NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

White Paper: Assessment of DER Impacts on NERC Reliability Standard TPL-001

System Planning Impacts of Distributed Energy Resources (SPIDERWG)

October 2020

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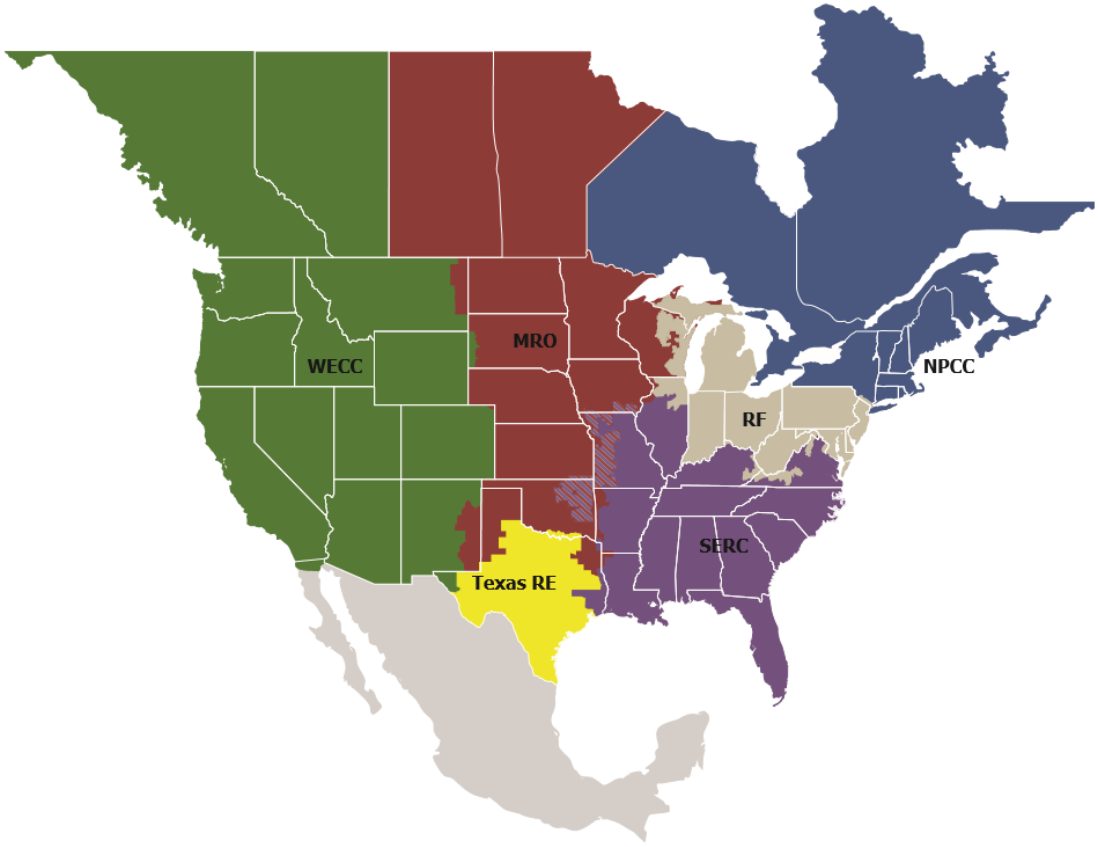
Preface

Electricity is a key component of the fabric of modern society and the Electric Reliability Organization (ERO) Enterprise serves to strengthen that fabric. The vision for the ERO Enterprise, which is comprised of the North American Electric Reliability Corporation (NERC) and the six Regional Entities (REs), is a highly reliable and secure North American bulk power system (BPS). Our mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid.

Reliability | Resilience | Security
Because nearly 400 million citizens in North America are counting on us

The North American BPS is divided into six RE boundaries as shown in the map and corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one RE while associated Transmission Owners (TOs)/Operators (TOPs) participate in another.



MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
Texas RE	Texas Reliability Entity
WECC	WECC

Executive Summary

Many areas of the North American bulk power system (BPS) are experiencing a transition towards increasing penetrations of distributed energy resources (DERs). NERC Reliability Standard TPL-001-4[1] was developed under a paradigm of predominantly BPS-connected generation, when penetrations of DERs were anticipated to be significantly lower than current and future projections, and without much impact on the BPS. Considering the current DER trend, the NERC System Planning Impacts of DER Working Group (SPIDERWG) undertook the task of evaluating the sufficiency and clarity of the TPL-001 standard for considering DER as part of annual Planning Assessment. The use of the term DER in this whitepaper is consistent with its description in NERC DERTF's DER Connection Modeling and Reliability Considerations report (Feb 2017)[2]. The same definition was also used in the SPIDERWG Terms and Definitions Working Document (draft) and the recently crafted MOD-032-1 Standard Authorization Request (SAR) [3] also suggested Standard Drafting Team (SDT) to consider DER definition in the NERC's glossary of terms.

This white paper discusses the impacts of DER on the standard requirements in three distinct ways:

1. Is the requirement relevant for consideration of DER?
2. Does the existing requirement language preclude consideration of DER in any way?
3. Is the requirement language clear regarding consideration of DER?

Table E.1 shows the key findings and recommendations from the SPIDERWG review of TPL-001 regarding impacts of DER on the standard requirements and industry implementation of the standard. The intent of this white paper is to highlight potential gaps or areas for improvement within TPL-001 along with some potential solutions such that a SAR can be developed, as needed, to address various issues by a SDT.

