NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

ERO Enterprise Joint IROL Activity Report

July 2024

RELIABILITY | RESILIENCE | SECURITY




3353 Peachtree Road NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

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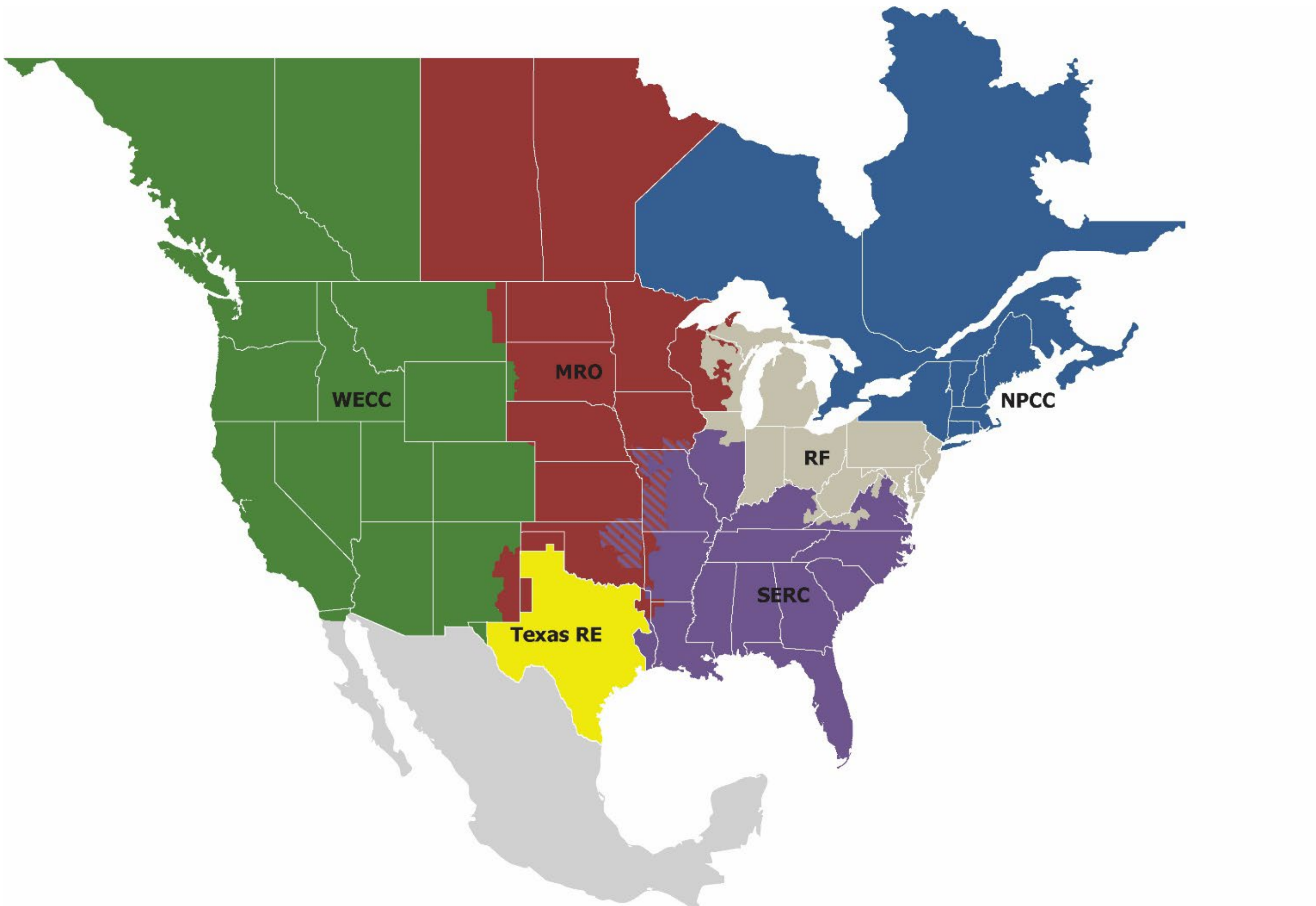
Preface

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 NERC and the six Regional Entities, is a highly reliable, resilient, 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 made up of six Regional Entities as shown on the map and in the corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one Regional Entity while associated Transmission Owners/Operators 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

Acknowledgement

This report is the result of a combined effort by staff from the North American Electric Reliability Corporation (NERC), the six Regional Entities—MRO, NPCC, SERC, RF, Texas RE, and WECC—and the participating Reliability Coordinators (participants).

Specific details of the participants have been excluded to protect the confidentiality of the participants' tools and practices. During the activity, each participant provided useful details regarding their approach to, and philosophy around, Interconnection Reliability Operating Limits (IROL). The joint review team (Team) would like to thank all those who contributed their time, resources, and expertise, without which this report would not have been possible.

Seventeen entities perform Reliability Coordinator functions for the North American BPS[1]; 11 in the United States and 6 in Canada. Sixteen of the seventeen entities participated in the IROL Activity. NERC would like to thank the following entities whose participation made the IROL Activity possible:

- Alberta Electric System Operator (AESO)
- British Columbia Hydro (BCH)
- California ISO – Reliability Coordinator West (CAISO)
- Electric Reliability Council of Texas (ERCOT)
- Florida Reliability Coordinating Council (FRCC)
- Hydro-Québec (HQ)
- Independent Electricity System Operator (IESO)
- ISO New England (ISONE)
- Midcontinent ISO (MISO)
- New York Independent System Operator (NYISO)
- PJM Interconnection (PJM)
- Saskatchewan Power Corporation (SASK)
- Southern Company Services (SOCO)
- Southwest Power Pool (SPP)
- Tennessee Valley Authority (TVA)
- VACAR South (VACAR)

[1] One entity performing Reliability Coordinator functions in Canada is not registered, nor required to be registered, as a Reliability Coordinator in the NERC Compliance Registry based on its provincial regulator's memorandum of understanding with NERC.

Executive Summary

As the interconnected structure of the electric grid grows more complex, maintaining reliability, resiliency, and security is paramount. Establishing and adhering to IROLs plays a pivotal role in this task. Over the past decade, revisions to NERC Reliability Standard requirements and definitions have highlighted a growing recognition of the need for more comprehensive guidance around establishing and managing IROLs. Striking a balance between allowing some flexibility for operators to manage their unique grid systems and providing more standardized criteria to ensure the overall consistency and effectiveness of the IROL framework remains necessary. Understanding this balance is central to preserving IROL effectiveness while ensuring reliable operation in the face of evolving challenges.

One element essential to maintaining a reliable, resilient, and secure BPS is a periodic review of the NERC Reliability Standards. The *NERC Periodic Review Team (PRT) 2015-03* performed a review of the Facilities Design, Connections, and Maintenance (FAC) standards and, as an outcome of that review, recommended[2] the formation of a standard drafting team (SDT) to address the identified issues. In response, in August 2015, *NERC Project 2015-09 Establish and Communicate System Operating Limits* was formed with the primary objective of revising the FAC standards to eliminate overlap with approved Transmission Planning (TPL) standard requirements[3], to enhance consistency with transmission operations[4] (TOP) and Interconnection reliability operations (IRO) standards[5], and to address other concerns within the existing FAC standards regarding determination and communication of System Operating limits (SOL) and IROLs. The scope of the project included development of new or revised requirements and *NERC Glossary of Terms* definitions to provide clarity and consistency for establishing SOLs and IROLs and to address potential reliability issues resulting from the application of the *NERC Glossary Terms* definitions for SOL and IROL.

The SDT reached a consensus on SOLs but not IROLs. As a result, the NERC Standards Committee (SC) requested the formation of a joint task force that was, comprised of both system planners and operators, to develop technical material that could be used as an industry reference to enhance the way IROLs are established. This technical material could also be used by the SDT as a technical basis for revising IROL-related Reliability Standards. The NERC Planning Committee (PC)[6] and the NERC Operating Committee (OC)[7] agreed and established the *Methods for Establishing IROLs Task Force (MEITF)*, which issued several documents to provide guidance to industry on the development of technically sound methods for establishing IROLs. These guidance documents also provide a detailed technical basis for revisions to IROL-related Reliability Standards. One of the MEITF-developed documents, the *Reliability Guideline Methods for Establishing IROLs*[8], is the basis for this activity.

However, consensus could still not be reached through the SDT or the MEITF efforts, and the SDT did not address IROLs in its modifications of the FAC standards. As part of the filing for Project 2015-09, NERC committed in its *June 2021 Petition for Approval of Proposed Reliability Standards Related to Establishing and Communicating SOLs*[9], to assessing the current state of IROLs and the apparent discrepancies implemented by Reliability Coordinators in their development. Specifically, NERC stated on page 10 of the petition its intention to: evaluate whether and how Reliability Coordinators have revised their methods for establishing IROLs in response to the Reliability Guideline and assess whether the revised methods have resulted in a more consistent approach to establishing IROLs across the

[2] https://www.nerc.com/pa/Stand/Prjct201503PrdcRvwofSstmOprtngLmtStndrdsDL/FAC-014_Periodic%20Review%20Template_Jul28_clean.pdf
[3] See, TPL-001-4
[4] See TOP-001-3, TOP-002-4, TOP-003-3
[5] See, IRO-001-4, IRO-002-4, IRO-008-2, IRO-010-2, IRO-014-3, IRO-017-1
[6] https://www.nerc.com/comm/PC/Pages/default.aspx
[7] https://www.nerc.com/comm/OC/Pages/default.aspx
[8] https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline_Methods_for_Establishing_IROLs.pdf
[9] https://www.nerc.com/FilingsOrders/us/NERC%20Filings%20to%20FERC%20DL/Petition%20for%20Approval%20of%20SOL%20Standards_Exhibits%20A-G.pdf

BPS. To meet this commitment, NERC established a joint[10] review team and initiated this IROL review activity in late 2021.

The Team's work was not a compliance review of prior activities; it instead focused on current, ongoing practices and procedures with the goal of gaining an understanding of the approaches and philosophies regarding methods for establishing IROLs and providing industry with additional technical supporting guidance. By serving as a platform for shared understanding and promoting best practices, this report aims to contribute to the ongoing efforts to enhance the reliability, resilience, and security of the BPS. Throughout 2022, the Team engaged in virtual discussions with 16 of the 17 entities performing Reliability Coordinator functions on the BPS. The review involved comprehensive discussions with the participating Reliability Coordinators to gain insight into their unique approaches for establishing and managing IROLs as well as their familiarity with recommended practices outlined in the *Reliability Guideline Methods for Establishing IROLs*. Through this activity the Team determined that the reliability guideline resulted in minimal impact (as only 2 of the 16 participating Reliability Coordinators implemented "some" of the recommended practices), and an extremely high level of inconsistency still exists among Reliability Coordinators regarding approaches to establishing IROLs.

This report includes detailed discussions on six topic areas related to IROLs. Each topic area includes the following subsections: Introduction, Observations[11], Conclusions, Recommendations, and Beneficial Practices. The six topic areas addressed are as follows:

- Terminology
- Establishing IROLs
- IROL-Like Conditions
- Tools and Practices
- Communication and Coordination
- Reliability Standards

Overview of Conclusions and Recommended Actions

The following is a summary of key issues and recommendations resulting from the IROL Activity; details of the key issues are discussed in the body of the report. In general, the IROL Activity team noted wide variations among the participating Reliability Coordinators relative to terminology, philosophies, approaches, and methodologies for establishing IROLs.

- **Terminology:** The Team concludes that numerous IROL-related terms are applied interchangeably between the participants and that the same terms often have different meanings. Several definitions in the NERC Glossary of Terms contain words, such as "widespread," that are not defined within the Glossary and therefore create additional confusion. The inconsistent use and understanding of IROL-related terminology resulted in impactful differences between the Reliability Coordinators in the establishment of IROLs. There is a need for clearly defined terms with specific meanings, including definitions for ambiguous or subjective terms used within other definitions. The Team found that several participants created new, or previously unheard of, terminology and believes that participants may use these terms in lieu of "IROL" to avoid having to assume the additional compliance burden of IROL-related Reliability Standards. The Teams recommendations focus around adding clarity to terminology.

[10] The joint review team consisted of members from NERC and all Regional Entities. FERC staff participated as observers for US jurisdictional Reliability Coordinators, and not team members.

[11] All observations, conclusions, recommendations, and beneficial practices are the Teams and not those of the FERC staff observers.

- **Establishing IROLs**: The Team concludes that there is a wide spectrum of variance among Reliability Coordinators regarding the criteria, thresholds, methodologies, philosophies, and number of established IROLs. The Team attributes this to the Reliability Coordinators exercising engineering judgment based on the non-specificity of the NERC Reliability Standards and related terminology regarding the establishment of IROLs. The Team also concludes that the non-prescriptive and vague nature of the Reliability Standards leads to a lack of understanding and confusion around the application of establishing IROLs. The Teams recommendations focus on Reliability Coordinator's practices and criteria, ensuring those practices and criteria are readily available, and sharing those practices and criteria with neighboring Reliability Coordinators.
- **IROL-Like Conditions**: This Real-time phenomenon is caused by unforeseen conditions due to unexpected outages stemming from issues such as weather, equipment failure, and human error and when the next Contingency could result in significant adverse reliability impacts. The Team concludes that there are variances among Reliability Coordinators regarding how IROL-like conditions are treated during and after the condition. The two common themes are: 1) All Reliability Coordinators treat IROL-like conditions as if they were IROLs and their main priority is to return the system to a secure operating state and 2) None of the Reliability Coordinators establish IROLs in real time, except for one Reliability Coordinator that establishes what it calls a "temporary IROL." The Teams recommendations focus on the need for more guidance around IROL-like conditions.
- **Tools and Practices**: The Team concludes that there are a variety of tools in use and that the tools each Reliability Coordinator uses reflect their philosophies and priorities relative to operating limits. The Team identified a common theme among the participating Reliability Coordinators in the expressed desire for better Real-time tools to study IROLs and IROL-like conditions, especially related to stability analysis. The tools that are currently available require a large amount of human interaction to enter the needed data, and the time needed to complete studies render them non-conducive to use in real time. Most Reliability Coordinators expressed interest in having a "common" tool with very high-end processing to study complex Real-time situations in a short period of time. The Teams recommendations focus on exploring the possibility of developing common tools that could be implemented by all Reliability Coordinators.
- **Communication and Coordination**: The Team concludes that more transparency, communication, and coordination regarding IROLs is needed among Reliability Coordinators. The Team attributes this to several factors, including the previously discussed issues around terminology, as well as the allowed flexibility and ambiguity of the Reliability Standards regarding unspecified criteria, thresholds, and methodology for establishing IROLs. The Team also concludes that communication among Reliability Coordinators is impeded by the Reliability Standards disincentivizing the establishment of IROLs, as well as the communication among Reliability Coordinators due to potential compliance implications. The Teams recommendations focus on developing information sharing processes, creating methods for communicating concerns, and developing a list of communication and coordination related resources.
- **Reliability Standards:** The Team concludes that SOLs are clearly understood by industry because of the revised definition of SOL, the new definition of System Voltage Limit, and the revised FAC-011-4, FAC-014-4, TOP-001-6, and IRO-008-3 standards. These standards clarify what an SOL is, when one needs to be established, and what it means to exceed one. The Team concludes that such clarity does not exist for IROLs, and that Reliability Coordinators are confused about what an IROL is, when one needs to be established, and what it means to exceed one. The Team believes that this absence of clarity around IROLs poses a reliability risk that needs to be addressed. The Teams recommendations focus on resolving industry confusion around IROLs by modifying the body of Reliability Standards to improve clarity and address reliability risks. The Team provides two optional paths to achieve the recommendation: 1) Maintain the current "limit exceedance" approach to reliable operations and address the IROL confusion, and 2) Consider a "performance criteria and

risk-based" approach as a replacement for the current "limit exceedance" approach to reliable operations codified into the Reliability Standards. The Team also identifies recent risk reductions and remaining risks.

