NERC Blackout and Disturbance Response Procedures

Effective October 18, 2007

North American Electric Reliability Corporation

NERC Blackout and Disturbance Response Procedures

Introduction

NERC, through its professional staff and the regional entities and their members, provide the best source of technical and managerial expertise for responding to major events that affect the bulk power system.

NERC's role following a blackout or other major bulk electric system disturbance or emergency is to provide leadership, coordination, technical expertise, and assistance to the industry in responding to the event. Working closely with the regional entities and reliability coordinators, NERC will coordinate efforts among industry participants, and with state, federal, and provincial governments in the United States and Canada to support the industry's response.

When responding to any event where physical or cyber security is suspected as a cause or contributing factor to an event, NERC will immediately notify appropriate government agencies and coordinate its analysis with them.

During the conduct of some NERC-level analyses, assistance may be needed from government agencies. Collaborative analysis with certain government agencies may be appropriate in some cases; e.g., collaborating with the Nuclear Regulatory Commission technical staff when a system event involves a nuclear unit. This assistance could include: authority to require data reporting from affected or involved parties; communications with other agencies of government; analyses related to possible criminal or terrorist involvement in the event; resources for initial data gathering immediately after the event; authority to call meetings of affected or involved parties; and technical and analytical resources for studies. If a federal or multi-national government analysis is called for, government agencies should work in primarily an oversight and support role, in close coordination with the NERC analysis.

It is critical to establish, up front, a clear delineation of roles, responsibilities, and coordination requirements among industry and government for the analysis and reporting of findings, conclusions, and recommendations related to major blackouts, disturbances, or other emergencies affecting the bulk power system.

Depending on the severity and of the event and the area impacted, the event analysis may be conducted either by NERC or by the impacted RE. If the analysis is conducted by the regional entity, NERC staff, at least one member of the NERC Event Analysis Working Group (in addition to the Event Analysis Working Group member from the impacted regional entity), and other appropriate technical experts from the NERC community will participate as members of the regional entity analysis team.

A regional entity may request NERC to elevate an analysis to a NERC-level. In such cases, all team responsibilities will shift to NERC, and the regional entity may continue to participate in the analysis on appropriate teams.

These procedures do not represent a "cookbook" to be followed blindly. They provide a framework to guide NERC's response to events that may have multiregional, national, or international implications. Experienced industry leadership would still be required to tailor the response to the specific circumstances of the event.

Responding to major blackouts and other system disturbances can be divided into four phases:

1. situation assessment and communications;
2. situation tracking and communications;
3. data collection, investigation, analysis and reporting; and
4. follow-up on recommendations.

Phase 1 — Situation Assessment and Communications

NERC's primary roles in Phase 1 are to:

- conduct an initial situation assessment;
- call for the collection of and analyze necessary initial data and information for the event;
- assist the regional entity-lead analysis with determining the need for supplemental technical expertise from the NERC community;
- issue initial findings, conclusions, and recommendations;
- maintain detailed data records (not subject to Freedom of Information Act);
- assist government agencies in criminal analyses when relevant;
- provide technical expertise for modeling and analyzing the event; and
- follow up on recommendations.

While conducting its initial situation assessment, NERC will make an early determination as to whether the cause of the event may be related to physical or cyber security, and communicate as appropriate with government agencies.

Notice of a event is typically received by the NERC Electricity Sector Information Sharing and Analysis Center (ESISAC) person on duty and relayed to other appropriate NERC personnel.[1] NERC performs an initial situation assessment by contacting the appropriate reliability coordinator(s), and makes a decision on whether to activate its crisis communications plan. At the initial stage in gathering information about an incident, it is critical to minimize interference with bulk electric system operators who are in the process of restoring the system. To minimize interference with their work, NERC, in its capacity as the ESISAC, should serve as the primary communications link with government agencies.

The ESISAC Concept of Operations (ConOps) specifies the operations plan, communications procedures, and logistics NERC will follow during normal conditions, emergencies, and National Security Special Events. The ConOps includes the primary points of contact (24x7) for the Federal Energy Regulatory Commission, U.S. Department of Energy, U.S. Department of Homeland Security, U.S. Nuclear Regulatory Commission, and Public Safety and Emergency Preparedness Canada.

It is important that during these early hours the ESISAC, in coordination with government agencies, determine whether this event was caused by the actions of criminal or terrorist parties. The results of this criminal assessment are essential to operators because if there is a possibility that the "attack" is still ongoing, restoration and response actions would need to be tailored to

[1] NERC maintains 24x7 contact information for its key personnel to facilitate such contacts.

these circumstances. If NERC and government agencies deem it necessary for further criminal analyses, NERC will issue a formal notice to affected systems to retain all relevant information gathered during this and subsequent phases of an analysis.