SPIDERWG recommends that the NERC PC review issues and that a future SDT assess the extent to which changes or implementation guidance are needed for each of these issues:

- Clarify Requirements R2.1 and R2.2 regarding use of phrase "System peak Load". This should be updated to "System peak net load"; The SDT should consider whether terms should be added to the NERC Glossary of Terms for "Gross Load" and "Net Load".
- Clarify Requirement R2.4 regarding capturing the dynamic behavior of DER, similar to the existing language used for induction motor loads in Requirement R2.4.1. Representation of the dynamic behavior of DERs should be applicable to all stability simulations, not just System peak conditions.
- In developing Contingency list as required by the Requirement R3.4, an implementation guideline should be developed to identify that the Contingency list should include contingency of explicitly modeled U-DER as well.
- In considering tripping of generators in simulation as required by the Requirement R3.3.1.1, an Implementation guideline should be developed to identify that the "tripping of generators" should include tripping of DER as well. Current language in the Standard uses the term "generator" which is not a defined term in the NERC Glossary and typically does not include DERs. Therefore, it is unclear whether DER tripping should be considered in this assessment.

[1] The scope of recent modifications to TPL-001-5 did not include considering the impacts of DER on BPS planning.
[2] Where DER is defined as "Any resource on the distribution system that produces electricity and is not otherwise included in the formal NERC definition of the Bulk Electric System (BES)":
https://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/Distributed_Energy_Resources_Report.pdf#search=distributed%20energy%20resource.
3 The MOD-032-1 SAR was submitted by NERC SPIDERWG to NERC PC, and endorsed by the NERC PC in December 2019.
https://www.nerc.com/pa/Stand/Pages/Project_2020-01_Modifications_to_MOD-032-1.aspx

- Clarify Requirements R4.1.1 and R4.1.2 regarding representing the dynamic behavior of DERs and the performance requirements applicable to DERs during stability simulations. For example, the language referring to "pulls out of synchronism" is only relevant to synchronous generation and is not applicable to inverter-based generation (including inverter-based DER). Large amounts of DER tripping on low/high voltage/frequency conditions can adversely affect BPS performance and may pose a risk to system stability, uncontrolled separation, or cascading events if not properly studied and identified ahead of real-time operations. Studies of these risks should account for
  - Updates to settings for existing and new inverters[4], and
  - The extent to which DERs are less exposed to voltage disturbances due to the impedance of the transmission and distribution equipment located between the DERs and a disturbance on the BPS.
- Clarify Requirement R4.3.1.2 regarding the "generators" referenced in the language are inclusive of DER as the tripping of these facilities can potentially have an adverse impact on BPS stability performance.
- Clarify Requirement R4.3.2 regarding expected automatic operation of DER (e.g., DER tripping, dynamic voltage and frequency controls, momentary cessation, etc.) should be considered in stability analyses.

Table E.1: Key Findings from SPIDERWG Review

Requirement	Key Findings and Recommendations
R1	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is** clear for consideration of DER.
R2.1	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is not** clear for consideration of DER.
R2.2	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is not** clear for consideration of DER.
R2.3	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is** clear for consideration of DER.
R2.4	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is not** clear for consideration of DER.
R2.5	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is** clear for consideration of DER.
R2.6	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER.

[4] Including those that have been made in response to the September 2018 Reliability Guideline "BPS-Connected Inverter-Based Resource Performance,"(https://www.nerc.com/comm/OC_Reliability_Guidelines_DL/Inverter-Based_Resource_Performance_Guideline.pdf), the September 2019 Reliability Guideline "Improvements to Interconnection Requirements for BPS-Connected Inverter-Based Resources," (https://www.nerc.com/comm/OC_Reliability_Guidelines_DL/Reliability_Guideline_IBR_Interconnection_Requirements_Improvements.pdf) revisions to PRC-024-2, revisions included in IEEE 1547-2018, and any subsequent guidelines and standards revisions

Table E.1: Key Findings from SPIDERWG Review	
Requirement	**Key Findings and Recommendations**
	• The existing language **is** clear for consideration of DER.
R2.7	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is not** clear for consideration of DER.
R2.8	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is** clear for consideration of DER.
R3.1	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is not** clear for consideration of DER.
R3.2	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is** clear for consideration of DER.
R3.3	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is not** clear for consideration of DER.
R3.4	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is not** clear for consideration of DER.
R3.5	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is** clear for consideration of DER.
R4.1	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is not** clear for consideration of DER.
R4.2	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is** clear for consideration of DER.
R4.3	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is not** clear for consideration of DER.
R4.4	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is** clear for consideration of DER.
R4.5	• This requirement **is** relevant for consideration of DER. • The existing language **does not** preclude consideration of DER. • The existing language **is** clear for consideration of DER.

Table E.1: Key Findings from SPIDERWG Review	
Requirement	**Key Findings and Recommendations**
R5	• This requirement **is** not relevant for consideration of DER.
R6	• This requirement **is** not relevant for consideration of DER.
R7	• This requirement **is** not relevant for consideration of DER.
R8	• This requirement **is** not relevant for consideration of DER.

Chapter 1: Requirement R1

Standard Requirement R1

- **R1.** Each Transmission Planner and Planning Coordinator shall maintain System models within its respective area for performing the studies needed to complete its Planning Assessment. The models shall use data consistent with that provided in accordance with the MOD-032 standard, supplemented by other sources as needed, including items represented in the Corrective Action Plan, and shall represent projected System conditions. This establishes Category P0 as the normal System condition in Table 1.
  - **R1.1.** System models shall represent:
    - R1.1.1. Existing Facilities
    - R1.1.2. New planned Facilities and changes to existing Facilities
    - R1.1.3. Real and reactive Load forecasts
    - R1.1.4. Known commitments for Firm Transmission Service and Interchange
    - R1.1.5. Resources (supply or demand side) required for Load

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is clear for consideration of DER.