Introduction

IROLs are a subset of SOLs in which reliable operation of the BPS may result in instability, uncontrolled separation, or Cascading outages if the limit is exceeded. These limits are used for Real-time operation and are generally established prior to Real-time operations during off-line studies. However, advanced tools are increasingly being used to update these limits in near real time and can be used to establish new IROLs in real time in some cases. Establishing SOLs and IROLs prior to Real-time operation ensures that the BPS remains reliable and that operating processes and plans are developed to provide System Operators with steps to operate within SOLs (including IROLs), ensuring that unforeseen operating conditions are minimized, and the system remains in a reliable operating state. Each IROL has a mitigation time (IROL T_v), and System Operators use any actions available to them, up to and including pre-Contingency load shedding, to prevent and mitigate an exceedance. IROLs are used in the operations horizon as "operating limits" in combination with outage coordination and other operating plans to ensure BPS reliability. Consistent with the FAC standards that become effective April 1, 2024[12], IROLs do not necessarily need to be established in the planning horizon; however, the relationship between planning and operations performance criteria is required to be consistent.

IROLs play a pivotal role in assuring the reliable operation of the BPS. An IROL is defined as a "*System Operating Limit that, if violated, could lead to instability, uncontrolled separation, or Cascading outages that adversely impact the reliability of the Bulk Electric System*."[13] Identifying and adhering to IROLs established by Reliability Coordinators is integral to reliable operations. The lack of uniform definitions of specific methods for analyzing and identifying these limits in the existing NERC Reliability Standards can lead to inconsistent application and implementation.

The process of establishing IROLs usually involves complex power flow modeling and analysis and relies heavily on System Operator knowledge and experience with their system. Given this complexity and the vast number of factors that can influence system stability, a considerable degree of flexibility in how System Operators can approach this task exists. As such, differences between topologies, analytical tools, operating conditions, and Contingencies[14] can result in disparate methods and criteria for determining IROLs. While one Reliability Coordinator might lean toward a more conservative approach that sets stricter limits, another might establish more flexible limits to optimize system operation or to accommodate for dynamic Facility Ratings or different market structures.

The lack of a single defined method allows the facts and circumstances of a Reliability Coordinator to be embedded in its practices and procedures. However, this absence of a single approach could result in wide variations in how Reliability Coordinators establish and manage their IROLs. These discrepancies in methodology and criteria could potentially impact IROL implementation consistency and effectiveness across the BPS. Disparities could also cause confusion and pose challenges for registered entities that operate across multiple Reliability Coordinator footprints, as they may not understand the varying strategies and differing operating limits from Reliability Coordinator to Reliability Coordinator.

Background

In 2015, the NERC Reliability Standards Project 2015-09 was created and tasked with revising requirements for determining and communicating SOLs and IROLs to address the PRT's recommendations[15] for SOL- and IROL-related

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[12] FAC-011-4 System Operating Limits Methodology for the Operations Horizon and FAC-014-3Establish and Communicate System Operating Limits

[13] https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary_of_Terms.pdf

[14] The unexpected failure or outage of a system component, such as a generator, transmission line, circuit breaker, switch, or other electrical element.

[15] See Final Recommendation to Standards Committee here: https://www.nerc.com/pa/Stand/Pages/Project-2015-03-Periodic-Review-of-System-Operating-Limit-Standards.aspx

standards and issues identified in Project 2015-03[16]. Additionally, FERC noted regional inconsistencies in Order No. 817[17]. Paragraph 27 of Order No. 817 reads as follows:

- "*It appears that regional discrepancies exist regarding the manner for calculating IROLs…*" and
- "*The specific regional difference of WECC's 1,000 MW threshold in IROLs should be evaluated in light of the Commission's directive in Order No. 802 (approving Reliability Standard CIP-014) to eliminate or clarify the 'widespread' qualifier on 'instability' as well as our statement in the Remand NOPR that "operators do not always foresee the consequences of exceeding such SOLs and thus cannot be sure of preventing harm to reliability.*'"

To address these inconsistencies, the Project 2015-09 SDT collected and reviewed information from Reliability Coordinators to better understand the methodologies for establishing IROLs. The SDT's findings confirmed the existence of these differences between Reliability Coordinators and identified that there was no single set of criteria on which all Reliability Coordinators aligned. Furthermore, each Reliability Coordinator explained their approach as necessary to accommodate their specific facts and circumstances.

The SDT was unable to reach consensus in their efforts on how to address IROLs in the FAC standard revisions, leading it to request support from the now defunct NERC PC and OC, which have been replaced by the Reliability and Security Technical Committee - RSTC[18], to form a team of industry subject matter experts to work through the IROL concerns. The team's goal was to develop technical material related to IROL methodologies while the SDT continued its work on addressing SOL-related matters. Specifically, the SDT requested technical expertise to assess the impact of instabilities on BPS reliability; simulate methods for assessment of instability, including appropriate methods for use in quantifying the instability's impact and available means for demonstrating impact containment; identify technically sound methodologies for use in establishing IROLs to address different types of instabilities; and evaluate the reliability impacts if any that resulting from the use of different methods to establish IROLs across North America. The SDT's strategy was to continue working on the FAC standards to address SOL-related requirements and to refrain from modifying the few IROL-related requirements until consensus could be achieved.

In response to the SDT's request, the NERC OC and PC jointly formed the MEITF[19] in 2017 to develop technical reference documents that focus on the types of power system instabilities, simulation methods for assessing instability, determining IROLs, and assessing the impact of instabilities on BPS reliability. The MEITF developed the *IROL Framework Assessment Report*[20] and the NERC *Reliability Guideline Methods for Establishing IROLs*[21] in conjunction with other MEITF activities to provide clarity to the IROL-related definitions and consistency on how those definitions are applied in the NERC standards.

The MEITF documents are technical references for industry as a set of recommended practices in the analysis of instability, uncontrolled separation, and Cascading and readers of this IROL Activity report should be familiar with the guidelines and technical specifics of the MEITF work products. These practices may also be used in the analytical process for calculating and establishing IROLs. The *IROL Framework Assessment Report* and the NERC *Reliability Guideline Methods for Establishing IROLs* were jointly approved by the NERC PC and OC in 2018. Like the Project 2015-09 SDT, the MEITF was unable to reach consensus on how IROLs should be addressed, leading to the two frameworks, "A" and "B," described in the MEITF *IROL Framework Assessment Report*. Because neither the SDT nor the MEITF

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[16] https://www.nerc.com/pa/Stand/Pages/Project-2015-09-Establish-and-Communicate-System-Operating-Limits.aspx
[17] https://www.nerc.com/FilingsOrders/us/FERCOrdersRules/Order%20No.%20817%20Approving%20TOP%20IRO%20Reliability%20Standards.pdf
[18] https://www.nerc.com/comm/RSTC/Pages/default.aspx
[19] https://www.nerc.com/comm/PC/Pages/Methods-for-Establishing-IROLs-(MEITF).aspx
[20] https://www.nerc.com/comm/PC/Methods%20for%20Establishing%20IROLs%20Joint%20Task%20Force%20ME/MEITF_IROL_Framework_Assessment_-_2018-08-21.pdf
[21] https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline_Methods_for_Establishing_IROLs.pdf

efforts led to consensus, the SDT did not address IROLs in its modifications of the FAC standards as reflected in NERC's petition to FERC in 2021.

Current State

As part of the filing for Project 2015-09, NERC included in its *June 2021 Petition for Approval of Proposed Reliability Standards Related to Establishing and Communicating SOLs* the needed next steps assess the current state of IROLs and the apparent discrepancies implemented by Reliability Coordinators in their development. Specifically, NERC stated the following on page 10 of the petition:

> "…*NERC will gather additional data through its compliance monitoring activities on: (1) whether and how Reliability Coordinators have revised their methods for establishing IROLs in response to the [MEITF] Reliability Guideline; and (2) whether the revised methods have resulted in a more consistent approach to establishing IROLs across the BPS. If NERC observes that significant regional discrepancies persist, and those discrepancies do not appear to be justified by the unique characteristics of the region, NERC would initiate a formal standards project to evaluate those issues. As NERC gathers data and conducts this evaluation, it will consult with FERC staff*."

Furthermore, FERC acknowledged the necessity of ongoing work in the letter order approving the June 2021 NERC Petition for Approval of Proposed Reliability Standards Related to Establishing and Communicating SOLs,[22] stating the following on page 2:

> "*Separately, NERC's petition addresses the statement in Order No. 817 that "it appears that regional discrepancies exist regarding the manner for calculating IROLs." NERC acknowledges that the directive in Order No. 817 remains outstanding. NERC explains that the standard drafting team originally intended to review the way IROLs are established to address the regional discrepancies discussed in Order No. 817. However, NERC subsequently determined that it would be beneficial to develop additional technical information on the establishment of IROLs prior to engaging in further standards development*."

In late 2021, to address these issues and the need for further technical information, the ERO Enterprise initiated a review of Reliability Coordinator approaches to analyzing and identifying IROLs. The review sought to determine discrepancies in IROL practices and establish a baseline understanding on whether—and, if so, how—the recommended practices outlined in the *Reliability Guideline Methods for Establishing IROLs* had been incorporated.

Joint Review Activity

Like prior assurance-based activities, such as the Restoration and Recovery Activity[23] and the Real-Time Assessment Activity[24], this review was structured to focus on information collected through discussions with applicable registered entities and their subject matter experts. The joint review team was comprised of staff from NERC, the Regional Entities, and FERC observers. The Team adopted a collaborative model to conduct the review as multiple subject matter experts were leveraged to provide the necessary planning, operations, and technology expertise. The review focused on understanding the practices of Reliability Coordinators relative to establishing IROLs and communicating IROL criteria information.

[22] https://elibrary.ferc.gov/eLibrary/filelist?accession_number=20220304-3004&ed=03%2F04%2F2022&sd=03%2F04%2F2022&iss_sub=issuance&lib=electric&docket=rd22-2

[23] https://www.ferc.gov/legal/staff-reports/2017/06-09-17-FERC-NERC-Report.pdf

[24] FERC and ERO Enterprise Joint Report on Real-time Assessments | Federal Energy Regulatory Commission

The goals of the Team were outlined in letters provided to each Reliability Coordinator and used to structure the discussions with the Reliability Coordinator subject matter experts. Reliability Coordinators were informed that the focus of the evaluation was not compliance related and it was not a Compliance Monitoring and Enforcement Program activity. During its review, the Team held discussions with the participants to gain information and insights into practices around identifying and mitigating IROLs. To facilitate a full and open discussion of each participant's approach, the Team agreed to avoid disclosing entity specific information that could be used to identify the participant. Accordingly, this report provides the results of the reviews without attribution to individual Reliability Coordinators.

The process used to perform this activity included seven steps:

1. Identify candidate Reliability Coordinators
2. Solicit Reliability Coordinator participation
3. Conduct kickoff calls and discussions
4. Ascertain Reliability Coordinator IROL practices
5. Develop conclusions
6. Develop report
7. Conduct industry outreach[25]

Sixteen of the seventeen solicited registered entities that perform Reliability Coordinator functions, as shown in **Figure 1**, agreed to participate in the activity. The Team and the participants engaged in virtual discussions that were conducted throughout 2022. Following the completion of initial discussions, the Team conducted follow-up discussions with several participants to clarify technical specifics and Team notes. Results from this activity have been analyzed and consolidated for this joint review report.

[25] To be conducted once industry has had time to review and digest the results of the activity.

Figure 1: NERC Reliability Coordinators as of July 2022

Joint Review Report

This report serves as an aggregation point for the Team's findings, providing a consolidated view of the diverse practices and methods. The Team compiled and analyzed information to identify common themes and trends in the analysis, establishment, and management of IROLs. This report highlights the data gathered, per NERCs commitment in its *June 2021 Petition for Approval of Proposed Reliability Standards Related to Establishing and Communicating SOLs*, and will provide details to indicate that Reliability Coordinators generally have not revised their methods for establishing IROLs in response to the MEITF Reliability Guideline; and (2) that any of the minor revisions that were made have not resulted in a more consistent approach to establishing IROLs across the BPS. Additionally, this report will provide a comprehensive overview of current practices and offer a series of recommendations that should result in enhanced industry-wide understanding. By comparing Reliability Coordinator practices this report will highlight the factors that influence the choices and strategies of Reliability Coordinators in their IROL-related operations. Finally, this report will provide recommendations and options for revising the Reliability Standards that will increase the likelihood of more consistent approaches to establishing IROLs across the BPS.

The intent of this report is not only to highlight these variations but to foster a better understanding among all stakeholders of the practical challenges and unique circumstances that shape these differences. By evaluating the effectiveness, efficiency, and overall impact of the various methods employed, Reliability Coordinators must implement practices that prioritize reliability and security while maintaining their own operational efficiency. In the subsequent sections of this report, the Team will bring awareness to these continuing discrepancies to provide data points that may be used in future IROL standards development projects. These findings can also serve as a basis for identifying and promoting beneficial practices. Identified beneficial practices can serve as a resource for Reliability Coordinators, providing actionable strategies and models that they can consider in refining IROL-related decisions. Importantly, these beneficial practices will also inform other technical experts, FERC, NERC, and the Regional Entities in their efforts to provide more specific guidance on establishing and managing IROLs, thereby aiding in the harmonization and effectiveness of IROLs.

This report does not delve into the technical depth and rigor found in the MEITF-produced *Reliability Guideline Methods for Establishing IROLs* and the *IROL Framework Assessment Report*. References to SOLs in this report include the subset of IROLs.

Chapter 1: Assessment

To understand Reliability Coordinators' various philosophies, approaches, and methodologies, staff from NERC, the Regional Entities (together, the Team), and FERC[26] engaged in virtual discussions with 16 of the 17 entities performing Reliability Coordinator functions on the BPS. The Team discussed six overarching topic areas with each participant. The six topic areas will be discussed individually in the following sections. Each topic area section includes subsections titled Introduction, Observations, Conclusions, Recommendations, and Beneficial Practices for Consideration. The topic areas include the following:

- Terminology
- Establishing IROLs
- IROL-Like Conditions
- Tools and Practices
- Communication and Coordination
- Reliability Standards

During the discussions, participants openly shared their philosophies, practices, and approaches to establishing and mitigating IROLs. The Team found that all participants have widely varying philosophies, strategies, and approaches to IROLs with varying levels of detail in IROL methodologies. Additionally, the Team identified varying degrees of awareness and implementation of the MEITF Guidelines recommended practices. The Team notes that, due to the varying terminology, definitions, interpretations, tools, practices, and depth of analysis used by each Reliability Coordinator that one-to-one Reliability Coordinator comparisons cannot be performed. Additionally, these disparities often cause neighboring Reliability Coordinators to not view the same conditions in the same manner, meaning that a condition may be considered serious by one Reliability Coordinator but not by its neighboring Reliability Coordinators.

