power system assets to less or avoid impacts from such emergencies. Additionally, the requirement to avoid overlap between automatic and manual load shedding schemes needs to consider the amount of DERs impacted by such load shedding practices to ensure minimal power system impact and that load is effectively shed without the loss of considerable levels of generation.

FAC Standards

The following is a summary of findings and recommended actions (see [Table 8](#)) for this body of standards:

- FAC-001-3 should be revised to include the DP in the Applicability section.
- FAC-002-2 should be revised to indicate that if DER aggregations result in “material modifications” to electricity end-user facilities, a study of the material modifications is required.
- FAC-011-3 should be revised to address the concerns of SOL inaccuracy brought by the uncertainty from increasing DER penetration.

Table 8: FAC Standards Review Outcome

Standard	Result of SPIDERWG Review
FAC-001-3	Revise Standard

¹¹ This information sharing may require coordination with other regulatory bodies in particular states/provinces.

Table 8: FAC Standards Review Outcome

Standard	Result of SPIDERWG Review
FAC-002-2	Revise Standard
FAC-003-5	No Action Needed
FAC-008-3	No Action Needed
FAC-010-3	No Action Needed
FAC-011-3	Revisions May Be Needed in Future
FAC-013-2	No Action Needed
FAC-014-2	No Action Needed

The following outcomes were identified by SPIDERWG:

- **FAC-001-4: Revise Standard**

A revision is needed to address the impact of DERs on the BES, and SPIDERWG recommends the DP be included in FAC-001 to have interconnection requirements made available to address “qualified changes” to its system. This standard was recently modified to allow the PC to address what a “qualified change” is for each applicable GO. Similarly, SPIDERWG identified that the DP should have these procedures available for “qualified change.” The DP should be included in the “Applicability” section of FAC-001. Requirements should be modified to include the DP and with consideration of the following options:

- Requirement 1, for a specified level of aggregate generation (a level to be discussed further by a future SDT)
- Requirement 2, for a specified level of aggregate DER installations (by a future SDT), to trigger a reliability impact study of affected the system
- Requirement 3 or Requirement 4, to ensure appropriate coordination studies be performed and what a “qualified change” is for the DP system

Additionally, considerations should be given to regional, jurisdictional, and penetration level differences for inclusion of the applicability. A discussion of the impact of DERs on the BES could be added as a separate item in the list of supplemental material that is presented at the end of the document and linked to Requirement #3. In all cases, some technical guidance (e.g., compliance implementation guideline, reliability guideline) will be needed for use by DPs in coordination with TOs.

- **FAC-002-4: Revise Standard**

SPIDERWG recommends that a standard drafting team review and modify FAC-002-2 as necessary such that the standard requires the study of material modifications to electricity end-user facilities related to increasing levels of aggregate DERs. Recent studies and presentations to SPIDERWG indicate that if aggregate DERs are integrated without adequate interconnection studies, reliable

operation of the BES is likely to be impacted (e.g., contingencies worsened by aggregate DER tripping off-line). Recently, NERC project 2020-05 changed the term “materially modify” to a “qualified change” for the purposes of facility interconnection” and added a requirement to have the PC define the qualified change in this standard and in FAC-001. SPIDERWG recommends that the TP be a part of the definition of qualified changes to determine what change would require a study (Requirement 1 of FAC-001) for the T–D interface in their planning area.

In the future, SPIDERWG could develop guidance material (e.g., reliability guidelines, compliance implementation guidance) to support implementation of FAC-002 specifically related to performing aggregate DER studies.

- **FAC-011-3: Revisions May Be Needed in the Future**

The main concern is whether the increasing penetration of DERS will affect the change of power flows at the T–D interface (not captured by Requirement 2 and Requirement 3 requirements) and the output of the SOL calculation. The DER uncertainty will have a larger impact with increasing DER penetration, so a new methodology may be needed to account for that uncertainty. A future revision should consider the DER response following a single contingency in Requirement 2.3. The increasing DER penetration will likely require the RC to change the methods of determining SOLs listed in R3.