Supplemental Discussion

As higher levels of DER are integrated across the Bulk Power System, DER should be part of system modeling. DER is included in R1.1.5 ("Resources (supply or demand side)"). DER data collection is consistent across the standards to reinforce the current understanding and need for inclusion of DER in BPS models used for planning assessments. While no specific threshold for DER modeling is suggested, each entity should keep track of DER to make such determinations. If the interconnecting utility is required to be notified of any newly connected DER, the data should exist for all installations of required size. If the data is available, then DER should be accounted for in the system model. Several other NERC Reliability Guidelines detail how the DER should be modeled.[5,6,7] For R-DER, it is sufficient to model the DER as a component of the composite load model, which reduces the level of effort and complexity required to incorporate while still providing valuable modeling enhancements.

It is noted that the MOD-032 SAR being proposed by SPIDERWG is seeking to include DER information as a necessary modeling component for BPS planning assessments. The SAR seeks DER information on steady state and dynamics data, and does not seek changes to the short circuit requirement "as steady-state column should have necessary information related to positive, negative, and zero sequence data provided accordingly".

[5] https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/Reliability_Guideline_-_DER_Modeling_Parameters_-_2017-08-18_-_FINAL.pdf
[6] https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/Reliability_Guideline_-_Modeling_DER_in_Dynamic_Load_Models_-_FINAL.pdf
[7] https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/Reliability_Guideline_DER_A_Parameterization.pdf

Chapter 2: Requirement R2

Standard Requirement R2

- **R2.** Each Transmission Planner and Planning Coordinator shall prepare an annual Planning Assessment of its portion of the BES. This Planning Assessment shall use current or qualified past studies (as indicated in Requirement R2, Part 2.6), document assumptions, and document summarized results of the steady state analyses, short circuit analyses, and Stability analyses.

Standard Requirement R2.1

- **R2.1.** For the Planning Assessment, the Near-Term Transmission Planning Horizon portion of the steady state analysis shall be assessed annually and be supported by current annual studies or qualified past studies as indicated in Requirement R2, Part 2.6. Qualifying studies need to include the following conditions:
  - **R2.1.1.** System peak Load for either Year One or year two, and for year five.
  - **R2.1.2.** System Off-Peak Load for one of the five years.
  - **R2.1.3.** For each of the studies described in Requirement R2, Parts 2.1.1 and 2.1.2, sensitivity case(s) shall be utilized to demonstrate the impact of changes to the basic assumptions used in the model. To accomplish this, the sensitivity analysis in the Planning Assessment must vary one or more of the following conditions by a sufficient amount to stress the System within a range of credible conditions that demonstrate a measurable change in System response:
    - Real and reactive forecasted Load.
    - Expected transfers.
    - Expected in service dates of new or modified Transmission Facilities.
    - Reactive resource capability.
    - Generation additions, retirements, or other dispatch scenarios.
    - Controllable Loads and Demand Side Management.
    - Duration or timing of known Transmission outages.
- **R2.1.4.** When known outage(s) of generation or Transmission Facility (ies) are planned in the Near-Term Planning Horizon, the impact of selected known outages on System performance shall be assessed. These known outage(s) shall be selected for assessment consistent with a documented outage coordination procedure or technical rationale by the Planning Coordinator or Transmission Planner. Known outage(s) shall not be excluded solely based upon outage duration. The assessment shall be performed for the P0 and P1 categories identified in Table 1 with the System peak or Off-Peak conditions that the System is expected to experience when the known outage(s) are planned. This assessment shall include, at a minimum known outages expected to produce more severe System impacts on the Planning Coordinator or Transmission Planner's portion of the BES. Past or current studies may support the selection of known outage(s), if the study(s) has comparable post-Contingency System conditions and configuration such as those following P3 or P6 category events in Table 1.
- **R2.1.5.** When an entity's spare equipment strategy could result in the unavailability of major Transmission equipment that has a lead-time of one year or more (such as a transformer), the impact of this possible unavailability on System performance shall be assessed. Based upon this assessment, an analysis shall be performed for the P0, P1, and P2 categories identified in Table 1 with the conditions that the System is expected to experience during the possible unavailability of the long lead-time equipment.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is not clear for consideration of DER.

Supplemental Discussion

The term Load is defined in NERC Glossary of Terms as "An end-use device or customer that receives power from the electric system." This definition is in line with the concept of "gross load" (or "gross demand") that refers to the total amount of power consumed by end-use device or customer, without any offset by generation on the demand side. Therefore, the current language of the standard may be interpreted as requiring to study peak or off-peak gross load.

With increased penetration of DER, what the transmission system supplies is the net load (net load = gross load – DER output) as seen at the T-D interface, which might reach its peak during operating conditions that are not at the gross peak load hour. Therefore, the most stressed condition of the overall transmission system should be defined by net load rather than gross load. R2.1.1 and 2.1.2 defines reference conditions to be studied. These reference conditions should be the most stressed condition, which is defined by the net load. As stated above, simply referring to "System peak Load" in the TPL-001 standard, the requirement may be interpreted as System peak gross load. This interpretation would limit the flexibility for the TP and PC to determine which reference condition is more appropriate for assessing their system. In addition, a high gross load hour may be the most stressed condition for contingencies that may trip large amounts of DER. High gross load may be added as additional sensitivity scenarios under R2.1.3.