The IROL Activity sought to determine a baseline understanding on whether the recommended practices outlined in the MEITF *Reliability Guideline Methods for Establishing IROLs* have been incorporated and to understand gaps, if any, between SOL and IROL definitions and methodologies. Prior to delving into the details of the participants' IROL practices, discussions were conducted around the participants' awareness of the MEITF Guideline. The Team identified a wide range of awareness and understanding of the Guideline, ranging from five Reliability Coordinators having representation on the MEITF to one Reliability Coordinator having no awareness until asked to participate in this activity. Thirteen of the 16 participating Reliability Coordinators indicated they are familiar with the MEITF Guideline but have not specifically implemented any of its recommendations or practices into their IROL processes. Three of the 13 Reliability Coordinators who are familiar with the Guideline state they reviewed the MEITF document and determined that their processes already reflect the content in the Guideline. Two Reliability Coordinators indicated that they have specifically implemented concepts from the Guideline into their processes, which resulted in one Reliability Coordinator increasing its number of IROLs in its footprint from three to five. Reliability Coordinator awareness and implementation is summarized in participants comments regarding the Guideline include:

- It is highly technical, and the reader will not learn much if they do not have a stability background.
- It is a good baseline but lacks specific detail for implementing recommended practices.
- It is complex and challenging to implement the recommended practices.

[26] FERC staff observed the activity for United States-based Reliability Coordinators only and did not observe the activity with Canada-based Reliability Coordinators.

- It does not recommend a minimum set of practices to consider.
- It does not help entities translate the technical work into a “number” for an actual IROL.
- It does not provide a correlation between IROLs and Flowgates.
- It lacks specific guidance, which could result in confusion on how to implement recommended practices.

Key takeaways from this activity indicate that the majority of Reliability Coordinators did not adopt the principles or implement the techniques described in the MEITF Guideline and that there are still significant discrepancies between Reliability Coordinators in their approaches to, and methods for, establishing IROLs.

Table 1:Awareness, Familiarity, and Implementation of MEITF Guideline				
	Little to No Awareness	**Familiar - No Implementation**	**Reviewed - Some Implementation**	**Reviewed - Full Implementation**
Reliability Coordinators	1	13	2	0

Terminology

Introduction

Terminology helps us understand specific topics. Clear and standardized terminology is essential to ensuring mutual understanding between all parties. Well-defined terminology minimizes ambiguity and enhances clarity, whereas inadequate or undefined terms create confusion. Many of the participants have different understandings and applications of the same terms. Variations in interpretation and use of terms often leads to ineffective communication between neighboring entities.

Observations

The Team observed that participants generally use the same IROL- related terminology. However, the understanding and application of the same terms varied widely among the participants. The lack of a common understanding of IROL- related terminology is a major contributor to the lack of consistency in the establishment and application of IROLs. Most participants expressed a desire for clear definitions for, and consistent use of, IROL-related terminology. Several examples of how key terms are defined and applied among the participants are discussed here.

IROL

IROL is defined in the NERC Glossary of Terms as “*A System Operating Limit that, if violated, could lead to instability, uncontrolled separation, or Cascading outages that adversely impact the reliability of the Bulk Electric System*.” However, the understanding and application of IROL varies widely among the participants. The following conditions are examples of what some participants consider an IROL:

- Only if exceeding a limit would result in wide-spread impact,
- Only during conditions when System Operators will not have time to respond post- Contingent,
- Only if an event puts system Frequency control at risk,
- Only for loading on extra-high voltage (EHV) Facilities,
- Only if an event constrains ties to a neighboring Reliability Coordinator(s),
- Only if generation cannot be reduced pre-Contingent,
- Only if it is a non-thermal limit,
- Only if the impact extends beyond the Reliability Coordinator’s footprint,

- Only if the impact cannot be contained within a single Transmission Operator (TOP) area.

IROL vs. IROL Exceedance

Participants view IROL and IROL exceedance[27] differently and are confused around these terms. Some participants view IROLs as a limit, while some view IROLs as a condition. Some participants view IROL exceedances as a reliability risk, while others view them as a compliance risk. Some participants act immediately upon an IROL exceedance, or to avoid an IROL exceedance, while others do not. One participant posed the philosophical question that if an entity is in an IROL exceedance, should the entity shed customer load pre-Contingent in the dead of winter to respect a T_v of 30 minutes when they know that they have taken actions that will resolve the IROL exceedance in 40 minutes. The risk associated with these varying viewpoints is that neighboring Reliability Coordinators may not plan for, operate to, and respect IROLs and IROL exceedances in the same manner and with the same sense of urgency. This could result in one Reliability Coordinator taking actions to prevent or mitigate an exceedance while a neighboring Reliability Coordinator could take actions that could exacerbate an exceedance.

Widespread vs. Local Impact

Cascading is defined as, "*The uncontrolled successive loss of System Elements triggered by an incident at any location. Cascading results in widespread electric service interruption that cannot be restrained from sequentially spreading beyond an area predetermined by studies*." Two elements of this definition cause the most confusion; the term "widespread" and the phrase "determined by studies".

Most participants expressed varying understandings and definitions of widespread vs. local impact, as well as a strong desire for the ERO to establish distinguishing characteristics, thresholds, and criteria for both terms. Some participants designate local impact as smaller load pockets within their Reliability Coordinator footprint, while other participants designate local impact as their Reliability Coordinator footprint. Conversely, some participants designate wide-area impact as affecting their Reliability Coordinator footprint, while other participants designate wide-area impact as impacting neighboring Reliability Coordinators. Additionally, some participants consider an incident widespread if it impacts multiple TOPs within their Reliability Coordinator footprint. Six Reliability Coordinators specifically mentioned widespread vs. local impact as a determining factor on whether an SOL is an IROL. One Reliability Coordinator uses the terms "widespread" and "local" in its definitions of IROL but does not define metrics around what those terms mean. The risk associated with these varying interpretations is that neighboring Reliability Coordinators may not establish IROLs, and operate to IROL exceedances, using the same criteria. What may be considered important for BPS reliability and security to one Reliability Coordinator may not be important to a neighboring Reliability Coordinator. This could result in one Reliability Coordinator planning for, and operating to, respect their established IROLs while a neighboring Reliability Coordinator may not plan for, or operate to, respect their neighboring Reliability Coordinators established IROLs, and could potentially take actions that contribute to an IROL exceedance.

The second point of confusion is the phrase "determined by studies". The issue Reliability Coordinators face is a question of "how far is too far?" A study can demonstrate that Cascading or instability stops at a certain point and does not propagate beyond a certain area; however, that known extent of impact can be very small or very large. For example, a study can demonstrate that a particular Cascading risk is "determined by studies" to be confined to the subsequent loss of two Facilities and 10MW of load loss. A different study can demonstrate that a particular Cascading risk is "determined by studies" to be confined to the loss of six Facilities and 3000 MW of load loss. In both cases, the "service interruption…[is] restrained from sequentially spreading beyond an area predetermined by studies[28];" however, the reliability impact is dramatically different. There is no guidance available to instruct the Reliability Coordinators on an unacceptable level of reliability impact when determining the need for establishing an IROL. This

[27] https://www.merriam-webster.com/dictionary/exceedance
[28] From NERC Glossary of Terms definition of Cascading.

is why some Reliability Coordinators adopted a load loss threshold to serve as a metric for reliability impact during IROL establishment.

New Terminology

The Team notes that several participants use terminology that is new, or previously unknown, to the Team. This terminology appears to be used in lieu of identifying an IROL and includes the following:

- Temporary IROL
- Potential IROL
- Serious SOL
- SOL Plus
- Transmission System Emergency (TSE)
- General Transmission Limit (GTL)

An example of how some of these terms are applied is "SOL Plus", which addresses "local" instability, Cascading, or load loss. This participant treats an SOL Plus like an IROL, but it is not an IROL. System Operators may shed a significant amount of load when exceeding SOL Plus limits, but there is no formal load-loss threshold or cut-off point.

Conclusions

The Team concludes that numerous IROL-related terms are applied interchangeably between the participants and that the same terms often have different meanings. Several definitions in the *NERC Glossary of Terms* contain words, such as "widespread," that are not defined within the Glossary and therefore create additional confusion. The inconsistent use and understanding of IROL-related terminology resulted in impactful differences between the Reliability Coordinators in the establishment of IROLs. There is a need for clearly defined terms with specific meanings, including definitions for ambiguous or subjective terms used within other definitions. The Team found that several participants created new, or previously unheard of, terminology and believes participants may use these terms in lieu of "IROL" to avoid having to assume the compliance burden of additional IROL-related Reliability Standards.

Recommendations

Recommendation 1

The NERC Standards Department and/or technical standing committees, such as the Reliability and Security Technical Committee (RSTC), should perform a comprehensive review of all SOL and IROL-related terminology and definitions, including those in the *NERC Glossary of Terms*, the *MEITF Reliability Guideline*, the *MEITF IROL Framework Assessment Report*, and current and future enforceable IROL-related Reliability Standards. The purpose of this comprehensive review is to ensure that registered entities have the same understanding, meaning, and application of each term. This can be accomplished by providing clarity on, and removing ambiguity from, all IROL-related terminology and definitions. Resulting proposals for recommended terminology revisions should include clear and unambiguous definitions, as well as thresholds, criteria, percentages, margins, buffers, etc. as applicable. Additionally, when subjective words are used within proposed definitions, those subjective words should also be defined to prevent potential confusion.

Terms requiring clear definitions with criteria or thresholds as applicable, include, but are not limited to:

- Adverse Reliability Impact (Defined) vs. Adverse
- Cascading – Depth of study criteria

- IROL Exceedance – Ambiguity during IROL-like condition[29]
- Unsecure Operating State
- Instability
- IROL-Like Condition
- Local [Impact/Instability]
- Margin
- Threshold
- Uncontrolled Separation – Undefined
    - Widespread [Impact/Instability] – Undefined and used in many *NERC Glossary of Terms* definitions
- Stability vs. Local Stability vs. System Stability
- Acceptable Level of Reliability (for risk-based analysis)
- Acceptable Load Loss (for risk-based analysis)

Beneficial Practices for Consideration

The Team did not observe any beneficial practices for consideration regarding terminology.

[29] Reference Finding 18 in the *Arizona-Southern California Outages Report*.

Establishing IROLs

Introduction

IROLs are a subset of SOLs and are limits and are established to prevent system instability, uncontrolled separation, and Cascading outages. Reliable operation of the BPS may be compromised if the limit is exceeded. These limits are used for Real-time operation but are generally established prior to Real-time operations using off-line studies. IROLs are established by Planning Coordinators (PC) and Reliability Coordinators; the IROL Activity findings are based on discussions with Reliability Coordinators and not Transmission Planners (TP) or Planning Coordinators[30]. IROLs are used as "operating limits" in the operations horizon to coordinate planned outages with Real-time operations and associated Operating Plans. Although IROLs are generally established prior to Real-time operations, there is no requirement to establish IROLs in the planning horizon. System instability, Cascading, or uncontrolled separation are outcomes of a Contingency and/or operating condition, not IROLs themselves.

Observations

The Team notes large variances among the Reliability Coordinators regarding criteria, philosophies, methodologies, and number of established IROLs. The NERC Reliability Standards[31] allow Reliability Coordinators to exercise some degree of judgment and offer an appropriate amount of flexibility regarding establishing IROLs for their Reliability Coordinator Area. Several key topics contributing to these variances are discussed here. The Team notes that established IROLs fall into several categories, including thermal, voltage, transient stability, frequency stability, and voltage stability. Many IROLs were historically established in the long-term transmission planning horizon, but some Reliability Coordinators establish IROLs in the operations planning time horizon. When IROLs are established in the operations planning time horizon, it is typically done during the outage coordination process.

Established IROLs

To contextualize the following discussions, it may be valuable to highlight the numbers of, and the basis for, the established IROLs. The Team notes that approximately 99 total IROLs have been established by the 16 participating Reliability Coordinators. The number of established IROLs varies widely among the Reliability Coordinators, with a range of 0 to 44 as indicated in **Table 2**:

Table 2: Number of Established IROLs

Established IROLs	Reliability Coordinators with Established IROLs
0	5
1	3
2	1
3	1
5	2
9	1
13	1
15	1
44	1

[30] Prior to April 1, 2024, Effective Date of FAC-011-4, FAC-014-3, IRO-008-3, and TOP-001-6.
[31] FAC-011-3, FAC-014-2

Additionally, the basis for the established IROLs varies widely, as indicated in **Table 3**. The count is not all-inclusive, and one IROL can be included in more than one category:

Table 3: IROL Basis	
Basis for IROLs	**Established IROLs**
Thermal	46 of 99
Transmission[32]	28 of 99
Generation[33]	18 of 99
Stability	27 of 99
Voltage	15 of 99
Cascading	1 of 99
Outage Condition	7 of 99

Establishing IROLs/IROL Methodologies/IROL Philosophies

The Team notes large variances among the Reliability Coordinators regarding methodologies, criteria, and philosophies for establishing IROLs. Each Reliability Coordinator has methodologies in place for establishing IROLs; however, two Reliability Coordinators indicate they are in the process of drafting new methodology documents to align with the new *Facilities Design, Connections, and Maintenance* (FAC) standards. Some Reliability Coordinators maintain their methodologies in one document, while others disperse theirs across several documents. Included in the methodologies are multiple variations on how Reliability Coordinators approach IROL study assumptions, Contingency selection, depth of analysis, margins, thresholds, and other practices. These topics are discussed here at a high level to highlight similarities and differences in approach.

The Team notes that each Reliability Coordinator with no established IROLs have the same criterion that requires a limit to impact external entities (Transmission Operators or Reliability Coordinators) before it can be considered an IROL. One Reliability Coordinator with no established IROLs mainly has Stability Limits but relies heavily on Remedial Action Schemes (RAS) and infrastructure investments, identified in the planning realm, as methods for mitigating the need to establish IROLs. Due to this reliance on RAS, this Reliability Coordinator states that it carefully monitors and controls power transfers and is extremely conservative during the outage coordination process to ensure that the overall RAS scheme remains viable. This Reliability Coordinator also states that the noted Stability Limits affect the market more than system reliability and that approaching these limits is rare and is protected by undervoltage load shedding. Another Reliability Coordinator with no established IROLs, and the criterion that external Reliability Coordinators must be impacted for a limit to be considered an IROL, also considers that large areas of instability internal to its footprint do not warrant the establishment of an IROL. The Team notes that this is a very different concept of an IROL compared to other Reliability Coordinators. Another Reliability Coordinator with no established IROLs has documented threshold criteria that is based on "industry research" and states it did not perform specific studies to validate those thresholds.

The Team notes that several Reliability Coordinators with established IROLs also have the same "must impact external entities" criterion as other Reliability Coordinators with no established IROLs. The Team notes one Reliability

[32] Loss of Transmission Element(s).

[33] Loss of Generation.