INT Standards

The following is a summary of findings and recommended actions (see [Table 9](#)) for this body of standards:

- No actions are needed with any of the INT standards.

Table 9: INT Standards Review Outcome

Standard	Result of SPIDERWG Review
INT-004-3.1	No Action Needed
INT-006-4	No Action Needed
INT-009-2.1	No Action Needed
INT-010-2.1	No Action Needed

IRO Standards

The following is a summary of findings and recommended actions (see [Table 10](#)) for this body of standards:

- IRO-001-4 should be revised in the future to consider the addition of the DER aggregator to the Applicability section of the standard and/or to the clarification that the Generator Operator includes the DER aggregator.
- A reliability guideline for IRO-018-1(i) should be developed to address the lack of observability and availability of real-time aggregate DER data and performance. The reliability guideline should clarify the telemetry requirements and communication capability as well as the increases in data handling capability and data quality issues with aggregate DERs in TOP real-time assessments.

Table 10: IRO Standards Review Outcome

Standard	Result of SPIDERWG Review
IRO-001-4	Revisions May Be Needed in the Future
IRO-002-6	No Action Needed
IRO-006-5	No Action Needed
IRO-008-2	No Action Needed
IRO-009-2	No Action Needed
IRO-010-2	No Action Needed
IRO-014-3	No Action Needed
IRO-017-1	No Action Needed
IRO-018-1(i)	Reliability Guideline

The following outcomes were identified by SPIDERWG:

- **IRO-001-4: Revisions May Be Needed in the Future**

SPIDERWG recommends that any future revisions to the standard consider adding the DER aggregator to the applicability section of the standard and/or clarify that the Generator Operator includes the DER aggregator.

Any future drafting efforts for a guideline or revision of this standard could ensure that the reliability of the grid is not compromised by DER impacts due to an RC’s coordination efforts from a transmission or distribution perspective. SPIDERWG also recommends that future conditions be reviewed at a later time to determine if a reliability guideline to the RC in issuing operating instructions to the appropriate entities on the distribution system to maintain BPS reliability would address SPIDERWG’s concerns.

SPIDERWG recommendations are primarily based on engineering judgement and not on a thorough body of research. Since the research in this area is still evolving, this initial evaluation is based on the following observations:

- Neither the entity Generator Operator nor the DP apply to DER aggregators that combine resources that do not meet FERC/NERC definition of the BES.
- The NARUC Resolution Recommending State Commissions Act to Adopt and Implement Distributed Energy Resource Standard IEEE 1547-2018 resolved at the 2020 Winter Policy Summit by the National Association of Regulatory Utility Commissioners¹² may lead to increasing deployment of communication-ready DER which, accelerated¹³ by the FERC Order 2222, may

¹² Available online: <https://pubs.naruc.org/pub/4C436369-155D-0A36-314F-8B6C4DE0F7C7>

¹³ <https://www.ferc.gov/news-events/news/ferc-opens-wholesale-markets-distributed-resources-landmark-action-breaks-down>

increase DER integration into DER management systems that may participate in grid operations via a DER aggregator.

- Any DER aggregation larger than 20–75 MVA¹⁴ may impact BES reliability if an RC is not able to direct actions or issue operating instructions that the DER aggregator shall comply with.
 - Some evolving specifications of bulk system reliability functions that DER aggregators may provide across the T–D interface are presented in some industry reports.¹⁵
- **IRO-018-1(i): Reliability Guideline**
In its review, SPIDERWG identified that this standard should include some guidance to consider the impact of DER penetration in the set of data quality checks used for real-time assessments. The standard requires that the RC develop and implement an operating process or an operating procedure to address the quality of the real-time data necessary to perform its real-time monitoring and real-time assessments. Increasing DER amounts will eventually necessitate accurate measurement of real-time DER data. This will require telemetry and communication capability as well as increases in data handling. It is anticipated that the monitoring of real-time DER data will have data quality issues due to the variability and differences associated with DERs. With consideration of increasing levels of DERs on the system and the current lack of wide-spread observability and availability of real-time data for DERs, it is anticipated that data quality of real-time DERs is questionable. SPIDERWG recommends a reliability guideline be written to assist RCs in producing data quality checks for aggregate DERs.