An example is provided in the diagram below of California's hourly profiles that illustrate differences between peak gross load and peak net load. Peak gross load occurred at 4pm at around 24,000 MW, however, due to DER output, the net load of that hour was around 20,000 MW. On the other hand, at 6 pm, although gross load was slightly lower than 4pm, due to significantly lower DER output, the net load reached peak at around 22,000 MW. The SPIDERWG recommends that the peak net load of 22,000 MW should be studies because it is the operation condition when the transmission system is under highest loading. However, the current language in TPL-001-5 can be interpreted to require TP or PC to study the peak gross load hour at 4pm, when net load was 20000 MW.

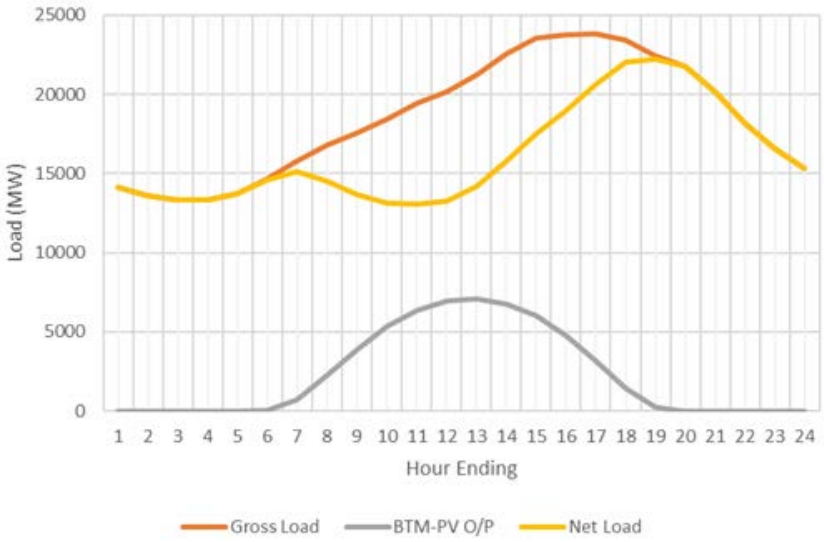


Figure 2.1: Area Peak Day Load Profile

As such, the term "System peak Load" generates different interpretations and confusion regarding what snapshot the scenario should represent. This raises the risk that entities may be interpreting this to mean either, which could

lead to increasingly disparate planning assumptions in the future. This issue should be addressed in a revision to the TPL-001 standard to clarify the intent and how TPs and PCs should implement the standard.

In addition to magnitude differences, the location of the load can vary between peak net load hours and peak gross load hours. In one condition, the residential area could have most of the load but in another condition where the sun is up the residential load could be small. As a result, even if net load levels are similar between peak hours of gross and net system load, they can have different impacts on the BPS if DER is spread unevenly relative to load.

Consistent with the NERC Reliability Guideline for DER modeling, DER should be modeled explicitly (no load netting). DER capacity and output in peak and off-peak load conditions should be modeled consistent with the year and the snapshot hour that the scenario represents. Sensitivity scenarios could include different output levels for DER (e.g., due to cloud cover or due to different operating hour assumptions). As there is no existing definition of term "Generation", it is not clear if different DER output levels are covered under the language in R 2.1.3 "Generation additions, retirements, or other dispatch scenarios. Clarification is needed or language edits is recommended to include DER output level sensitivities.

The SPIDERWG recommends the SDT to review and edit the current language in R2.1 regarding the use of term "Load", to ensure it clearly defines most critical conditions as intended, in systems with high DER penetration. When selecting steady state reference conditions to study for Planning Assessment, the distinction between gross load and net load is quite important. The SPIDERWG recommends that the SDT should also consider whether the terms "Gross Load" and "Net Load" be added to the NERC Glossary of Terms. Standard Requirement R2.2

- **R2.2.** For the Planning Assessment, the Long-Term Transmission Planning Horizon portion of the steady state analysis shall be assessed annually and be supported by the following annual current study, supplemented with qualified past studies as indicated in Requirement R2, Part 2.6:
  - **R2.2.1.** A current study assessing expected System peak Load conditions for one of the years in the Long-Term Transmission Planning Horizon and the rationale for why that year was selected

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is not clear for consideration of DER.

Supplemental Discussion

Same comments as R2.1 on "definition of "System peak".

Standard Requirement R2.3

- **R2.3.** The short circuit analysis portion of the Planning Assessment shall be conducted annually addressing the Near-Term Transmission Planning Horizon and can be supported by current or past studies as qualified in Requirement R2, Part 2.6. The analysis shall be used to determine whether circuit breakers have, interrupting capability for Faults that they will be expected to interrupt using the System short circuit model with any planned generation and Transmission Facilities in service, which could impact the study area.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.

- The existing language is clear for consideration of DER.

Supplemental Discussion

Make sure that inverter-based DERs are modeled appropriately in the short circuit model using the latest developed models that reflect the converter interface. Unlike synchronous generators, the short circuit current contribution from the inverter-based generation is usually limited to 100-120% of the rated load current[8].