Coordinator with established IROLs considers all Stability Limits to be IROLs and this is the only Reliability Coordinator using this approach. Most Reliability Coordinators consider generator Stability Limits to be SOLs rather than IROLs. The stated justification is that, while these Stability Limits prevent a generator (or collection of generators) from tripping off-line due to transient instability in response to a Contingency event, they do not result in adverse reliability impacts such as system instability, Cascading, or uncontrolled separation; the unit simply trips off-line. Conversely, there is another Reliability Coordinator with established IROLs that considers only voltage stability limits to be IROLs and all thermal limits to be SOLs. Only one Reliability Coordinator establishes IROLs in the operations planning time horizon. One Reliability Coordinator develops a Flowgate for every identified IROL, but not every Flowgate is an IROL. Two Reliability Coordinators reinforce their systems when IROLs are identified in the planning horizon.

Triggers

The Team notes that each Reliability Coordinator uses different triggers for when an IROL should be established, reviewed, or retired. There are differing philosophies around retiring IROLs. For example, some Reliability Coordinators have no IROL review process, others have periodic IROL review processes, and one Reliability Coordinator has created a Transmission Planner task force to develop criteria for identifying IROL-related issues. One Reliability Coordinator tracks system projects to include in its regular summer and winter studies to evaluate if IROLs can be retired; this has resulted in the retirement of two IROLs. Two other Reliability Coordinators note changes in topology, new generation, system behavior, and neighboring system conditions as triggers for a potential review of IROLs; most of these triggers are identified in the operations planning horizon.

Margins

Operating up to an IROL may not provide the System Operator with enough time to take corrective action to mitigate an exceedance. Therefore, an IROL margin may be applied to provide this capability. IROL margins are used to keep the system from being operated too closely to the predetermined IROL. Margins are a conservative approach to account for uncertainties and differences between studied conditions and the actual conditions experienced in real time. Some entities treat the margin as the operating IROL, and System Operators are expected to act within T_v to get below that limit.

The Team notes variances among the Reliability Coordinators regarding the use of IROL margins. Some Reliability Coordinators include margins in IROLs, while others do not. Participants that include margins use different approaches to establishing margins. Some establish margins based on a percentage of the limit, while some establish margins based on a load-shed amount. Several Reliability Coordinators state they build in additional margin to ensure the actual IROL is never approached. Most Reliability Coordinators that include additional margin in their IROLs state that they will respect the additional margin, and not reduce it, to avoid pre-Contingency load shed.

Depth of Analysis and Contingency Event Selection

IROLs are established by Reliability Coordinators performing studies that simulate system conditions, including various credible Contingency events. The results of these studies indicate system conditions if the modeled Contingencies occur, including loss of generation, consequential loss of load, Facility overloads, tripping, and other adverse conditions. The NERC Transmission Planning standards provide categories of Contingencies and performance requirements in the Long-Term Transmission Planning Horizon to ensure the BPS will operate reliably over a wide range of system conditions under a wide range of Contingencies.

A predefined Contingency occurring with the next worst Contingency could result in instability, Cascading, or uncontrolled separation. Mitigation steps should be developed, including the possibility of shedding load, if necessary, to ensure the system is maintained in a secure operating state if a critical Contingency were to occur.

Contingency event selection is one factor that impacts the depth of analysis being performed by the Reliability Coordinators. The Team notes a wide range of Contingency events are being analyzed and therefore results in varying depths of study. As an example, if one Reliability Coordinator establishes IROLs based on N-1[34] studies and its neighboring Reliability Coordinator establishes IROLs based on N-2[35] studies, it can be stated that the N-2 study is deeper than the N-1 study, rendering significant differences in the number of IROLs established. Additionally, if a Reliability Coordinator limits its Cascading studies to a specific number of Contingencies or criterion and its neighboring Reliability Coordinator studies a greater number of Contingencies or a more stringent criterion, it is very likely that these neighboring Reliability Coordinator will have differing results, even if they were to use the same model and include the same initial Contingency events. These differing results could lead to disagreements and vastly differing operational actions between neighboring Reliability Coordinators.

All Reliability Coordinators state they study the Contingency events in the Long-Term Transmission Planning Horizon as required by the TPL standards. However, the Team notes the following variations of studies in the operations planning horizon:

- One Reliability Coordinator studies from N-1-1 to N-5 or more if needed in the operations planning horizon.
- One Reliability Coordinator studies N-1 in the operations planning horizon and rarely studies N-2.
- One Reliability Coordinator studies N-X until its 1,000 MW load-loss threshold is met; if load loss is >1,000 MW, it is considered an IROL.
- One Reliability Coordinator follows the 2,000 MW MEITF Guideline threshold.
- Three Reliability Coordinators study to N-1-1.
- Several Reliability Coordinators study for loss of natural gas facilities, double circuit towers (DCT), and stuck breaker Contingencies.
- Two Reliability Coordinators include sub-100 kV Facilities.
- Several Reliability Coordinator study external Contingency events to determine the impact on their system.

Instability

While "instability” is not defined in the *NERC Glossary of Terms*, it can be inferred from “Stability,” which is defined as the ability of an electric system to maintain a state of equilibrium during normal and abnormal conditions or disturbances. “Stability Limit” is defined as “*The maximum power flow possible through some particular point in the system while maintaining stability in the entire system or the part of the system to which the stability limit refers*”. System stability is mainly dependent on how synchronous machines, such as generators, react after system disturbances.

The Team notes that all participating Reliability Coordinators consider system stability to identify and establish IROLs. However, a good number of Reliability Coordinators express the viewpoint that not all stability issues warrant the establishment of an IROL. Several Reliability Coordinators express a belief that there is a regulatory preference that IROLs be established to prevent any kind of instability, irrespective of severity of impact, and that Interconnection reliability and local reliability should be treated the same (i.e., any form of instability warrants IROL establishment). However, most Reliability Coordinators believe that local instability, uncontrolled separation, or Cascading that is proved to be contained to a relatively small area should not necessarily warrant the establishment of an IROL. Additionally, most Reliability Coordinators do not support IROL-related Reliability Standards that impact local jurisdictions and would like to keep the focus on “what’s really important.” As an example, one Reliability Coordinator states that it is not good operating practice to shed 50 MW of load pre-Contingent to prevent a Contingency from

[34] The current normal (N) system condition plus the unexpected failure or outage of one (-1) system component, such as a generator, transmission line, circuit breaker, switch, or other electrical element.

[35] The current normal (N) system condition plus the unexpected failure or outage of two (-2) system components, such as generators, transmission lines, circuit breakers, switches, or other electrical elements.

resulting in the loss of 100 MW of localized load due to instability, when technical analyses clearly demonstrate the instability remains localized and does not impact the remainder of the transmission system.

However, the Team notes the following unique or uncommon practices regarding stability studies:

- One Reliability Coordinator studies for both single and multiple unit instability.
- One Reliability Coordinator conducts stability analysis using a planning model with all Facilities in service but does not conduct stability analysis for outage conditions within the operations horizon.
- One Reliability Coordinator studies both voltage and frequency criteria.
- One Reliability Coordinator studies thermal, voltage stability, and angular stability.
- One Reliability Coordinator assesses neighboring Reliability Coordinator angular stability and large voltage declines.

Uncontrolled Separation

Uncontrolled separation is the unintended islanding of a portion of a power system that includes load or generation. Uncontrolled separation occurs when protection or control systems operate because of a system condition or Contingency event. The Team notes that the topic of uncontrolled separation was the least discussed topic among "instability, uncontrolled separation, or Cascading outages." Uncontrolled separation appears to be a concern for only one Reliability Coordinator, that only assesses voltage stability on a case-by-case basis when a voltage issue is brought to its attention. The primary concern for this Reliability Coordinator is the potential of thermal Cascading that could result in uncontrolled separation due to loss of imports. One Reliability Coordinator reported having no uncontrolled separation issues due to the very high voltage background of its system.

Cascading

Cascading is defined as "*The uncontrolled successive loss of System Elements triggered by an incident at any location. Cascading results in widespread electric service interruption that cannot be restrained from sequentially spreading beyond an area predetermined by studies*." A concept that is integral to determining Cascading and its impact on the system is whether the uncontrolled successive loss of system elements ceases or progresses to an unknown operating state, known as unbounded Cascading. Reliability Coordinators will determine which Cascading events are acceptable or whether an IROL should be established; this acceptance criterion is generally included in the Reliability Coordinators methodology documentation.

The Team notes that the limits, methodologies, and criteria used in Cascading analysis vary widely among participating Reliability Coordinators. Most limits have specified criteria associated with them. For example, one Reliability Coordinator requires Cascading studies to simply go four Contingencies deep, while another Reliability Coordinator requires Cascading studies to be four Contingencies deep, with >500 MW of load loss and 140% of the emergency rating exceeded to be considered an IROL. Another Reliability Coordinator performs Cascading studies until 125% of emergency ratings are exceeded and there is >1,000 MW of load or generation loss before it is considered an IROL.

The following summarizes noted disparities between Reliability Coordinator Cascading analysis:

- Thermal limits as assumed tripping points:
  - 100% of 15-minute emergency ratings
  - 110% of operational ratings
  - 115% of emergency ratings
  - 115% of load-dump rating

    - 120% of emergency ratings
    - 125% of 30-minute emergency ratings
    - 125% of 2-hour emergency ratings
    - 130% of operational ratings
    - 140% of emergency ratings
    - Loading that approaches relay loadability limits
    - 100% of conservative relay loadability limits
    - Actual generator protection and transmission protection settings
- Voltage limits as assumed tripping points and simulated system behavior:
    - Voltage not considered at all
    - Voltage tripping only if necessary to get study to solve
    - Simulated generation tripping for low voltage
    - Simulated load tripping for low voltage
    - Simulated transmission tripping for low voltage
- Criteria to constitute a Cascade with unacceptable performance:
    - No criteria for pass-fail except "engineering judgment"
    - No criteria for loss of load
    - 300 MW of load at risk
    - Cascading outage of 4 or more lines
    - Cascading outage of 5 or more lines
    - Any overload of a BPS transformer

Thresholds

Facility Rating overload thresholds and load-loss thresholds are often used by Reliability Coordinators during Cascading and stability analysis. Thresholds are a method of tracking a value, such as load or generation loss, that some Reliability Coordinators use as a proxy for determining the severity and extent of impact. As Cascading outages occur the loading on elements remaining in service increases, sometimes reaching, and exceeding their Facility Ratings, including their highest emergency rating. Some Reliability Coordinators track the cumulative load tripped from the Cascading and compare it against a predetermined load-loss threshold as a factor in establishing IROLs. Typically, if the cumulative load lost exceeds the threshold, it is considered unacceptable Cascading and an IROL should be established.

The Team notes that all participating Reliability Coordinators have a methodology for preventing smaller multi-Element outages from being classified as an IROL. Some do so with their interpretation and application of the definition of an IROL, some use load- or generation-loss thresholds, and others do both. Approximately half of the participating Reliability Coordinators use load-loss thresholds for IROL establishment—some in the planning horizon, some in the operations planning horizon, and some in both horizons. The Reliability Coordinators using thresholds determine the unacceptable amount of load loss due to instability, Cascading outages, or uncontrolled separation and apply that as a threshold for establishing IROLs. One Reliability Coordinator states that it recently increased its load-loss threshold from a percentage of system load to 2,000 MW, per the *MEITF Framework* document, resulting in the establishment of three additional IROLs. Two Reliability Coordinators that do not have established load thresholds state that they are in the initial stages of potentially developing them. One of those two Reliability Coordinators currently uses engineering judgment to establish load-loss thresholds and considers load-loss location when using thresholds (e.g., urban vs rural).

The load-loss thresholds in use vary between Reliability Coordinators and include:

- 1,000 MW of load at risk of loss post-Contingency
- 1,200 MW of load at risk of loss post-Contingency
- 1,300 MW of load at risk of loss post-Contingency
- 2,000 MW of load at risk of loss post-Contingency
- 2,400 MW of load at risk of loss post-Contingency
- 2,000 MW of generation loss post-Contingency
- 2,400 MW of generation loss post-Contingency

Most Reliability Coordinators who perform Cascading analysis use triggering thresholds that vary considerably from Reliability Coordinator to Reliability Coordinator and include the following:

- The highest thermal rating
- The short-term emergency rating
- A percentage of the various emergency ratings (e.g., 115%, 125%, 140%)
- A percentage of the Facility Rating when emergency ratings are not used (e.g., 130%)

Conclusions

The Team concludes that there is a wide spectrum of variance among Reliability Coordinators regarding the criteria, thresholds, methodologies, philosophies, and number of established IROLs. The Team attributes this to the Reliability Coordinators exercising engineering judgment based on the non-specificity of NERC Standards, and related terminology, regarding the establishment of IROLs. The Team also concludes that the non-prescriptive and vague nature of the Reliability Standards leads to a lack of understanding and confusion around the application of establishing IROLs. These variances inherently lead to increased risk to the BPS due to the differing criteria for establishing, and priority operating to, IROLs. As an example, one Reliability Coordinator may consider an IROL, or Contingency, a risk to the system and will operate more conservatively, while another Reliability Coordinator may not consider it a risk to the system and does not operate as conservatively. Additionally, it is apparent to the Team that industry is seeking more guidance, direction, and clarification from their regulators, including defining and establishing specific criteria around all elements required to establish IROLs. This was discussed in the previous section on terminology and will be discussed in more detail in the ensuing section on Reliability Standards.

Recommendations

Recommendation 2

Reliability Coordinators should include or consolidate all IROL methodology documents in a single SOL methodology document or binder to ensure that they are easily referenced, compared, and updated.

Recommendation 3

Reliability Coordinators should establish a minimum set of Contingency events to be studied for establishing IROLs, including testing for Cascading, uncontrolled separation, and instability, to ensure consistency in internal Reliability Coordinator IROL studies.

Recommendation 4

Reliability Coordinators should document their IROL establishment criteria, testing procedures, and minimum set of Contingencies for Cascading, uncontrolled separation, and instability analysis and share this documentation with neighboring Reliability Coordinators to aid in a better understanding of how each neighboring Reliability Coordinator establishes IROLs.

Beneficial Practices for Consideration

Beneficial Practice 1

Reliability Coordinators should consider a periodic review of their IROL methodology, including a process to receive comments from their TOPs, neighboring Reliability Coordinators, and industry, to allow for more transparency.

Beneficial Practice 2

Reliability Coordinators should consider including the loss of natural gas facilities in studied Contingency events to understand the impact to their system, especially during extreme weather events.

Beneficial Practice 3

Reliability Coordinators should consider requiring all personnel who are involved in establishing IROLs to review the *Reliability Guideline Methods for Establishing IROLs* and the *IROL Framework Assessment Report – NERC Methods for Establishing IROLs Task Force (MEITF)* documents as well as the related MEITF webinar.[36]

Beneficial Practice 4

Reliability Coordinators should consider periodically examining and adjusting their load-loss thresholds to determine if unidentified IROLs exist that are slightly outside the purview of current studies at designated thresholds.

Beneficial Practice 5

Reliability Coordinators should consider incorporating sub-100 kV Facilities and Contingencies in models, where warranted, to better understand the impact on their system and neighboring Reliability Coordinators’ systems.