MOD Standards

The following is a summary of findings and recommended actions (see [Table 11](#)) for this body of standards:

- MOD-032 was excluded from this review. The NERC RSTC approved a MOD-032 SAR developed by SPIDERWG at the RSTC December 2021 meeting.
- MOD-031-2 should be revised to allow for the PC to obtain existing and forecasted DER information from DPs or TPs. The TP should have the ability to act as an intermediary to provide data from DPs to the PC.
- A reliability guideline should be developed that provides industry with recommended practices for DER validation in MOD-033-1.

¹⁴ Magnitude to be further specified along with any other qualifiers to such a threshold.

¹⁵ Prominent reports are the following:

- Common Functions for DER Group Management, Third Edition. EPRI, Palo Alto, CA: 2016. 3002008215<https://www.epri.com/research/products/000000003002008215>
- DER Group Management for Coordinated Operations across the T&D Interface. EPRI, Palo Alto, CA: 2019. 3002016174
- DER Group Management for Coordinated Operations across the T&D Interface. EPRI, Palo Alto, CA: 2020 (In publication). 30020XXXXX

Table 11: MOD Standards Review Outcome

Standard	Result of SPIDERWG Review
MOD-001-1a	No Action Needed
MOD-004-1	No Action Needed
MOD-008-1	No Action Needed
MOD-020-0	No Action Needed (retired)
MOD-025-2	No Action Needed
MOD-026-1	No Action Needed
MOD-027-1	No Action Needed
MOD-028-2	No Action Needed
MOD-029-2a	No Action Needed
MOD-030-3	No Action Needed
MOD-031-2	Revise Standard
MOD-033-1	Reliability Guideline

The following outcomes were identified by SPIDERWG:

- **MOD-031-2: Revise Standard**

SPIDERWG recommends adding a requirement to MOD-031 that DPs and TPs are required to provide existing and forecasted DER data when the PC determines a need¹⁶ as it is becoming critical to know how much actual demand is on the system given the amount being served by embedded generation. Thus, SPIDERWG identified that standards revisions be made to MOD-031 to have specific language reflecting DERs¹⁷ and how to address them. TPs should be an intermediary to provide this data from DPs to the PC as the DERs from the DP affect the existing and forecasted DERs amount of the TP’s planning area. This process continues up for each TP in a PC’s planning area. Because of how each entity’s output is dependent on the results of another, the standard should be both clear on DERs and revised to ensure the PC’s need to obtain existing and forecasted gross demand. The current structure of MOD-031 has a PC information request of entities, and this change would have the TP act as an intermediary to the DP for PC requests for existing and forecasted DER information.

¹⁶ Guidance on Solar PV Adoption Forecasting Methods for Distribution Planning. EPRI. Palo Alto, CA: 2018. 3002014724

¹⁷ MOD-031 calls out “Demand-side Management” whose definition is “All activities or programs undertaken by any applicable entity to achieve a reduction in Demand.” A reading of this definition includes generation sources as they offset Demand, or “the rate at which electric energy is delivered to or by a system or part of a system.” The SPIDERWG review of this standard calls for greater specificity to be added to this standard.

- **MOD-033-1: Reliability Guideline**

MOD-033 focuses on PCs developing a process for performing system model validation. The standard does not prescribe a specific method or procedure for the validation, so PC model validation practices may need to be adapted over time as more DERs come on-line; however, the standard does not need a revision at this time. PCs should ensure that aggregate DERs are appropriately modeled in system model validation cases.