Standard Requirement R2.4

- **R2.4.** For the Planning Assessment, the Near-Term Transmission Planning Horizon portion of the Stability analysis shall be assessed annually and be supported by current or past studies as qualified in Requirement R2, Part2.6. The following studies are required:
  - **R2.4.1** System peak Load for one of the five years. System peak Load levels shall include a Load model which represents the expected dynamic behavior of Loads that could impact the study area, considering the behavior of induction motor Loads. An aggregate System Load model, which represents the overall dynamic behavior of the Load, is acceptable.
    - **R2.4.2.** System Off-Peak Load for one of the five years.
    - **R2.4.3.** For each of the studies described in Requirement R2, Parts 2.4.1 and 2.4.2, sensitivity case(s) shall be utilized to demonstrate the impact of changes to the basic assumptions used in the model. To accomplish this, the sensitivity analysis in the Planning Assessment must vary one or more of the following conditions by a sufficient amount to stress the System within a range of credible conditions that demonstrate a measurable change in performance:
      - Load level, Load forecast, or dynamic Load model assumptions.
      - Expected transfers.
      - Expected in service dates of new or modified Transmission Facilities.
      - Reactive resource capability.
      - Generation additions, retirements, or other dispatch scenarios.
    - **R2.4.4.** When known outage(s) of generation or Transmission Facility (ies) are planned in the Near-Term Planning Horizon, the impact of selected known outages on System performance shall be assessed. These known outage(s) shall be selected for assessment consistent with a documented outage coordination procedure or technical rationale by the Planning Coordinator or Transmission Planner. Known outage(s) shall not be excluded solely based upon outage duration. The assessment shall be performed for the P1 categories identified in Table 1 with the System peak or Off-Peak conditions that the System is expected to experience when the known outage(s) are planned. This assessment shall include, at a minimum, those known outages expected to produce more severe System impacts on the Planning Coordinator or Transmission Planner's portion of the BES. Past or current studies may support the selection of known outage(s), if the study(s) has comparable post-Contingency System conditions and configuration such as those following P3 or P6 category events in Table 1.
    - **R2.4.5.** When an entity's spare equipment strategy could result in the unavailability of major Transmission equipment that has a lead-time of one year or more (such as a transformer), the impact of this possible unavailability on System performance shall be assessed. Based upon this assessment, an analysis shall be performed for the selected P1 and P2 category events identified in Table 1 for

[8] See the *IEEE Joint Working Group Report, Fault Current Contributions from Wind Plants, 2013* for more details (http://www.pes-psrc.org/kb/published/reports/Fault%20Current%20Contributions%20from%20Wind%20Plants.pdf).

which the unavailability is expected to produce more severe System impacts on its portion of the BES. The analysis shall simulate the conditions that the System is expected to experience during the possible unavailability of the long lead-time equipment.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is not clear for consideration of DER.

Supplemental Discussion

Similar comment as in R2.1 and 2.2 in regards to the terms "System peak Load" and "System Off-Peak Load". Consistent with the NERC Reliability Guideline for Distributed Energy Resource Modeling[9], DERs should be modeled explicitly (no load netting). DER capacity and output in peak and Off-Peak load conditions should be modeled consistent with the year and the snapshot hour that the case represents. To evaluate the dynamic behavior of the BPS under System peak Load and Off-Peak Load, DERs should be represented appropriately as either a generator model or a DER component of the load record in stability analysis. Consistent with the NERC Reliability Guideline for modeling DER in Dynamic Load Models[10], inverter-based DER can be represented in Stability analysis using the DER_A model. The NERC Reliability Guideline for parameterization of the DER_A model[11] can be used for developing required parameters. In addition, language regarding capturing the dynamic behavior of DER should be added for clarity, similar to the language used for representing induction motor loads in the current TPL-001 version. However, representation of the dynamic behavior of DERs is critical in all stability studies, not just System peak conditions.

Standard Requirement R2.5

- **R2.5.** For the Planning Assessment, the Long-Term Transmission Planning Horizon portion of the Stability analysis shall be assessed to address the impact of proposed material generation additions or changes in that timeframe and be supported by current or past studies as qualified in Requirement R2, Part2.6 and shall include documentation to support the technical rationale for determining material changes.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is clear for consideration of DER.

Supplemental Discussion

Same comments as R2.2.

Standard Requirement R2.6

- **R2.6.** Past studies may be used to support the Planning Assessment if they meet the following requirements:

[9] https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/Reliability_Guideline_-_DER_Modeling_Parameters_-_2017-08-18_-_FINAL.pdf
[10] https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/Reliability_Guideline_-_Modeling_DER_in_Dynamic_Load_Models_-_FINAL.pdf
[11] https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/Reliability_Guideline_DER_A_Parameterization.pdf

- **R2.6.1.** For steady state, short circuit, or Stability analysis: the study shall be five calendar years old or less, unless a technical rationale can be provided to demonstrate that the results of an older study are still valid.
- **R2.6.2.** For steady state, short circuit, or Stability analysis: no material changes have occurred to the System represented in the study. Documentation to support the technical rationale for determining material changes shall be included.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is clear for consideration of DER.

Supplemental Discussion

Consider change in DER penetration level in determining material change for evaluation of use of past studies. As DER penetration increases along with the gross load, the net load growth at the T-D interface could remain flat or even decline. This may result in similar steady-state result as in past studies, depending on how evenly the DER is spread relative to the load. However, this could result in very different dynamic performance due to the change in load composition and dynamic behavior of the DER. It is not clear whether a change in inverter technology request by resource entity qualifies as material change. As DER are included in TPL-001 studies, it is important to account for changes, in response to NERC guidelines, standards, and IEEE 1547 that alter their performance.