[36] https://nerc.webex.com/cmp3300/webcomponents/widget/playback.do?siteurl=nerc&recordID=79153287&isnbr=true&ticket=4832534b0000000740f9a7c9fd2f5a8a6e9e598423e7ae9176c7d0fc6c70518f48d44146d8e506fa&timestamp=1717679058516&serviceRecordID=79153292&nbrhomepageurl=

IROL-Like Conditions

Introduction

The BPS should be operated within established limits to ensure reliable operations. Before Real-time operations, an Operations Planning Analysis (OPA) is performed to assess anticipated (pre-Contingency) and potential (post-Contingency) conditions for next-day operations. OPAs reflect expected load forecasts; generation output levels; interchange; known protection system and RAS status or degradation, functions, and limitations; transmission outages; and generator outages. Despite the use of OPAs, unforeseen conditions are possible due to unexpected outages stemming from issues such as weather (including storms), equipment failure, and human error. During these unexpected conditions, System Operators may encounter a phenomenon that can be referred to as "IROL-like conditions," which are unanticipated conditions where the next Contingency could result in significant adverse reliability impact. For example, consider a fictional scenario in which a Reliability Coordinator's Real-Time Assessment indicates that all Facilities are within limits, the Real-Time Contingency Analysis (RTCA) tool indicates no unsolved Contingencies, and no Contingencies would result in an exceedance of emergency ratings. At that time, unanticipated adverse weather results in the loss of five BPS Transmission elements. The following RTCA results show several new unsolved Contingencies in the area and many post-Contingency exceedances of more than 140% of emergency ratings; this can be considered an IROL-like condition. Reliability Coordinators consistently state that when unforeseen operating conditions, such as the example above, present themselves that their System Operators' primary focus is on returning the system to a reliable operating state and not on establishing an IROL in real time.

Observations

The Team observed that many of the participating Reliability Coordinators have encountered IROL-like conditions, while others claimed to have not, while one Reliability Coordinator was unfamiliar with the concept. Several Reliability Coordinators have formal processes in place that System Operators can reference when IROL-like conditions are encountered in real time, while others do not. There are no Reliability Coordinators that establish IROLs in real time, and some Reliability Coordinators have different terms for a IROL like-conditions. One Reliability Coordinator states that it trains System Operators heavily on IROLs and actions to be taken during IROL-like conditions, while another Reliability Coordinator states that most of its System Operators only perform N-1 studies and would be unable to perform the Cascading studies needed to determine the impact of an IROL-like condition.

Operational Actions

The Team notes that, when IROL-like conditions are encountered, many of the Reliability Coordinators initiate operational actions in a similar manner by treating the condition as if it were an established IROL. Some Reliability Coordinators have different terms for the same condition, such as insecure operating state and SOL Plus. The Reliability Coordinators primary goal during IROL-like conditions is to perform a study to assess the situation and return the system to a reliable operating state. Reliability Coordinators state that they would adhere to the 30-minute T_v but with some timing differences between them.

One Reliability Coordinator with established IROLs uses a formal load-relief procedure to stay within SOLs and IROLs. Another Reliability Coordinator with established IROLs states that any Real-time Contingency resulting in an exceedance of 125% of an emergency rating is called a "temporary IROL" until the System Operators can complete a study within 15 minutes to assess whether the Contingency will result in instability, uncontrolled separation, or Cascading outages. If the study results in Cascading for the next N-1 Contingency, a temporary IROL is called. If the study cannot be completed in 15 minutes, an emergency is declared, and the incident is treated like an IROL exceedance and actions taken to mitigate the condition up to and including pre-Contingent load shed. This Reliability Coordinator counts the 15 minutes allotted for study time toward the 30-minute T_v. If the study indicates no risk of instability, uncontrolled separation, or Cascading outages, then the condition is treated as an SOL exceedance. Conversely, another Reliability Coordinator with no established IROLs calls IROL-like conditions an "insecure operating state" and requires its System Operators to complete studies to assess whether the Contingency will result in instability, uncontrolled separation, or Cascading outages. However, this Reliability Coordinator will not perform pre-Contingent load shedding for an insecure operating state and does not start the 30-minute T_v timer until studies are completed that verify the Reliability Coordinator is in an insecure operating state. Another Reliability Coordinator without established IROLs would take the same actions for an IROL-like condition as it would for an SOL exceedance by specifically treating the condition like an IROL and respecting an inferred 30-minute T_v, up to and including pre- and post-Contingency load shedding to prevent equipment damage. This same Reliability Coordinator would also initiate pre-Contingency load shedding if there was not enough time for the System Operator to mitigate the exceedance. One Reliability Coordinator refers to IROL-like conditions as an SOL+ and may, or may not, shed load pre-Contingent during an SOL+ condition based on circumstances. This Reliability Coordinator presented a rhetorical question, that applies to both established IROLs and IROL-like conditions, around why a Reliability Coordinator should shed load in the dead of winter or summer to respect T_v of 30 minutes when it has taken actions that will resolve the exceedance in 35 minutes. As an example, at time T=0, the Reliability Coordinator exceeds a limit (IROL, SOL+, etc.) and the Reliability Coordinator implements its operating plan to mitigate the exceedance. The plan takes effect and mitigation activities begin (such as generation starting to move), and the situation is improving. At T=25, the generation is not moving fast enough to get below the exceedance by T=30; however, it is expected that the exceedance will be mitigated by T=35. Assuming there would be compliance implications; the Reliability Coordinator would need to shed load to respect T_v of 30 minutes. However, such an action could be considered detrimental to customers during extreme cold or heat conditions given the fact that the reliability risk would be averted in five more minutes.

Post-Condition Actions

There are varying degrees of post IROL-like condition actions that would be taken. Several Reliability Coordinators state they would perform after-the-fact analysis, such as determining the cause of the condition, evaluating operator actions during the condition, and identifying whether an IROL should be established for that condition going forward. However, some Reliability Coordinators also state they may, or may not, perform after-the-fact analysis, depending upon the conditions encountered. One Reliability Coordinator identified its criteria for performing after-the-fact analysis as a load loss of 1,000 MW or more. This Reliability Coordinator states they maintain a System Operator scorecard metric, that measures response rates to SOL exceedances. The scorecard scores exceedances based on exceedance return time, thereby encouraging System Operators to clear exceedances within 30 minutes. Finally, several Reliability Coordinators state they proactively self-report IROL-like condition exceedances lasting longer than 30 minutes for compliance purposes. Conversely, some Reliability Coordinator do not self-report these types of exceedances for compliance purposes.

Potentially Conflicting Messages

There are two Reliability Coordinators that view IROLs as conditions and not limits, as the other Reliability Coordinators do. These two Reliability Coordinators state they have self-reported compliance violations for IROL-like conditions that have persisted for longer than 30 minutes. An IROL's status as a limit vs. a condition is a point of significant confusion in the industry; this confusion may have been exacerbated by potentially conflicting messages from regulatory bodies. The definition of IROL in the NERC Glossary begins with "*A System Operating limit…*" clearly reflecting the notion that an IROL is a limit - a value known to System Operators and monitored in Real-time operations. However, statements from regulators in historical documents appear to conflict with this concept. The *Arizona-California Southwest Outage Report on September 11, 2011,* demonstrates that operating conditions are considered IROL violations regardless of whether an IROL is established. On page 97 of the report, Finding 18 states, *"The Cascading nature of the event that led to uncontrolled separation of San Diego, IID, Yuma, and CFE indicates that an IROL was violated on September 8, 2011, even though WECC Reliability Coordinator did not recognize any IROLs in existence on that day."* Such language may be a contributing factor to industry confusion around the nature of IROLs.

Conclusions

The Team concludes that there are variances among Reliability Coordinators regarding how IROL-like conditions are treated during and after the condition. The two common themes are: 1) All Reliability Coordinators treat IROL-like conditions as if they are IROLs and their main priority is to return the system to a reliable operating state, and 2) None of the Reliability Coordinators establish IROLs in real time, except for the one Reliability Coordinator that establishes what it calls a “temporary IROL.” The Team concludes that more guidance is needed around IROL-like conditions as noted in the recommendations that follow.

Recommendations

Recommendation 5

The ERO should consider defining “IROL-like condition” and addressing operational expectations during IROL-like conditions either through outreach and guidance documents or through modifications to the Reliability Standards. The operational expectations should consider the availability of high-performance analysis tools for use in Real-time operations (e.g., stability studies and applicable Contingency event types).

Recommendation 6

The ERO should consider developing flexible load-shed/exceedance criteria for times when unforeseen circumstances that result in IROL-like conditions and an IROL has not been established (e.g., Do not require load shedding for the 30-minute T_v equivalent for exceedances when actions have been taken that will return the system to a reliable operating state in slightly more time). Consideration should be given to whether this could be accomplished through modifications to the Reliability Standards or as a mitigating factor in the enforcement process.

Beneficial Practices for Consideration

Beneficial Practice 6

Reliability Coordinators should consider incorporating “IROL-like condition” training into System Operator training programs. At a minimum, the training should include System Operator expectations, available operational actions, and practical application on performing Real-time Cascading studies.

Beneficial Practice 7

Reliability Coordinators should consider developing a System Operator metric that measures response rates to all SOL exceedances, including IROLs. The metric should score exceedances based on exceedance return time as well as other metrics as deemed appropriate.

Tools and Practices

Introduction

Tools are integral to establishing and monitoring system limits, including SOLs and IROLs. Off-the-shelf tools are available for studying all types of system conditions, such as thermal, voltage, and the various stability classifications. These tools may be used on-line or off-line and are used in the various time horizons, as shown in **Figure 2**, based on what they are being used for, who is using them, and their operational viability. Again, IROLs are generally established prior to Real-time operation using off-line studies in the operations planning horizon, per the new FAC-011-4. However, advanced tools are being increasingly used to update these limits in near real time. Several of the tools discussed here appear in more than one time horizon.

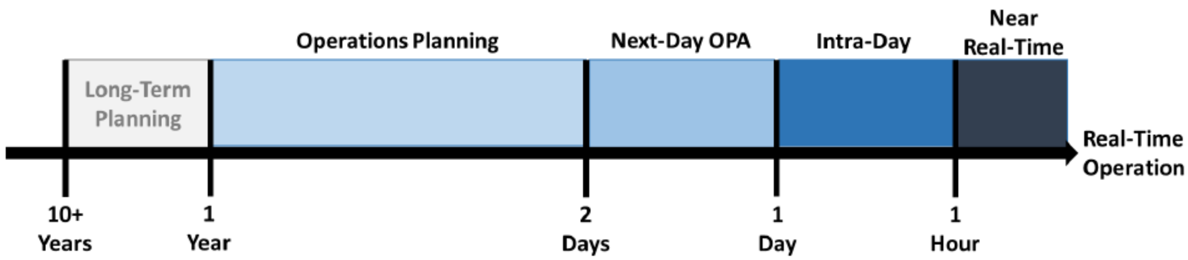

Figure 2: NERC Reliability Standard Time Horizons

Observations

The Team observed that there are as many combinations of IROL-related tools in use as there are Reliability Coordinators performing IROL studies. Many of the participating Reliability Coordinators use some of the same "off the shelf" tools, such as Power System Simulation for Engineering (PSSE), for different reasons and during different time horizons. Additionally, several Reliability Coordinators have developed in-house Reliability Coordinator specific tools to address their unique requirements. All Reliability Coordinators use tools from various developers for thermal related analysis. These tools include Energy Management Systems (EMS), State Estimators (SE), Power-Flow (PF), and Contingency Analysis (CA) tools in the Operations Planning through Real-Time Operation horizons. All Reliability Coordinators also use tools from various developers for stability-related analysis, including Power System Simulation (PSS), Voltage Stability Analysis (VSA), and Transient Stability Analysis (TSA) tools in the Long-Term Transmission Planning through Real-Time Operation horizons; how and when these stability tools are used represents the greatest difference in practices across the Reliability Coordinators. The models on which the Reliability Coordinators run these tools have different criteria regarding the level of detail in the models, as well as the timing and processes for updating and maintaining them. The following sections discuss the various tools Reliability Coordinators are using, categorized by the time horizons in which they are being used.

Long-Term Transmission Planning Horizon

The long-term transmission planning period covers years 6 through 10 or beyond, when required, to accommodate known projects with longer lead times that may take more than 10 years to complete. One of the most used tools in this horizon is the PSSE tool, which performs a wide variety of analysis functions, including power flow, dynamics, Contingency analysis, optimal power flow, and voltage, and transient stability simulation. A minimum of six Reliability Coordinators use this tool for steady-state and dynamic analysis for thermal, voltage, and stability. Other common tools used in this horizon include the Voltage Security Assessment Tool (VSAT) and Transient Security Assessment Tool (TSAT), which are used off-line in this horizon. Reliability Coordinators also use VSAT to facilitate voltage stability analysis of their systems under various operating conditions, Contingencies, and power transfers, and use TSAT to assess system dynamic behavior and performance. Like VSAT, TSAT is used to calculate transient stability limits under specified criteria, Contingencies, and transfer conditions.

Operations Planning Horizon

The operations planning period covers one year and less through two days prior to Real-time operation. In this horizon, Reliability Coordinators use EMS, SE, PF, and CA tools. Most Reliability Coordinators use these tools to perform thermal and voltage-related studies, including Cascading analysis, but do not generally use these tools for stability-related studies. Several Reliability Coordinators use VSAT in the operations planning horizon, with at least one Reliability Coordinator using it to perform Cascading analysis and assess relay clearing data. One Reliability Coordinator uses TSAT in the operations planning horizon, but most do not; however, several Reliability Coordinators are reviewing how to incorporate it into their operations planning going forward. A minimum of two Reliability Coordinators use PSSE in the operations planning horizon. Two Reliability Coordinators use Bigwood Systems Inc. voltage stability tools to determine dynamic system operating limits and margins; one uses these tools regularly in the operations planning and Real-time operation horizons, and one uses them in the operations planning horizon as needed, based on results of their 2–10 day-ahead studies.

Next-day through Real-Time Operation Horizon

The next-day through Real-time operation period covers two days prior to Real-time operations through Real-time operations. Like in the operations planning horizon, all Reliability Coordinators use EMS, SE, PF, and CA tools in these horizons. Several Reliability Coordinators incorporate features into their EMS to ensure reliable operations and assist System Operators. These features include the integration of IROLs, operating guides, protection system actions, RAS arming, equipment tags, and a multitude of credible system Contingencies, including stuck breakers, DCT, and greater than N-1.

Three Reliability Coordinators have programmed RAS-arming scripts into their EMS. One Reliability Coordinators scripts determine which RAS to arm or disarm based on current system configuration. Another Reliability Coordinator’s scripts allow the System Operator to enter, enable, and disable information so the results of RAS actions are available in power flow study results. The other Reliability Coordinator’s EMS considers information such as RAS availability, outages, and environmental conditions to calculate RAS reductions and create operating plans. All of the three Reliability Coordinators RAS scripts allow for manual override by the System Operators if needed. In addition to these standard tools, the Reliability Coordinators that operate in a market environment use unit dispatch software that assists in preventing SOL exceedances. If the unit dispatch software will not correct an SOL limit exceedance, all Reliability Coordinators operating in a market environment require manual intervention by System Operators.

Several Reliability Coordinators do not use stability tools in this horizon but monitor pre-established Stability Limits using tools such as EMS screens, operating guides, and spreadsheets. Several Reliability Coordinators monitor voltage stability in this horizon using various vendor tools, which generally execute every 5–10 minutes. Several Reliability Coordinators perform transient stability analysis in Real-time, and several other Reliability Coordinators are reviewing how to incorporate it into Real-time going forward.