A reliability guideline for providing industry recommended practices for system model validation that is inclusive of aggregate DER representation in the MOD-033-1 should be developed.¹⁸ For dynamic validation in particular, fast recording data of aggregate DER response will be needed. How to collect and validate aggregated DER responses could be addressed in the reliability guideline. Discussion is warranted for determining how to validate distribution level characteristics given the measurement equipment at the transmission level.

NUC Standards

The NERC NUC Standards were not reviewed as part of the SPIDERWG review process.

PER Standards

The following is a summary of findings and recommended actions (see [Table 12](#)) for this body of standards:

- No actions are needed with any of these standards.

Table 12: PER Standards Review Outcome

Standard	Result of SPIDERWG Review
PER-003-2	No Action Needed
PER-005-2	No Action Needed
PER-006-1	No Action Needed

PRC Standards

The following is a summary of findings and recommended actions (see [Table 13](#)) for this body of standards:

- The standards listed in the table that required no action were focused on transmission level system protection settings, so they are not applicable to the distribution system or DERs. SPIDERWG acknowledges that increasing DER levels will change system dynamics (particularly short circuit dynamics), and protection systems need to account for this. The present construct for protection system coordination and current industry practices in this area may not be well-suited to handle the impacts to the BPS from rapidly increasing DER levels in some areas.

¹⁸ This item was already identified as a work plan item early in SPIDERWG and has been approved in December 2021. It is available here: https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline%20DER_Model_Verification_of_Aggregate_DER_Models_used_in_Planning_Studies.pdf

Table 13: PRC Standards Review Outcome

Standard	Result of SPIDERWG Review
PRC-001-1.1(ii)	No Action Needed
PRC-002-2 ¹⁹	No Action Needed
PRC-004-5(i)	No Action Needed
PRC-005-1.1b	No Action Needed
PRC-005-6	No Action Needed
PRC-006-3	Revise Standard
PRC-008-0	No Action Needed
PRC-010-2	Reliability Guideline (White Paper)
PRC-011-0	No Action Needed
PRC-012-2	Reliability Guideline
PRC-015-1	No Action Needed
PRC-016-1	No Action Needed
PRC-017-1	No Action Needed
PRC-018-1	No Action Needed
PRC-019-2	No Action Needed
PRC-023-4	No Action Needed
PRC-024-2	No Action Needed
PRC-025-2	No Action Needed
PRC-026-1	No Action Needed
PRC-027-1	Reliability Guideline

The following outcomes were identified by SPIDERWG:

- **PRC-006-3: Revise Standard**

Recent studies by ISO-NE and CAISO have demonstrated the importance of modeling gross load and aggregate DERs in UFLS simulations to ensure representation of the actual behavior of the BPS. In

¹⁹ The requirement 5.1 is written generically enough and allows PC/TP to require DDR at the BES bus where response of aggregate DER to system disturbances may be recorded.

PRC-006-3 R3; however, the term "load" is used, not "Load" as defined in the NERC Glossary of Terms, allowing net load to be modeled in UFLS simulations.

To ensure that gross load is modeled, a standard drafting team should modify PRC-006-3 R3 to change the term "load" to "Load," which references gross load. Furthermore, R3 only uses the term "generation," which may lead to ambiguity in terms of whether aggregate DERs should be modelled. A standard drafting team should therefore revise R3 to require the use of "data consistent with that provided in accordance with the MOD-032 standard," which is currently undergoing a process to initiate a SAR for MOD-032-1. This approach is consistent with that of TPL-001-5.1 R1. Similarly, a standard drafting team should revise R6 to ensure that the UFLS database is "consistent with that provided in accordance with the MOD-032 standard."