Standard Requirement R2.7

- **R2.7.** For planning events shown in Table 1, when the analysis indicates an inability of the System to meet the performance requirements in Table 1, the Planning Assessment shall include Corrective Action Plan(s) addressing how the performance requirements will be met. Revisions to the Corrective Action Plan(s) are allowed in subsequent Planning Assessments but the planned System shall continue to meet the performance requirements in Table 1. Corrective Action Plan(s) do not need to be developed solely to meet the performance requirements for a single sensitivity case analyzed in accordance with Requirements R2, Parts 2.1.4 and 2.4.3. The Corrective Action Plan(s) shall: [Requirements 2.7.1 – 2.7.4]
  - **R2.7.1.** List System deficiencies and the associated actions needed to achieve required System performance. Examples of such actions include:
    - Installation, modification, retirement, or removal of Transmission and generation Facilities and any associated equipment.
    - Installation, modification, or removal of Protection Systems or Remedial Action Schemes.
    - Installation or modification of automatic generation tripping as a response to a single or multiple Contingency to mitigate Stability performance violations.
    - Installation or modification of manual and automatic generation runback/tripping as a response to a single or multiple Contingency to mitigate steady state performance violations.
    - Use of Operating Procedures specifying how long they will be needed as part of the Corrective Action Plan.
    - Use of rate applications, DSM, new technologies, or other initiatives.
  - **R2.7.2.** Include actions to resolve performance deficiencies identified in multiple sensitivity studies or provide a rationale for why actions were not necessary.

- **R2.7.3.** If situations arise that are beyond the control of the Transmission Planner or Planning Coordinator that prevent the implementation of a Corrective Action Plan in the required timeframe, then the Transmission Planner or Planning Coordinator is permitted to utilize Non-Consequential Load Loss and curtailment of Firm Transmission Service to correct the situation that would normally not be permitted in Table 1, provided that the Transmission Planner or Planning Coordinator documents that they are taking actions to resolve the situation. The Transmission Planner or Planning Coordinator shall document the situation causing the problem, alternatives evaluated, and the use of Non-Consequential Load Loss or curtailment of Firm Transmission Service.
- **R2.7.4.** Be reviewed in subsequent annual Planning Assessments for continued validity and implementation status of identified System Facilities and Operating Procedures.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is not clear for consideration of DER.

Supplemental Discussion

DER could alleviate system deficiencies by reducing net load and reducing flows on the bulk power system, depending on how DER is spread relative to the load. As such, DER could be part of CAP and could be included within the list of actions needed to achieve required system performance. An implementation guideline should be developed to clarify that DER could part of CAP.

Standard Requirement R2.8

- **R2.8**. For short circuit analysis, if the short circuit current interrupting duty on circuit breakers determined in Requirement R2, Part 2.3 exceeds their Equipment Rating, the Planning Assessment shall include a Corrective Action Plan to address the Equipment Rating violations. The Corrective Action Plan shall:
  - **R2.8.1.** List System deficiencies and the associated actions needed to achieve required System performance.
  - **R2.8.2.** Be reviewed in subsequent annual Planning Assessments for continued validity and implementation status of identified System Facilities and Operating Procedures.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is clear for consideration of DER.

Supplemental Discussion

DERs fault contribution characteristics could be considered as part of remedial actions assessment. Similar to 2.7 above, DER could be part of CAP and could be included within the list of actions needed to address the equipment rating violations. “Use of rate applications, DSM, new technologies or other initiatives”.

Chapter 3: Requirement R3

Standard Requirement R3

- **R3.** For the steady state portion of the Planning Assessment, each Transmission Planner and Planning Coordinator shall perform studies for the Near-Term and Long-Term Transmission Planning Horizons in Requirement R2, Parts 2.1, and 2.2. The studies shall be based on computer simulation models using data provided in Requirement R1.

Standard Requirement 3.1

- **R3.1.** Studies shall be performed for planning events to determine whether the BES meets the performance requirements in Table 1 based on the Contingency list created in Requirement R3, Part 3.4.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is not clear for consideration of DER.

Supplemental Discussion

The current language in R3 is not clear regarding whether and how to consider DER as planning events. While the current language in the R3 does not preclude consideration of DER, it also does not explicitly require inclusion of DER contingencies. Requirement R3.4 allows PC and TP to include only contingencies that are expected to produce more severe System impacts with the rationale for those Contingencies selected for evaluation shall be available as supporting information. Without changes to the Standard or further guidelines, the assessments may neglect to evaluate the impact of DER planning events (*i.e.* loss of a generator), regardless of the penetration level. Development of Contingency list should include contingency of explicitly modeled DER when they are expected to produce a more serve System impact on the BES. The DERs categorized as U-DER in the NERC Reliability Guideline for Distributed Energy Resource Modeling[12] are typically the ones that are modeled explicitly in the power flow model. The R-DER are not expected to be included in the Contingency list. If the level of penetration or U-DER size is not significant, the assessment may be able to exclude DER contingencies with rationale.

Standard Requirement R3.2

- **R3.2.** Studies shall be performed to assess the impact of the extreme events, which are identified by the list created in Requirement R3, Part 3.5. If the analysis concludes there is Cascading caused by the occurrence of extreme events, an evaluation of possible actions designed to reduce the likelihood or mitigate the consequences and adverse impacts of the event(s) shall be conducted.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is clear for consideration of DER.

[12] https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/Reliability_Guideline_-_DER_Modeling_Parameters_-_2017-08-18_-_FINAL.pdf

Supplemental Discussion

With heavy penetration of DER, extreme events could include impacts of DER. Events like wide-area cloud cover and solar eclipse could significantly reduce DER output (predominantly solar) in a relatively short time (in addition to the reduction of BPS-connected solar PV generation). Based on discussions within SPIDERWG, this should not considered extreme events due to its time frame. Rather, TPs and PCs should consider developing base case scenarios that account for the spatial aspects and any common modes that could affect DER output.