Several Reliability Coordinators have developed in-house Reliability Coordinator-specific tools to address their unique requirements. Two Reliability Coordinators have developed tools for calculating interface transfer limits. One of these tools calculates and displays interface limits based on current system configuration and exports the limits into the EMS for use with their power flow and Contingency analysis tools. The Reliability Coordinator using this tool is also in the process of developing a tool for analyzing inverter stability. Another Reliability Coordinator developed an off-line Real-time thermal Cascading analysis tool used in conjunction with its Study Time Contingency Analysis (STCA) and includes Contingencies not included in its RTCA. The tool is triggered when RTCA indicates an exceedance of 110% of a Facility Rating.

Several Reliability Coordinators also use operating guides as tools for ensuring SOLs are not exceeded. One Reliability Coordinator developed an intelligent tool that uses Boolean logic to determine the current system configuration and highlights the applicable operating procedures to ensure System Operators have quick access to the appropriate procedures in case actions are required. The other Reliability Coordinators that rely heavily on operating guides develop guides as needed for equipment outages, and these guides can address thermal, voltage, or stability concerns. Two Reliability Coordinators ensure their operating guides remain relevant and up to date by establishing a mandatory periodic review cycle for every guide.

Models

The previously discussed tools require models that simulate the BPS. It is typical for operating entities to use models that only simulate the portion of the BPS for which they are responsible and up to several busses into neighboring systems. Models used for planning studies and operational studies can vary widely regarding the details and attributes of the equipment being modeled, even within the same organization. Additionally, neighboring Reliability Coordinators use different models, and it is extremely likely that they will have differing results, even when analyzing the same Contingency events. Models used for on-line operational studies often use more simplified models that do not include the same level of detail found in off-line planning study models. Details that may have differing attributes include items such as load, generation, interchange, and protection system/RAS actions.

Conclusions

The Team concludes that there are a variety of tools in use and that the tools each Reliability Coordinator uses reflect their varying philosophies and priorities relative to operating limits. The Team identified a common theme among the Reliability Coordinators is the expressed desire for better Real-time tools to study IROLs and IROL-like conditions, especially related to stability analysis. The tools that are currently available require a large amount of human interaction to enter the required data, and the time needed to complete the studies render them non-conducive to use in Real-time. Some Reliability Coordinators indicate that validating limits from Real-time stability tools is a concern. Most Reliability Coordinators express interest in having a “common” tool with very high-end processing to study complex Real-time situations in a short period of time. The benefits of such a tool would include a more uniform and consistent approach to assessing IROLs, including identification of IROLs that may impact neighboring Reliability Coordinators. The Team notes the development of in-house tools that address Reliability Coordinator-specific concerns as a positive practice.

Recommendations

Recommendation 7

Reliability Coordinators should assemble a team of subject matter experts to explore the possibility of developing one or multiple common high-performance analysis tools that can be implemented by all Reliability Coordinators in Real-time. The tool should include the ability to assess thermal, Cascading, and stability concerns in Real-time in a timely manner. Stability assessments should include voltage, frequency, rotor angle, and potential inverter-based resource (IBR) stability through use of available Phasor Measurement Unit (PMU) data, if possible.

Beneficial Practices for Consideration

Beneficial Practice 8

Reliability Coordinators should consider linking operating guides to their related Transmission elements in the EMS, so the guides are readily accessible to System Operators while viewing EMS screens. This can include permanent operating guides or temporary operating guides developed for specific outages. During multiple outages, a restoration prioritization system can be established by attaching an operating guide to the equipment that is to be restored first, then attaching a guide to the next equipment to be restored, and so on.

Beneficial Practice 9

Reliability Coordinators should consider developing an intelligent tool that determines the current system configuration and highlights applicable operating procedures to ensure that System Operators have quick access to the appropriate procedures in case actions are required.

Beneficial Practice 10

Reliability Coordinators should consider developing programmed RAS arming scripts to assist System Operators in determining when to arm or disarm RAS and how many MW to arm or disarm. Intelligent scripts could recommend arming and disarming based on the current system configuration. RAS actions could be included in power-flow and Contingency analysis results to allow System Operators to understand impending system conditions if the RAS were to trigger. Priority should be given to the most critical RAS. All scripts should include a System Operator manual override.

Beneficial Practice 11

Reliability Coordinators should consider incorporating protective relays into power-flow and Contingency analysis results to allow System Operators to understand impending system conditions if protection systems were to trigger. Options may include automated or manual input for protection system status, as well as the capability for System Operators to perform "what if" scenarios during studies. Priority should be given to the most critical protection systems.

Beneficial Practice 12

Reliability Coordinators should consider incorporating interface limit change tables into the EMS to update interface limits automatically based on actual system configuration. Elements that may be included in the change table include applicable lines, transformers, generation, and reactive resources. Features may include highlighting critical elements in the EMS and outage coordination software.

Beneficial Practice 13

Reliability Coordinators should consider establishing a mandatory review cycle for all operating guides to ensure they remain relevant and up to date. Installation of new equipment, or removal of old equipment, should be considered triggers for early review. The review cycle process should include information around the triggers for review, who is responsible for ensuring reviews are completed, deadlines for review completion, and if peer review and management sign-off is required for the reviews.

Communication and Coordination

Introduction

Reliability Coordinators have a shared responsibility to maintain the reliability of the BPS. Reliability Coordinators must remain continuously aware of conditions that may have significant impacts upon their Reliability Coordinator Area and neighboring Reliability Coordinator Areas during normal and emergency conditions. Reliability Coordinator operations should be coordinated such that they will not adversely impact other Reliability Coordinator Areas and will preserve the reliability benefits of interconnected operations. Effective communication among Reliability Coordinators is a critical element to ensuring continued and complete information sharing and coordination.

Observations

The Team observed that there is a lack of communication and coordination among the participating Reliability Coordinators regarding the establishment of IROLs, especially in the Long-Term Planning Horizon. One of the main indicators of this lack of communication and coordination is that neighboring Reliability Coordinators are viewing IROLs differently, meaning that what one Reliability Coordinator may consider important its neighbor may consider irrelevant. Several participating Reliability Coordinators state their desire for better communication, coordination, and practice sharing among the Reliability Coordinators. At least two Reliability Coordinators state they would like to speak with other Reliability Coordinators about the tools they have implemented to study dynamic stability in Real-time. Although some good communication and coordination practices exist, improvement in this area is warranted.

An example of effective communication and coordination is where one Reliability Coordinator with multiple IROLs actively participates in an operating studies task force that includes subordinate Transmission Owners (TO) and TOPs as well as neighboring Reliability Coordinators. This Reliability Coordinator considers analysis and reviews from the task force when establishing IROLs. Another example of good communication and coordination is where one Reliability Coordinator with multiple IROLs requires impacts to neighboring Reliability Coordinators to be considered when establishing IROLs. This Reliability Coordinator reviews all potential IROLs with neighboring Reliability Coordinators that could be impacted. If the neighboring Reliability Coordinators confirm the impact, the Reliability Coordinator will establish an IROL. If the neighboring Reliability Coordinators do not believe it would impact them, then the Reliability Coordinator would hold internal discussions to decide if an IROL should be established. Another positive example where one Reliability Coordinator established a formal process to share and discuss next-day limits with its neighboring Reliability Coordinators.

An example of ineffective communication and coordination is one Reliability Coordinator respects stuck breaker Contingencies in their analysis, while a neighboring Reliability Coordinator does not; this leads to disagreement on whether an IROL should be established and the potential impact of the IROL. Conversely, this same Reliability Coordinator identified and established an IROL that impacted its system that is caused by a stuck breaker in its neighboring Reliability Coordinators system. The impacted Reliability Coordinator requests the neighboring Reliability Coordinators assistance in mitigating the impact of the stuck breaker, however, because the neighboring Reliability Coordinator does not respect stuck breaker Contingencies, the discussions fail. Similarly, one Reliability Coordinator studies external Contingencies that could impact its system but experiences problems in obtaining relay trip setting and rating change data from its neighboring Reliability Coordinators. This Reliability Coordinator desires a streamlined process for sharing data among Reliability Coordinators so needed data can be obtained in a timely manner without the extended waiting period typical of formal data requests. Another example of ineffective communication and coordination is when Reliability Coordinators are members of IROL-related technical groups but inconsistently attend the group meetings, or do not attend at all. Finally, all Reliability Coordinators state that inconsistent use of terminology is a major contributor to ineffective communication and coordination between neighboring entities.

Conclusions

The Team concludes that more communication, coordination, and transparency around IROLs is needed amongst Reliability Coordinators. The Team attributes the lack of communication and coordination to several factors, including the previously discussed issues around terminology, as well as the allowed flexibility and ambiguity of the Reliability

Standards regarding unspecified criteria, thresholds, and methodology for establishing IROLs. The Team also concludes, as stated by several Reliability Coordinators, that Reliability Coordinator communication is impeded by the Reliability Standards disincentivizing the establishment of IROLs and communication among Reliability Coordinators due to potential compliance implications.

Recommendations

Recommendation 8

Reliability Coordinators should compile a list of all active committees, task forces, and working groups that discuss SOL and IROL studies, tools, and methodologies then share that list with neighboring Reliability Coordinators for awareness purposes. Reliability Coordinators should be encouraged to actively participate in all groups in which they are members, especially when there may be mutual benefit for neighboring Reliability Coordinators. The goal of this participation is better communication, coordination, and transparency around processes, tools, methodologies, and study results.

Recommendation 9

Reliability Coordinators should collaborate to create a group, forum, or tool where Reliability Coordinators can openly voice concerns, share ideas, actively coordinate, and solicit feedback around SOL-related tools and practices in confidence. This could consist of periodic group discussions as well as a discussion board where participants could receive timely responses to their questions or scenarios. This could include a resolution process for resolving disagreements with neighboring Reliability Coordinators that have differing views on topics such as Contingencies or impact.

Recommendation 10

Reliability Coordinators should develop a streamlined process to share important data needed for SOL and IROL studies with neighboring Reliability Coordinators in a timely manner to ensure that these studies provide accurate results. The process should cover what data is to be shared, such as relay setting changes, interface limit changes, and Facility Rating updates. The process should establish triggers and controls to ensure the requesting and sharing Reliability Coordinators are aware of the need to share data that has been changed.

Beneficial Practices for Consideration

Beneficial Practice 14

Reliability Coordinators should consider developing a process to regularly review all potential SOL and IROL-related concerns with neighboring Reliability Coordinators to validate results and discuss potential impact. This should be an open line of communications flowing both, or multiple, directions.

Reliability Standards

Introduction

The NERC Reliability Standards define the reliability requirements for planning and operating the North American BPS and apply to owners, operators, and users of the BPS. They can be viewed as the minimum set of criteria to be complied with to address reliability gaps and to mitigate BPS risks. References to IROLs, which are a subset of SOLs, appear in 16[37] Reliability Standards and the related compliance obligations apply to six[38] registered functions.

Observations

The Team noted two common Reliability Standard-related themes among most participating Reliability Coordinators: 1) Reliability Standards disincentivize establishing IROLs and 2) clarity around IROLs is desired and needed.

Reliability Standards Disincentivize IROL Establishment

Almost all participating Reliability Coordinators state that the Reliability Standards disincentivize IROL establishment because IROLs are used for compliance determinations in other standards, such as Critical Infrastructure Protection (CIP) and FAC. Establishing just one IROL brings additional compliance risk and burden and is cited as a significant concern among participants. One Reliability Coordinator states that 21 different Reliability Standards reference SOLs and IROLs and that, once a Reliability Coordinator establishes an IROL, the Reliability Coordinator needs to ensure compliance with these 21 additional standards. One Reliability Coordinator states that entities do not want to establish IROLs because they "cost too much" for CIP hardening and vegetation management compliance. The Reliability Coordinators are overwhelmingly unanimous in their opinion that IROLs should not be tied to other standards, meaning that, when an IROL is established, it should not trigger compliance with any other standards. The Reliability Coordinators are emphatic in stating that IROLs should only be used in the operating space to help protect the BPS and that any other use of IROLs for compliance disincentivizes the establishment of IROLs. Therefore, Reliability Coordinators will consciously or unconsciously avoid establishing IROLs to reduce the additional risk.

Clarity in Reliability Standards for SOLs but not for IROLs

Most Reliability Coordinators express the desire and need for the same clarity in IROL standards that exists in SOL standards and are looking for the ERO Enterprise to provide that clarity. Historically, an SOL as reflected in the original body of the standards and the NERC SOL definition was described as a limit calculated from studies that, if operated within, was to render reliable operations for the pre- and post-Contingency state thermal limits, voltage limits, and stability performance. In this paradigm, the SOL was an output from a study or a set of studies. The SOL was then communicated to others and used in Real-time operations, the presumption being that if the SOL was operated to in real time, meeting both pre- and post-Contingency reliability criteria for thermal, voltage, and Stability Limits would be the reliability outcome. The IROL concept was similar; however, instead of addressing pre- and post-Contingency performance for thermal and voltage limits, the IROL was intended to address more severe reliability risks of instability, Cascading, and uncontrolled separation. Conceptually, the SOL and the IROL functioned the same way, hence the notion that an IROL is considered a subset of an SOL, or a "special" SOL.

Achieving SOL Clarity – History

The revised TOP and IRO standards resulting from *NERC Project 2014-03 Revisions to TOP and IRO Standards* that became effective in 2017 upended this legacy approach and better reflected what Reliability Coordinators and Transmission Operators do for operational reliability. These revised standards require Reliability Coordinators and Transmission Operators to have OPAs for each day and to perform Real-time Assessments (RTA) at least once every 30 minutes. The NERC definitions of OPA and RTA were revised to specify that these terms include an evaluation of the pre- and post-Contingency states. While these revisions represented a significant step forward in ensuring reliable

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[37] CIP-002-5.1a, CIP-014-3, EOP-011-2, FAC-008-5, FAC-010-3, FAC-011-3, FAC-014-2, IRO-002-7, IRO-008-2, IRO-009-2, PER-005-2, PRC-002-2, PRC-010-2, PRC-023-4, TOP-001-5, VAR-001-5.

[38] Balancing Authority (BA), Planning Authority (PA), Planning Coordinator (PC), Reliability Coordinator (RC), Transmission Planner (TP), Transmission Operator (TOP).

operations, the creation of these standards and definitions resulted in significant misalignment with the original SOL concept and the associated requirements in FAC-011.

NERC Project 2015-09 Establish and Communicate SOLs recognized this misalignment and significantly changed the SOL concept (and thus the definition) and the related FAC standards to better align with the revised TOP and IRO standards and the definitions of OPA and RTA. The revised SOL definition and FAC standards become effective on April 1, 2024.

FAC-011-4 contains requirement R6, which requires each Reliability Coordinators SOL methodology to contain the framework for SOL exceedance specified in the requirement. This requirement describes "the floor" for SOL exceedance that must be included in each Reliability Coordinators SOL methodology; however, this requirement and the framework do not provide allowable time frames to mitigate SOL exceedances. Revised standards TOP-001-6 and IRO-008-3 contain a new requirement that Reliability Coordinators and Transmission Operators must use the Reliability Coordinators SOL methodology when determining SOL exceedance for OPAs and RTAs.