SPIDERWG has developed a reliability guideline²⁰ on this topic specifically to help industry understand these concepts as well as to provide best practices on the study and implementation of UFLS systems with DERs. However, the guideline is not sufficient to address the issues identified in the standard, so standard revisions are still needed to for consistency and correct planning practices to meet the purpose of the standard.

- **PRC-010-2: Reliability Guideline (White Paper)**

SPIDERWG determined that PRC-010-2 does not currently require revisions due to the impacts of aggregate DERs. PRC-010-2 R1.2 requires that UVLS Programs are "integrated through coordination with generator voltage ride-through capabilities and other protection and control systems, including, but not limited to, transmission line protection, auto-reclosing, remedial action schemes, and other under voltage-based load shedding programs." Since January 2019, SPIDERWG has not been presented with a study nor evidence that indicate UVLS programs are not currently coordinated with DER protection and control ride-through capabilities.

SPIDERWG will continue its work plan to deliver a white paper to the RSTC on the importance of coordinating UVLS with "other protection and control systems," including, but not limited to, transmission line protection, auto-reclosing, remedial action schemes, other under voltage-based load shedding programs, and DER ride through capability. The white paper will also emphasize that TPs and PCs should consider the performance of aggregate DERs when developing UVLS Programs.

- **PRC-012-2: Reliability Guideline**

A reliability guideline discussing the impact of DERs on RAS design and performance should be created. This standard requires a process of implementation and periodic assessment of RASs. If any deficiencies are identified either during an assessment or an event, the development and implementation of a corrective action plan is required. The existing requirements do not need to change with increasing DER levels. However, as the RAS may include tripping/shedding of a large amount of load, the loss of DERs alongside the load may have an impact on BPS reliability. This is due to the implemented RAS tripping feeder breakers in a distribution substation rather than operability of demand-only breakers. This potential reliability impact increases in geographical areas with high DER penetrations. Even if the RAS is not configured to shed load, it is necessary that RAS design and performance consider interactions with DERs, especially when DER penetration is high.

²⁰ Available here: <https://www.nerc.com/comm/Pages/Reliability-and-Security-Guidelines.aspx>

As such, SPIDERWG recommends a reliability guideline be developed on the DER impacts on RAS schemes.

- **PRC-027-1: Reliability Guideline**

A reliability guideline discussing the impact of nuisance trips of aggregate amounts of DERs for BPS faults due to lack of coordination of DP-owned protection systems should be created.²¹ The purpose of PRC-027 is to maintain the coordination of protection systems installed to detect and isolate faults on BES elements such that those protection systems operate in the intended sequence during faults. The standard applies to TOs, GOs, and to a limited extent also to DPs that own protection systems that are installed to detect and isolate faults on BES elements. The limited applicability to DPs could lead to a coordination gap with regard to DP-owned protection systems that may be configured such that they inadvertently trip aggregate amounts of DERs for BPS faults.²² Examples may include undervoltage relays configured more sensitive than allowed per IEEE 1547-2018 and distribution-connected synchronous generator overcurrent relays that are not coordinated adequately with expected dynamic response of these resources to BPS faults. SPIDERWG’s findings urge the creation of a reliability guideline discussing the coordination of protection systems to reduce any nuisance trips of aggregate DER amounts.

TOP Standards

The following is a summary of findings and recommended actions (see [Table 14](#)) for this body of standards:

- The OPA and RTA definitions in the NERC Glossary of Terms should be changed as part of standards revisions to explicitly include aggregate DERs or non-BES generation for all TOP standards.

Table 14: TOP Standards Review Outcome

Standard	Result of SPIDERWG Review
TOP-001-4	Revise Standard
TOP-002-4	Revise Standard
TOP-003-3	Revise Standard
TOP-010-1(i)	Revise Standard

²¹ The IEEE P1547.2 Draft 5.1 and its section 6.2.1.5 on “Considerations when Setting Protection Devices in Distribution Utility Equipment with DER Ride-Through” can be used as a starting reference when drafting the NERC reliability guideline.