Large amounts of DER could trip following other contingencies (e.g., loss of transmission circuits), and this can amplify the impact of the triggering contingency (as was observed in the UK disturbance in summer 2019). Existing language in Table 1 on extreme events is sufficient to allow such DER considerations by 3.b "Other events based upon operating experience that may result in wide area disturbances."

Standard Requirement R3.3

- **R3.3.** Contingency analyses for Requirement R3, Parts 3.1 and 3.2 shall:
  - **R3.3.1.** Simulate the removal of all elements that the Protection System and other automatic controls are expected to disconnect for each Contingency without operator intervention. The analyses shall include the impact of subsequent:
    - **R3.3.1.1.** Tripping of generators where simulations show generator bus voltages or high side of the generation step up (GSU) voltages are less than known or assumed minimum generator steady state or ride through voltage limitations. Include in the assessment any assumptions made.
    - **R3.3.1.2.** Tripping of Transmission elements where relay loadability limits are exceeded.
- **R3.3.2.** Simulate the expected automatic operation of existing and planned devices designed to provide steady state control of electrical system quantities when such devices impact the study area. These devices may include equipment such as phase-shifting transformers, load tap changing transformers, and switched capacitors and inductors.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is not clear for consideration of DER.

Supplemental Discussion

DERs should be tripped where simulations show bus voltages that are less than known or assumed minimum DER steady state or ride-through voltage limits. It is also recommended to include in the assessment any assumptions made in estimating DER bus voltage. The existing language does not preclude consideration of DER. R1 specifies that the "System models" for the "Planning Assessment" discussed in R3 must: "Use data consistent with that provided in accordance with the MOD-032 standard, supplemented by other sources as needed" and "System models shall represent: …1.1.5 Resources (supply or demand side) required for Load." Thus, R3 does not preclude the consideration of DER by the PC and TP. After all, (1) under MOD-032-1, the PC and TP may already request DER data "necessary for modeling purposes" and (2) DER is a "demand side" resource increasingly required for serving load. R1.1.5 uses the term "Resources" when specifying inclusion of demand side resources, but R3.3 used the term "generators" which is not a defined term in the NERC Glossary. Therefore, it is not clear whether this requirement applies to DERs that are located on the demand side offsetting the load. Terminology and consideration for DER should be addressed by language modifications to bring clarity to the requirements.

Standard Requirement R3.4

- **R3.4.** Those planning events in Table 1, that are expected to produce more severe System impacts on its portion of the BES, shall be identified and a list of those Contingencies to be evaluated for System performance in Requirement R3, Part 3.1 created. The rationale for those Contingencies selected for evaluation shall be available as supporting information.
  - **R3.4.1.** The Planning Coordinator and Transmission Planner shall coordinate with adjacent Planning Coordinators and Transmission Planners to ensure that Contingencies on adjacent Systems, which may impact their Systems, are included in the Contingency list.

Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is not clear for consideration of DER.

Supplemental Discussion

Same comments as R3.1.

Standard Requirement R3.5

- **R3.5.** Those extreme events in Table 1 that are expected to produce more severe System impacts shall be identified and a list created of those events to be evaluated in Requirement R3, Part 3.2. The rationale for those Contingencies selected for evaluation shall be available as supporting information.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is clear for consideration of DER.

Supplemental Discussion

Same comments as R3.2

Chapter 4: Requirement R4

Standard Requirement R4

- **R4.** For the Stability portion of the Planning Assessment, as described in Requirement R2, Parts 2.4 and 2.5, each Transmission Planner and Planning Coordinator shall perform the Contingency analyses listed in Table 1. The studies shall be based on computer simulation models using data provided in Requirement R1.

Standard Requirement R4.1

- **R4.1.** Studies shall be performed for planning events to determine whether the BES meets the performance requirements in Table 1 based on the Contingency list created in Requirement R4, Part 4.4.
  - **R4.1.1.** For planning event P1: No generating unit shall pull out of synchronism. A generator being disconnected from the System by fault clearing action or by a Special Protection System is not considered pulling out of synchronism.
  - **R4.1.2.** For planning events P2 through P7: When a generator pulls out of synchronism in the simulations, the resulting apparent impedance swings shall not result in the tripping of any Transmission system elements other than the generating unit and its directly connected Facilities.
  - **R4.1.3.** For planning events P1 through P7: Power oscillations shall exhibit acceptable damping as established by the Planning Coordinator and Transmission Planning Engineer.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is not clear for consideration of DER.

Supplemental Discussion

In Requirements R4.1.1 and R4.1.2, performance criteria “pulls out of synchronism” is specific to synchronous generators and is not addressing performance requirement for asynchronous generators including DER. The language should be clarified to address performance requirements for both synchronous and non-synchronous generators.

Standard Requirement R4.2

- **R4.2.** Studies shall be performed to assess the impact of the extreme events, which are identified by the list created in Requirement R4, Part 4.5. If the analysis concludes there is Cascading caused by the occurrence of extreme events, an evaluation of possible actions designed to reduce the likelihood or mitigate the consequences of the event (s) shall be conducted.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is clear for consideration of DER.

Supplemental Discussion

Same comments as 3.2 Dynamic contingencies should include DER tripping for voltage/frequency.