When stepping back and looking broadly at key Reliability Standards, a type of operations reliability workflow is recognized. For context, the revised definition of SOL clarifies that SOLs are "*All Facility Ratings, System Voltage Limits, and stability limits, applicable to specified System configurations, used in Bulk Electric System operations for monitoring and assessing pre- and post-Contingency operating states*." The SOL "workflow" is characterized by the following standards:

1. TOP-001-6 R25 and IRO-008-3 R7 (Effective 4/1/2024) require Reliability Coordinators and Transmission Operators to use the Reliability Coordinators SOL methodology for determining SOL exceedances.
2. TOP-002-4 R1 and IRO-008-3 R1 require Reliability Coordinators and Transmission Operators to perform an OPA to identify SOL exceedances.
3. TOP-002-4 R2 and IRO-008-3 R2 require Reliability Coordinators and Transmission Operators to develop and communicate operating plans for SOL exceedances identified in the OPA.
4. TOP-001-6 R13 and IRO-008-2 R4 require Reliability Coordinators and Transmission Operators to perform RTAs at least once every 30 minutes.
5. TOP-001-6 R14 requires Transmission Operators to implement Operating Plans for SOL exceedances identified in their Real-time monitoring or RTA.
6. IRO-008-3 R5 requires Reliability Coordinators to notify Transmission Operators and Balancing Authorities of SOL or IROL exceedances in accordance with the Reliability Coordinators SOL methodology.
7. TOP-001-6 R15 requires Transmission Operators to notify their Reliability Coordinator of actions taken to address SOL exceedances in accordance with its Reliability Coordinators SOL methodology.

With this "workflow," SOL exceedances are identified and communicated, Operating Plans are developed and implemented, and SOL exceedances are mitigated.

Further, FAC-011-4 requirement R8, including subparts 8.1 and 8.2, requires Reliability Coordinators to include in their SOL methodologies a description of how to identify the subset of SOLs that qualify as IROLs and the criteria for determining when exceeding a SOL qualifies as exceeding an IROL and criteria for developing any associated IROL T_v.[39]

[39] The NERC Glossary of Terms defines IROL T_v as "The maximum time that an Interconnection Reliability Operating Limit can be violated before the risk to the interconnection or other Reliability Coordinator Area(s) becomes greater than acceptable. Each Interconnection Reliability Operating Limit's T_v shall be less than or equal to 30 minutes."

The IROL and IROL exceedance “workflow” is characterized by the following TOP and IRO standards:

1. IRO-008-2 R1 requires Reliability Coordinators to perform an OPA that will allow the Reliability Coordinator to assess whether the planned operations for the next day will exceed SOLs and IROLs within the Reliability Coordinators wide area.
2. IRO-008-2 R2 requires Reliability Coordinators to have a coordinated Operating Plan(s) for next-day operations to address potential SOL and IROL exceedances identified as a result of the Reliability Coordinators OPA while considering the Operating Plans for the next-day provided by the Reliability Coordinators Transmission Operators and Balancing Authorities.
3. IRO-009-2 R1 requires the Reliability Coordinator, for each IROL (in its Reliability Coordinator Area) that the Reliability Coordinator identifies one or more days prior to the current day, to have one or more operating processes, procedures, or plans that identify actions the Reliability Coordinator shall take or direct others to take (up to and including load shedding) that can (1) be implemented in time to prevent the identified IROL exceedance and (2) mitigate the magnitude and duration of an IROL exceedance such that the IROL exceedance is relieved within the IROL’s T_v.
4. IRO-009-2 R2 requires Reliability Coordinators to initiate one or more operating processes, procedures, or plans that are intended to prevent an IROL exceedance, as identified in the Reliability Coordinator’s Real-time monitoring or RTA.
5. IRO-009-2 R3 requires Reliability Coordinators to act or direct others to act so that the magnitude and duration of an IROL exceedance is mitigated within the IROL’s T_v, as identified in the Reliability Coordinators Real-time monitoring or RTA.
6. TOP-001-5 R12 requires Transmission Operators to avoid operating outside any identified IROL for a continuous duration exceeding its associated IROL T_v.

Each of the requirements listed above in the “workflows” for SOLs and IROLs are clear and meaningful, provided the language and terms used in those requirements are clear and meaningful. For example, TOP-001-6 R14 requires Transmission Operators to “*implement Operating Plans for SOL exceedances identified in [their] real-time monitoring or RTA.”* This requirement is clear and meaningful, provided there is a common and clear understanding of what it means to exceed an SOL. If that common and clear understanding exists in the standards, then this requirement - and all other requirements that use the SOL exceedance language - are consequentially clear and meaningful. If such clarity does not exist in the standards, then the meaning of TOP-001-6 R14 - and any other requirement that uses the SOL exceedance language - depends on how that registered entity views and defines SOL exceedance. In this case, the very meaning of the requirement is completely relative and thus can have a plethora of meanings. This brings into question the value of demonstrating compliance with a requirement that can have a variety of meanings.

The revised FAC-011-4 standard along with the revised definition of SOL and the new definition of System Voltage Limit[40] provide the context and clarity needed for the SOL “workflow” to have consistent and clear meaning for Transmission Operators. The revised SOL definition should make it unequivocally clear what an SOL is, and the new FAC-011-4 and FAC-014-3 standards should clarify when an SOL needs to be established and what it means to exceed one. As a result, the requirements in the SOL “workflow” should be clear, meaningful, and consistently applied across North America.

The same cannot be said about the IROL “workflow” requirements. The Team learned that there is a lack of clarity and consistency among Reliability Coordinators about what an IROL is, when it needs to be established, or what it means to exceed one. Consequently, the meaning of the IROL “workflow” requirements is purely a function of a given Reliability Coordinators interpretation, and, therefore, compliance with these standards may vary according to a

[40] The maximum and minimum steady-state voltage limits (both normal and emergency) that provide for acceptable System performance.

particular Reliability Coordinators interpretation of them. Table 4 below compares the current state of SOLs and IROLs in industry.

Table 4: Current State of SOLs and IROLs		
	System Operating Limits (SOL)	**Interconnection Reliability Operating Limits (IROL)**
What It Is:	Explicitly Clear: • All Facility Ratings, System Voltage Limits, and Stability Limits, applicable to specified system configurations, used in BPS operations for monitoring and assessing pre- and post-Contingency operating states.	Unclear: • Project 2015-09 and the MEITF did not provide clarity on what an IROL is.
When It Needs to Be Established	Explicitly Clear: • Every Facility has a Facility Rating, and SOLs include all Facility Ratings (revised definition of SOL). • Every BPS bus/station has a System Voltage Limit, and SOLs include all System Voltage Limits (FAC-011-4 requirement R3 part 3.1 and the definition of System Voltage Limit). • Each Reliability Coordinator's SOL methodology must include stability performance criteria, and Stability Limits must be established to meet those criteria. All Stability Limits are SOLs (FAC-011-4 requirement R4 and subparts).	Unclear: Project 2015-09 and the MEITF did not provide clarity on when an IROL needs to be established.
What It Means to Exceed One:	Explicitly clear: • Each Reliability Coordinator shall include the following performance framework in its SOL methodology to determine SOL exceedances when performing Real-time monitoring, RTAs, and OPAs: (FAC-011-4, R6) • Each Transmission Operator shall use the applicable Reliability Coordinators SOL methodology when determining SOL exceedances for RTAs, Real-time monitoring, and OPA (TOP-001-6, R25). • Each Reliability Coordinator shall use its SOL methodology when	Unclear: Industry confusion continues to exist between "exceeding a pre-determined limit" vs. "entering into a condition where the next Contingency could result in instability, Cascading, or uncontrolled separation.". The *Arizona-California Southwest Outage Report on September 11, 2011,* report demonstrates that operating conditions are considered IROL violations regardless of whether an IROL is established.[41]

[41] The *Arizona-California Southwest Outage Report on September 11, 2011* report, page 97, Finding 18 states, "The Cascading nature of the event that led to uncontrolled separation of San Diego, IID, Yuma, and CFE indicates that an IROL was violated on September 8, 2011, even though WECC Reliability Coordinator did not recognize any IROLs in existence on that day."

	determining SOL exceedances for RTAs, Real-time monitoring, and OPA (IRO-008-3, R7).	

Achieving IROL Clarity – Potential Paths Forward

The body of Reliability Standards became effective in 2007. At that time, the concepts of SOL and IROL were codified into the standards, and requirements were formed around these concepts. The previous section, to some extent, describes how the Reliability Standards have evolved and how the FAC standards and the SOL concept (and definition) were changed to reflect that evolution. Steps were taken under NERC Project 2015-09 to bring explicit clarity to SOLs. However, as has been discussed, there is an absence of clarity for IROLs. One way to address IROL clarity is to modify the Reliability Standards and the NERC Glossary of Terms to clarify IROLs, much in the same way Project 2015-09 clarified SOLs, including what they are, when they need to be established, and what it means to exceed them.

The next section explores the possibility of addressing the IROL challenges through an alternate approach that considers concepts and ideas that could achieve the clarity needed but potentially in a much simpler, faster, and more efficient manner.

A "Performance Criteria and Risk Based Approach" to Operations Reliability

The body of NERC Reliability Standards uses a “limit exceedance” approach to operations reliability, whether those limits be SOLs or IROLs. Many examples of this approach are described in the previous sections of this report. When the body of related Reliability Standards are taken together, operations reliability is achieved through a “limit exceedance” approach by:

1. Establishing limits,
2. Performing various studies to see if those limits are exceeded,
3. Developing Operating Plans for identified limit exceedances,
4. Implementing Operating Plans when limits are exceeded in Real-time operations.

This section explores the possibility of shifting from a “limit exceedance” approach to a “performance criteria and risk-based” approach to operations reliability. To begin, let’s examine a few new requirements that were created under Project 2015-09 that are effective on April 1, 2024:

The new FAC-011-4 Requirement R6 states the following:

R6 Each Reliability Coordinator shall include the following performance framework in its SOL methodology to determine SOL exceedances when performing Real-time monitoring, Real-time Assessments, and Operational Planning Analyses: [Violation Risk Factor: High] [Time Horizon: Operations Planning]

6.1. System performance for no Contingencies demonstrates the following:

6.1.1. Steady state flow through Facilities are within Normal Ratings; however, Emergency Ratings may be used when System adjustments to return the flow within its Normal Rating could be executed and completed within the specified time duration of those Emergency Ratings.

6.1.2. Steady state voltages are within normal System Voltage Limits; however, emergency System Voltage Limits may be used when System adjustments to return the voltage within its normal System Voltage Limits could be executed and completed within the specified time duration of those emergency System Voltage Limits.

6.1.3. Predetermined stability limits are not exceeded.

6.1.4. Instability, Cascading or uncontrolled separation that adversely impact the reliability of the Bulk Electric System does not occur.

6.2. System performance for the single Contingencies listed in Part 5.1 demonstrates the following:

6.2.1. Steady state post-Contingency flow through Facilities within applicable Emergency Ratings. Steady state post-Contingency flow through a Facility must not be above the Facility's highest Emergency Rating.

6.2.2. Steady state post-Contingency voltages are within emergency System Voltage Limits.

6.2.3. The stability performance criteria defined in the Reliability Coordinators SOL methodology are met.

6.2.4. Instability, Cascading or uncontrolled separation that adversely impact the reliability of the Bulk Electric System does not occur.

6.3. System performance for applicable Contingencies identified in Part 5.2 demonstrates that: instability, Cascading, or uncontrolled separation that adversely impact the reliability of the Bulk Electric System does not occur.

6.4. In determining the System's response to any Contingency identified in Requirement R5, planned manual load shedding is acceptable only after all other available System adjustments have been made.

Corresponding new requirements in TOP-001-6 and IRO-008-3 state the following:

TOP-001-6 R25. Each Transmission Operator shall use the applicable Reliability Coordinators SOL methodology when determining SOL exceedances for Real-time Assessments, Realtime monitoring, and Operational Planning Analysis.

IRO-008-3 R7. Each Reliability Coordinator shall use its SOL methodology when determining SOL exceedances for Real-time Assessments, Real-time monitoring, and Operational Planning Analysis.

It is important to note a few key aspects of these three requirements:

- The Reliability Coordinator's SOL methodology must include the performance framework described in requirement R6.
- Subparts 6.1.3, 6.1.4, 6.2.3, 6.2.4, and 6.3 of FAC-001-4 requirement R6 address stability performance requirements and state that instability, Cascading, and uncontrolled separation that adversely impact the reliability of the BPS do not occur.
- New requirements TOP-001-6 R25 and IRO-008-3 R7 tie the Reliability Coordinator's SOL methodology to Real-time operations and operations planning when determining SOL exceedances, which includes the performance framework required in FAC-011-4 R6.

When the FAC-011-4, TOP-001-6, and IRO-008-3 requirements noted above are considered together, the reliability outcome should be operating in a manner that avoids and mitigates instability, Cascading, and uncontrolled separation; however, these requirements rely on SOL establishment and SOL exceedance to accomplish the reliability objective. While these requirements improve reliability, they still fall within the "limit exceedance" approach to achieving operations reliability.

A "performance criteria and risk-based" approach changes the focus of the Reliability Standards from exceeding limits to meeting performance criteria. It is possible that minor modifications to the Reliability Standards can be made to shift from a "limit exceedance" approach to a "performance criteria and risk-based" approach to operations reliability. To achieve this transition, the "limit exceedance" based requirements that exist today could be replaced with requirements to:

1. Clearly state the performance criteria for N-0, N-1, and any N-2 Contingencies deemed credible for Real-time operations (largely accomplished by FAC-011-4 requirement R6).
2. Require Reliability Coordinators and Transmission Operators to conduct studies in the operations planning horizon to identify reasonable risks for instability, Cascading, and uncontrolled separation. Consideration should be given to whether this type of requirement is necessary.

3. Require Reliability Coordinators and Transmission Operators to perform outage coordination studies (IRO-017) and Operational Planning Analysis to determine if any of the performance criteria will not be met and to develop Operating Plans for instances where the performance criteria are not being met. This is similar to existing requirements but focuses on meeting performance criteria rather than identifying SOL/IROL exceedances.
4. Require Reliability Coordinators and Transmission Operators to perform Real-time Assessments to determine if performance criteria are being met and to implement Operating Plans if they are not being met. This is similar to existing requirements but focuses on meeting performance criteria rather than addressing SOL/IROL exceedances.

It can be argued that Reliability Standards should specify the required reliability performance outcome, the “what”, regarding operations reliability. In the case of IROLs, the Reliability Standards should focus on operating in a way that instability, Cascading, and uncontrolled separation do not occur. The essential reliability objective, the “what”, is to avoid instability, Cascading, or uncontrolled separation; how Reliability Coordinators achieve this reliability objective may be determined by a given Reliability Coordinator. It can be argued that the use of a “limit” such as an IROL to achieve this reliability objective specifies “how” Reliability Coordinators are required to achieve the reliability outcome of prevention and mitigation of instances of instability, Cascading, or uncontrolled separation. NERC Reliability Standards typically specify the “what”, not the “how”, and it can be argued that the use of IROLs (a limit) falls squarely in the “how” space. It is worth considering that if Reliability Coordinators have developed a more effective “how” to achieve the “what,” the standards should allow for that.