²² The concern here is *not* about coordination of DP relay settings for faults on distribution circuits as current research has not indicated that distribution relays tripping following distribution faults would result in significant loss of aggregate DERs large enough to negatively impact reliability of the BES.

SPIDERWG in its review identified the following:

- **TOP-001-4, TOP-002-4, TOP-003-3, and TOP-010(i): Revise Standard**

All four TOP standards refer to either an OPA or RTA or both. These standards require applicable entities to consistently perform OPAs²³ and RTAs.²⁴

Not accurately accounting for aggregate DER levels with a reasonable allocation of their connection points to the BPS could affect the quality and accuracy of OPAs and RTAs. SPIDERWG recommends revising the OPA and RTA definitions in the NERC Glossary of Terms to explicitly include aggregate DERs (and non-BES generation output levels) as a component of both the OPA and RTA definitions. The definitions of OPA and RTA both state that the assessments must, at a minimum, include inputs of “load,” “load forecast,” and “generation output levels.” Both net load quantities and BPS generation output (and forecast) levels are affected as the penetration of DERs increases since DERs offset net loading and consequentially affect the amount of on-line BPS generation. Not accounting for both the steady-state and dynamic behavior of DERs will likely have an increasingly adverse impact on the quality of OPAs and RTAs in the future.

As demonstrated in the August 9, 2019, grid disturbance in the United Kingdom,²⁵ aggregate DERs can trip off-line during BPS fault and contingency events, impacting the overall performance of the BPS and possible operation of safety nets, such as underfrequency load shedding. The Palmdale Roost, Angeles Forest, and San Fernando BPS disturbance events in the Southern California area have all included around 100 MW of DER tripping off-line for BPS faults as well.²⁶ Furthermore, inclusion of aggregate levels of DERs in OPAs and RTAs may impact system operating limits. As “load,” “load forecast,” and “generation output levels” are not defined in the NERC Glossary of Terms, they are subject to interpretation (i.e., entities can decide for themselves whether to include or exclude the aggregate amounts of DERs in their assessments).

In TOP-002-4, Requirement R4.1 includes “expected generation resource commitment and dispatch” and Requirement R4.3 includes “demand patterns” that should also be inclusive of aggregate levels of DERs since they will affect both. Requirement R4 should be updated to account for DER impacts. SPIDERWG recommends the standard revisions and glossary term updates be made to ensure the impact of aggregate DERs are covered by the OPAs and RTAs.

²³ “Operational Planning Analysis (OPA): An evaluation of projected system conditions to assess anticipated (pre-Contingency) and potential (post-Contingency) conditions for next-day operations. The evaluation shall reflect applicable inputs including, but not limited to, load forecasts; generation output levels; Interchange; known Protection System and Special Protection System status or degradation; Transmission outages; generator outages; Facility Ratings; and identified phase angle and equipment limitations. (Operational Planning Analysis may be provided through internal systems or through third-party services.)”

²⁴ “Real-time Assessment (RTA): An evaluation of system conditions using Real-time data to assess existing (pre-Contingency) and potential (post-Contingency) operating conditions. The assessment shall reflect applicable inputs including, but not limited to: load, generation output levels, known Protection System and Special Protection System status or degradation, Transmission outages, generator outages, Interchange, Facility Ratings, and identified phase angle and equipment limitations. (Real-time Assessment may be provided through internal systems or through third-party services.)”