Standard Requirement R4.3

- **R4.3.** Contingency analyses for Requirement R4, Parts 4.1 and 4.2 shall:
  - **R4.3.1.** Simulate the removal of all elements that the Protection System and other automatic controls are expected to disconnect for each Contingency without operator intervention. The analyses shall include the impact of subsequent:
    - **R4.3.1.1.** Successful high speed (less than one second) reclosing and unsuccessful high-speed reclosing into a Fault where high speed reclosing is utilized.
    - **R4.3.1.2.** Tripping of generators where simulations show generator bus voltages or high side of the GSU voltages are less than known or assumed generator low voltage ride through capability. Include in the assessment any assumptions made. Contingency analysis should include aggregated DER loss as a contingency where applicable.
    - **R4.3.1.3.** Tripping of Transmission lines and transformers where transient swings cause Protection System operation based on generic or actual relay models.
  - **R4.3.2.** Simulate the expected automatic operation of existing and planned devices designed to provide dynamic control of electrical system quantities when such devices impact the study area. These devices may include equipment such as generation exciter control and power system stabilizers, static var compensators, power flow controllers, and DC Transmission controllers.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is not clear for consideration of DER.

Supplemental Discussion

DERs should be tripped where simulations show load bus voltages that are less than known or assumed minimum DER ride-through voltage limits. It is also recommended to include in the assessment any assumptions made in estimating DER bus voltage. The existing language does not preclude consideration of DER. R1 specifies that the "System models" for the "Planning Assessment" discussed in R4 must: "Use data consistent with that provided in accordance with the MOD-032 standard, supplemented by other sources as needed" and "System models shall represent: …1.1.5 Resources (supply or demand side) required for Load." Thus, R4 does not preclude the consideration of DER by the PC and TP. After all, (1) under MOD-032-1, the PC and TP may already request DER data "necessary for modeling purposes" and (2) DER is a "demand side" resource increasingly required for serving load. R1.1.5 uses the term "Resources" when specifying inclusion of demand side resources, but R4.3 used the term "generators" which is not a defined term in the NERC Glossary. Therefore, it is not clear whether it includes DERs. Terminology and consideration for DER should be addressed by language modifications to bring clarity to the requirements. Requirement R4.3.2 should include DER's dynamic controls, if any, such as DER tripping, dynamic reactive support, active power-frequency control, etc.

Standard Requirement R4.4

- **R4.4.** Those planning events in Table 1 that are expected to produce more severe System impacts on its portion of the BES, shall be identified, and a list created of those Contingencies to be evaluated in Requirement R4, Part 4.1. The rationale for those Contingencies selected for evaluation shall be available as supporting information.

- **R4.4.1.** Each Planning Coordinator and Transmission Planner shall coordinate with adjacent Planning Coordinators and Transmission Planners to ensure that Contingencies on adjacent Systems, which may impact their Systems, are included in the Contingency list.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is clear for consideration of DER.

Supplemental Discussion

Same comments as R3.1.

Standard Requirement R4.5

- **R4.5**. Those extreme events in Table 1 that are expected to produce more severe System impacts shall be identified and a list created of those events to be evaluated in Requirement R4, Part 4.2. The rationale for those Contingencies selected for evaluation shall be available as supporting information.

SPIDERWG Review Finding

- This requirement is relevant for consideration of DER.
- The existing language does not preclude consideration of DER.
- The existing language is clear for consideration of DER.

Supplemental Discussion

Same comments as R4.2.

Chapter 5: Requirement R5-R8

Standard Requirement R5

- **R5.** Each Transmission Planning Engineer and Planning Coordinator shall have criteria for acceptable System steady state voltage limits, post-Contingency voltage deviations, and the transient voltage response for its System. For transient voltage response, the criteria shall at a minimum, specify a low voltage level and a maximum length of time that transient voltages may remain below that level.

Standard Requirement R6

- **R6.** Each Transmission Planning Engineer and Planning Coordinator shall define and document, within their Planning Assessment, the criteria or methodology used in the analysis to identify System instability for conditions such as Cascading, voltage instability, or uncontrolled islanding.

Standard Requirement R7

- **R7.** Each Planning Coordinator, in conjunction with each of its Transmission Planning Engineers, shall determine and identify each entity's individual and joint responsibilities for performing the required studies for the Planning Assessment.

Standard Requirement R8

- **R8.** Each Planning Coordinator and Transmission Planning Engineer shall distribute its Planning Assessment results to adjacent Planning Coordinators and adjacent Transmission Planning Engineers within 90 calendar days of completing its Planning Assessment, and to any functional entity that has a reliability related need and submits a written request for the information within 30 days of such a request.
    - **R8.1.** If a recipient of the Planning Assessment results provides documented comments on the results, the respective Planning Coordinator or Transmission Planning Engineer shall provide a documented response to that recipient within 90 calendar days of receipt of those comments.

SPIDERWG Review Finding

- Requirements R5–R8 are not relevant for consideration of DER.

Chapter 6: Participants

Name	Entity
Binaya Shrestha (Sub-Group Task Co-Lead)	California Independent System Operator
Chelsea Zhu (Sub-Group Task Co-Lead)	National Grid
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Keith Burrell	New York Independent System Operator
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Ransome Egunjobi	Lower Colorado River Authority
Sirisha Tanneeru	Xcel Energy
Stephanie Schmidt	Federal Energy Regulatory Commission
Ting Zhang	Alberta Electric System Operator
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Kun Zhu (SPIDERWG Chair)	Midcontinent Independent System Operator
Bill Quaintance (SPIDERWG Vice Chair)	Duke Progress
Ryan Quint (SPIDERWG Coordinator)	North American Electric Reliability Corporation
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