For example, Reliability Coordinator's and Transmission Operators currently use RTCA to ensure post-Contingency reliable operations for Facility Ratings and System Voltage Limits and may use it for Cascading prevention. A few Reliability Coordinators use Real-time tools for voltage and transient stability, and a few more Reliability Coordinators are evaluating the use of these tools for Real-time operations. These Real-time tools continually assess how close the system is to the edge of stability, Cascading, and uncontrolled separation. The integration of these Real-time tools allow or would allow Reliability Coordinators and Transmission Operators to manage these risks without the use of predetermined limits, and even without the use of “limits” in the classic sense at all. One must ask, if a Reliability Coordinator uses Real-time tools to ensure that risks for instability, Cascading, or uncontrolled separation are being addressed continually in Real-time through the ongoing use of Real-time tools and processes, what reliability need is there to determine “a limit”, called an IROL? At the same time, however, many Reliability Coordinators use predetermined limits to prevent instability, Cascading, or uncontrolled separation. But it must be acknowledged that the use of such limits represents a Reliability Coordinators chosen mechanism (the “how”) for achieving the reliability objective of preventing and mitigating instability, Cascading, and uncontrolled separation (the “what”).

While it can be argued that the current standards and the new FAC-011-4, TOP-001-6, and IRO-008-3 may in some ways address operating in a manner that avoids and mitigates instability, Cascading, and uncontrolled separation, the ultimate reliability objective, these requirements do not address the concept of ensuring that Reliability Coordinators and Transmission Operators mitigate these risks within 30 minutes. If a “performance criteria and risk-based” approach is adopted, IROLs are removed from the Reliability Standards, and there is a reliability need to maintain the 30-minute risk duration cap currently accomplished through IROL T_v, it can be accomplished through minimal additions or modifications to the Reliability Standards.

One potential advantage of a “performance criteria and risk-based” approach is the clarity and consistency issue. If Reliability Standards are going to use the SOL and IROL terms in the Reliability Standards, then it is critical that there is clarity and consistency in the meaning and application of these terms. Due to the work accomplished by Project 2015-09, the SOL term is now abundantly clear, and therefore the SOL is applied consistently across Reliability Coordinator and Transmission Operators in the Reliability Standards. If the IROL term is maintained in the Reliability Standards, then that same level of clarity must be achieved for IROLs. However, if the IROL term is removed from the Reliability Standards and the “performance criteria and risk-based” approach described here is integrated into the

Reliability Standards, then the need for clarifying IROLs disappears (i.e., obtaining consistency on their meaning and application and, understanding what they are, when they need to be established, and what it means to exceed them). Again, “how” a Reliability Coordinator chooses to meet the performance criteria described above would be the responsibility of each Reliability Coordinator.

Several participating Reliability Coordinator have questioned whether the IROL is still the best mechanism for achieving its intended reliability objective, and some Reliability Coordinator state there is no reliability need for having IROLs. This section of the report is meant to highlight such concerns and stimulate thought on whether they are valid and warrant consideration.

Reliability Risks

There are several reliability risks associated with the inconsistencies and confusion around IROLs described in this report; however, recent changes in the Reliability Standards may help reduce some of those risks, specifically, the new Reliability Standards that are effective April 1, 2024. These recent risk reductions and the remaining risks are described below.

Recent Risk Reductions

The following are some potential reductions in risk for instability, Cascading, and uncontrolled separation that may result from the new standards, as described above:

1. New requirements reduce reliability risk by requiring Reliability Coordinators to specify a reliability performance framework in its SOL Methodology and requiring Reliability Coordinators and Transmission Operators to use that reliability performance framework when determining SOL exceedances. FAC-011-4 requirement R6 requires the Reliability Coordinator to include in its SOL Methodology the performance framework described in the requirement. TOP-001-6 requirement R25, and IRO-008-3 requirement R7 tie the Reliability Coordinators SOL methodology to Real-time operations and operations planning by requiring Reliability Coordinators and Transmission Operators respectively to use the framework described in its Reliability Coordinators SOL Methodology when determining SOL exceedances.
    a. FAC-011-4 requirement R6 addresses stability performance and states that instability, Cascading, and uncontrolled separation that adversely impact the reliability of the BPS do[es] not occur [i.e., under N-0 conditions, N-1 conditions, and pre-determined multiple Facility Contingencies deemed credible for Real-time operations].
    b. If, in response to these requirements, SOLs are developed that prevent instability, Cascading, and uncontrolled separation, and Operating Plans are developed and implemented for these SOLs, then the ultimate outcome should help to avoid instability, Cascading, and uncontrolled separation.
2. FAC-014-3 requirement R7 requires Transmission Planners and Planning Coordinators to communicate Corrective Action Plan (CAP) information to the Reliability Coordinator for instability identified in its TPL assessments. Because the Reliability Coordinator can use this information to screen for potential instability in the operations horizon, this requirement can reduce the risk of instability.
3. FAC-011-4 requirement R4 reduces risk of instability by requiring the Reliability Coordinator, in its SOL Methodology, to establish stability criteria for steady-state voltage stability, transient voltage response, angular stability, and System damping. Additionally, the standard requires Stability Limits to be established to meet these performance criteria. FAC-014-3 requirement R2 requires Transmission Operators to establish SOLs in accordance with its Reliability Coordinators SOL Methodology. Per the revised SOL definition, SOLs include Stability Limits. Taken together, these requirements may reduce the risk of instability.

Remaining Risks

The following are reliability risks that remain and were not addressed in the new standards, as described above:

1. There is a need to clarify and create more specific and granular definitions so that there is a common understanding and application of IROL-related terms to achieve a risk-based approach for operations reliability. The absence of a risk-based approach to operations can result in operators taking urgent action unwarranted for low-impact, local operations risks or in operators not taking urgent action for high-impact operations risks.
   a. For example, "Stability" can refer to stability of a single unit, that when compromised, can have no reliability impact. “Stability” can also refer to system-wide stability, that when compromised, can result in the loss of an entire Interconnection. The same word is used for both low/no risks and extreme risks related to stability, thus undermining a risk-based approach.
   b. Another example is “Cascading”. In order to consistently and adequately prevent Cascading, there first needs to be a clear and consistent risk-centric description of what Cascading means and what it does not mean. The misalignment prevalent among Reliability Coordinators today is a reliability risk.
2. There is a lack of Reliability standards that specifically require the Reliability Coordinator or TOP to perform any kind of studies aimed at identifying potential risks of instability, Cascading, or uncontrolled separation, for example, system stressing studies, N-1-1 studies, etc. The Reliability Coordinator and TOP may or may not run such studies, and accordingly, the Reliability Coordinator and TOP may or may not have awareness of those risks. There are standards that require TOPs and Reliability Coordinators to perform Operations Planning Analysis to identify SOL exceedances and to develop Operating Plans for those exceedances; however, it is possible that these studies may assess expected system conditions rather than stressed system conditions, these studies might miss identifying critical risks to the system that might otherwise be identified if more rigorous system stressing studies were required and performed in the operations planning horizon.
3. The Reliability standards fail to address unforeseen operating scenarios that have been characterized in this report as an “IROL-like condition”. The Reliability standards lack the required action to be achieved within a certain timeframe when unforeseen risks of instability, Cascading, or uncontrolled separation arise in Real-time operations. It is possible that the standards that become effective on April 1, 2024, may reduce this risk. Also, all Reliability Coordinators indicated during the discussions that they treat “IROL-like conditions” with the same degree of urgency that they would treat an actual IROL exceedance. Therefore, this risk might be considered minimal.
4. If the “limit exceedance” approach is going to persist into the future, and IROLs are going to continue to exist as the primary mechanism for ensuring that the system is operated in a manner that avoids and mitigates risks for instability, Cascading, or uncontrolled separation, then several reliability risks exist:
   a. The disincentivizing of IROL establishment in the Reliability Standards poses a significant risk to reliability. If IROLs are not established, it is possible that the risks associated with instability, Cascading, or uncontrolled separation may not be identified and accounted for in Real-time operations, resulting in Contingency events that could result in wide-area collapse. For example, prior to 2011, there were no IROLs on the Western Interconnection; however, on September 8, 2011, an N-1 Contingency event led to the wide-area collapse of the San Diego area. If the risks of instability, Cascading, and uncontrolled separation are not adequately identified, then Operating Plans are not developed for those risks. The absence of adequate Operating Plans increases the risk of instability, Cascading, and uncontrolled separation.
   b. Wide variances among the Reliability Coordinators regarding methodologies, criteria, and philosophies for establishing IROLs poses a significant reliability risk. Discussions with the Reliability Coordinators led the Team to conclude that there is significant confusion in industry regarding what an IROL is, when one needs to be established, and what it means to exceed one. The reliability risks associated with this current state are seen in Reliability Coordinator-to-Reliability Coordinator communications, understanding and clarity of common reliability objectives and outcomes, misaligned operating processes, inefficient and

ineffective operations, and administrative requirements that can distract Operators from focusing on reliable operations.

c. The Team learned that there is no consistency among Reliability Coordinators in the meaning and application of the IROL term. Today, the meaning of the IROL term is purely a function of a given Reliability Coordinator's interpretation and application of the term. At the same time, the IROL term exists in many Reliability Standards – in requirements, applicability sections, purposes, VSLs, appendices, etc. Therefore, compliance with these standards varies according to a particular Reliability Coordinator's interpretation of the IROL term, rendering requirements that can have a wide range of meanings, measures, and ultimately reliability outcomes. The confusion around the IROL term today has resulted in a body of requirements that may be ineffective for accomplishing its intended purpose of reducing reliability risks.

d. With the continuing transition from fossil fuel-based energy production to inverter-based resources (solar, wind, and batteries), the modeling and tools to properly and adequately capture reliability risks from their expanding role are under-developed, not well understood, or not utilized within the industry. This leads to increased risks of large inverter-based source losses (as shown by multiple actual events), which in turn could create new IROLs or expand the size and scale of existing, source-loss focused IROLs. These compounding risks amplify the reliability risks associated with the current confusion around IROLs across North America.

Conclusions

The Team concludes that, because of the work accomplished by NERC Project 2015-09, SOLs are clear and clearly understood by industry. The revised definition of SOL, the new definition of System Voltage Limit, and the revised FAC-011-4, FAC-014-4, TOP-001-6, and IRO-008-3 standards clarify what an SOL is, when one needs need to be established, and what it means to exceed one. Through discussions with Reliability Coordinators the Team learned that such clarity for IROLs does not exist. Instead, Reliability Coordinators are confused about what an IROL is, one needs to be established, and what it means to exceed one. The Team believes that this absence of clarity around IROLs poses a reliability risk that must be addressed.

Recommendations

Recommendation 11: The ERO should resolve industry confusion around IROLs by modifying the body of Reliability Standards to improve clarity. The following are considerations for achieving this much-needed clarity and to address reliability risks. The Team recommends two optional paths for this work:

Optional Path 1 – Consider a "performance criteria and risk-based" approach as a replacement for the current "limit exceedance" approach to reliable operations codified into the Reliability Standards.

- Modify the NERC Glossary of terms to create more specific and granular definitions as needed to achieve a common understanding and application of terms such as stability, instability, local instability, system instability, Cascading, uncontrolled separation, widespread, and others as needed (this item is common to both options, less the IROL definition).
- Modify the NERC Reliability Standards by replacing the existing SOL and IROL concept with a "performance criteria and risk-based" approach through consideration of the following:
  - **Consideration A:** Consider whether a "performance criteria and risk-based" approach serves as a more effective, efficient, and reliable approach to achieving operations reliability than the current "limit exceedance" approach. Consider building on the work accomplished by Project 2015-09 and determining any standard modifications, deletions, and additions that are necessary to transition from a "limit exceedance" approach to a "performance criteria and risk-based approach" to reliable operations.

- **Consideration B:** Given the FAC-011-4, TOP-001-6, and IRO-008-3 standard changes, consider whether the IROL concept is extraneous, duplicative, and unnecessary for operational reliability.
- **Consideration C:** Determine whether the "limit exceedance" approach and the IROL concept represents the "how" rather than the "what" and whether it is appropriate for the NERC Reliability Standards to specify this "how," especially given changes in operating practices, technology advancements, and the proliferation of Real-time tools such as RTCA and Real-time stability tools since the inception of the original SOL and IROL concept.
- **Consideration D**: Given the significant disparity in the use of IROLs across North America and the industry concerns around IROLs that are captured in this report, consider whether an simpler, faster, and more effective path forward could be to abandon the IROL concept altogether and modify the standards to address the current T_v requirement, and other issues as needed, in an appropriate manner as part of the transition to a "performance criteria and risk-based" approach.

Optional Path 2 – Maintain the current "limit exceedance" approach to reliable operations and address the IROL confusion.

- Modify the NERC Glossary of terms to create more specific and granular definitions as needed to achieve a common understanding and application of terms such as IROL, stability, instability, local instability, system instability, Cascading, uncontrolled separation, widespread, and others as needed. (This item is common to both options)
- Modify the body of NERC Reliability Standards, the NERC Glossary of Terms, and all IROL-related guidance to clarify what an IROL is, what it means to exceed one, and when they need to be established. In essence, achieve the same level of clarity around IROLs – including instability, Cascading, and uncontrolled separation – that the new FAC-011-4 and FAC-014-3 and associated definitions achieved for SOLs[42].
- Address the disincentivizing of IROL establishment by modifying the body of NERC Reliability Standards such that establishing IROLs no longer pulls in additional compliance obligations with other Reliability Standards.

Beneficial Practices for Consideration

Beneficial Practice:

The Team did not observe any beneficial practices for consideration regarding Reliability Standards.

[42] https://www.nerc.com/pa/Stand/Pages/Project-2015-09-Establish-and-Communicate-System-Operating-Limits.aspx

Summary

The IROL Activity was initiated as a follow up to work performed by the *NERC Project 2015-09 Establish and Communicate System Operating Limits* Standards Drafting Team, the Methods for Establishing IROLs Task Force, and NERCs petition-based commitment to evaluate whether and how Reliability Coordinators have revised their methods for establishing IROLs in response to the *Reliability Guideline Methods for Establishing IROLs* and to assess whether the revised methods have resulted in a more consistent approach to establishing IROLs across the BPS.

The IROL Activity Team notes large variances and inconsistencies in Reliability Coordinator philosophies and approaches to establishing IROLs. The Team concludes that these large variances and inconsistencies pose a risk to BPS reliability, as described in the preceding sections of this report. The Team identifies specific risks and provides specific recommendations for mitigating those risks as well as achieving consistency in the establishment and treatment of IROLs. The Team also provides Reliability Coordinators with beneficial practices to consider for improving IROL-related activities and tasks; these are positive practices the Team identified during the activity.

The Team believes that if the recommendations and beneficial practices identified in this report are implemented, they will result in a more reliable and secure BPS. Again, NERC and the Team would like to thank all participating Reliability Coordinators, whose open and honest dialogue made the IROL Activity, and this report, possible.

Appendix A: Joint Review Team

North American Electric Reliability Corporation:
Craig Struck*
Jamie Calderon*

Midwest Reliability Organization:
Dianlong Wang

Northeast Power Coordinating Council Inc.:
Matthew Forrest

ReliabilityFirst Corporation:
Courtney Fasca
Ray Mason

SERC Reliability Corporation:
Heath Martin

Texas Reliability Entity Inc.:
Brad Woods

Western Electricity Coordinating Council:
Vic Howell

Federal Energy Regulatory Commission Staff:
Eugene Blick⁺
David O'Connor⁺

* Team Co-Leads
⁺ Observers