²⁵ https://www.ofgem.gov.uk/system/files/docs/2019/09/eso_technical_report_-_final.pdf

²⁶ <https://www.nerc.com/pa/rrm/ea/Pages/April-May-2018-Fault-Induced-Solar-PV-Resource-Interruption-Disturbances-Report.aspx>
https://www.nerc.com/pa/rrm/ea/Pages/July_2020_San_Fernando_Disturbance_Report.aspx

TPL Standards

The following is a summary of findings and recommended actions (see [Table 15](#)) for this body of standards:

- The TPL-001-5 standard was not considered in this effort since SPIDERWG recently developed a white paper on a detailed review of the standard that was approved by the NERC RSTC. Furthermore, the RSTC approved the SPIDERWG SAR covering the white paper’s topics in the RSTC December 2021 meeting.
- SPIDERWG also reviewed TPL-007-3 and determined that no actions are needed.

Table 15: TPL Standards Review Outcome

Standard	Result of SPIDERWG Review
TPL-007-3	No Action Needed

VAR Standards

The following is a summary of findings and recommended actions (see [Table 16](#)) for this body of standards:

- No actions are needed for either standard.

Table 16: VAR Standards Review Outcome

Standard	Result of SPIDERWG Review
VAR-001-5	No Action Needed
VAR-002-4.1	No Action Needed

SPIDERWG identified a possible gap regarding BPS voltage control as the DER penetration grows in conjunction with non-BES BPS-connected inverter-based resources. An increasing reliance of non-BES resources, even only under certain hours of the year, could pose significant challenges for TOPs to manage BPS voltages since limited resources would be required to meet a voltage schedule and operate in automatic voltage control. Without NERC Reliability Standards driving this performance, industry will need to rely on local interconnection requirements to ensure this capability. Furthermore, under high DER penetrations, the BPS may be stressed to have sufficient reactive power capability to support BPS voltages; reliance on accurate planning assessments will be critical and will also require accurate modeling of aggregate amounts of DERs to identify these possible operating conditions. While there are presently no identified issues with the VAR-001 or VAR-002 standards, SPIDERWG would like to recognize the issue presented here, but SPIDERWG does not have a recommended solution as this is more of a jurisdictional issue that needs to be addressed by NERC.

Appendix A: Review Approach

The SPIDERWG Coordination sub-group performed a comprehensive review of the NERC Reliability Standards to identify any possible reliability gaps or areas of improvements with the existing standards as the penetration of DERs continues to increase across North America. The review team documented its findings in detailed review sheets and consolidated those reviews into the white paper presented here. A total of 77 of the 96 NERC Reliability Standards were reviewed. The NUC were not reviewed because they are not relevant to DERs, and the CIP standards were not reviewed because SPIDERWG does not have security-related expertise. Lastly, MOD-032 and TPL-001 were not reviewed as those standards have already been reviewed in great depth by SPIDERWG recently.

A review template was developed by the team to cover the most relevant and important information that the reviewers should consider during the review. The template provided operations under each question in order to maintain a consistent review. However, a comments section at the end was also provided for reviewers to elaborate on any issues identified. The questions posed to the reviewers are provided in the following.

Review Outcomes:

- What is the outcome of this review?

Review Details:

- Does the standard require any revisions?
- Is Compliance Implementation Guidance needed to provide examples for implementing the standard (i.e., how to be compliant with the requirement(s) of the standard)?
- Is Reliability Guideline needed to provide industry recommended practices related to the standard?

Items Considered during Review:

- Should the standard Applicability section be updated to consider aggregate DERs?
- If the standard uses the terms "Load" or "Demand", are these terms still clear with the consideration of DERs so that no changes to the standard requirements are needed?
- Are the standard requirements clear regarding how to account for DERs? (e.g., in planning, operating, modeling, and/or design activities)
- Will the effectiveness of the standard be affected by increasing levels of DERs?
- Would the collection of DER data affect the implementation of the standard (i.e., would the ability to gather DER data affect the ability to fulfill the purpose of the standard)?
- Will the increasing penetration of DERs require entities to change the methods they use to implement the standard requirements?
- Other Comments

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NERC gratefully acknowledges the invaluable contributions and assistance of the following industry experts in the preparation of this guideline. NERC also would like to acknowledge all the contributions of the NERC SPIDERWG.

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