The specific criteria for reporting disturbances and other events are described in NERC Reliability Standard EOP-004-1. These criteria and procedures are intended to provide a common basis for consistent reporting of abnormal system conditions and events that occur in North America. All entities responsible for the reliability of bulk power systems in North America must ensure that sufficient information is submitted to NERC within the time frame required. Reliability coordinators will use the Reliability Coordinator Information System (RCIS) as the primary method of communications to NERC. The ESISAC duty person is responsible for monitoring the RCIS for such notifications.

Depending on the scope and magnitude of the event, NERC will issue media advisories through its crisis communications plan.

Phase 2 — Situation Tracking and Communications

Based on the nature and severity of the event, in Phase 2 NERC will continue to track progress in restoring the bulk power system and service to customers, and keep industry, government agencies, and the public informed. The most important thing to recognize in this phase is that the primary focus of reliability coordinators and transmission operators is the prompt restoration of the bulk electric system. NERC will coordinate requests by government agencies for information from reliability coordinators and transmission operators, and serve as a conduit and coordinator between industry and government for regular status reports on the restoration.

As events continue, NERC will determine whether a detailed analysis of the event should be conducted, and start to identify manpower requirements, data collection and retention requirements, and at what level the analysis should be conducted. If the event is localized within a region, NERC will participate in the event analysis of the regional entity.

Phase 3 — Data Collection, Investigation, Analysis, and Reporting

Based on the scope, magnitude, and impact of an event, during Phase 3 NERC may:

1. perform an overview analysis of system and generator response;
2. rely on one of its regional entities to conduct the analysis and monitor the analysis results;
3. work with a regional entity in its analysis; or
4. conduct a NERC-level analysis.

The NERC CEO will decide, based on the initial situation assessment and consultation with the NERC technical committee officers[2], if a NERC-level analysis is warranted. If a NERC-level analysis is to be conducted, the NERC CEO will appoint the Director of Events Analysis and Information Exchange to lead the analysis and assemble a high-level technical steering group to provide guidance and support throughout the analysis.

[2] NERC will maintain a list of 24x7 contact information for its technical committee officers.

NERC reserves the right to elevate or augment an analysis performed by a regional entity pending the results of the regional entity analysis. Additional requests for analyses or supporting data may be made by NERC at any time in the investigation process.

A regional entity may request NERC to elevate an analysis to a NERC-level. In such cases, all team responsibilities will shift to NERC, and the regional entity may continue to participate in the analysis on appropriate teams.

If the analysis is to be lead by one of the regional entities, a member of the NERC staff, at least one member of the NERC Event Analysis Working Group (in addition to an Event Analysis Working Group member from the impacted regional entity), and other appropriate technical experts from the NERC community will participate as a triage team. The triage team will participate as members of the regional entity analysis team. The triage team will also will assist the regional entity with determining if additional technical expertise from the NERC community are needed for the analysis.

For NERC-level analyses, the first task of the Director of Events Analysis and Information Exchange would be to identify what technical and other resources and data would be needed from staff, the industry, and government, and to issue those requests immediately. This task will include identification of any special managerial, forensic, or engineering skills needed for the analysis. Secondly, the Director of Events Analysis and Information Exchange must issue requests for those resources and information. Third, the Director of Events Analysis and Information Exchange must organize the teams that will conduct and report on the analysis.

The teams needed for a particular analysis will vary with the nature and scope of the event. Attachment A describes the typical teams that would be required for a NERC-level analysis, and Attachment B provides suggested guidelines for the NERC-level analysis team scopes. Individuals that participate on these teams will be expected to sign an appropriate confidentiality agreement. NERC uses a standard (pro forma) confidentiality agreement (Attachment C) for participants in event analyses, which it will adapt for specific analyses.

The Blackout and Disturbance Analysis Objectives, Approach, Schedule, and Status (Attachment D) and Guidelines for NERC Reports on Blackouts and Disturbances (Attachment E) are used to guide and manage analysis and reporting on major blackouts and disturbances.

A NERC-level analysis will comprise (a) collecting pertinent event data; (b) constructing a detailed sequence of events leading to and triggering the disturbance; (c) assembling system models and data and conducting detailed system analysis to simulate pre- and post-event conditions; and (d) issuing findings, conclusions, and recommendations. The details of these four phases of the analysis are:

a. Collecting Pertinent Event Data

- Collect all pertinent event logs, disturbance recorders, operator transcripts, and other system data.

b. Detailed Sequence of Events

- Construct a detailed sequence of events leading to and triggering the event. Reconcile event logs, disturbance recorders, operator transcripts, and other system data to create an accurate sequence of events.

- Enter and preserve all data in a secure data warehouse.

c. Detailed System Analysis

- Assess the sequence of events to determine critical times for study.
- Assemble the necessary system models and data from regional entity and operating entities to accurately model (with power flow and dynamic simulations) the pre-event conditions.[3] Determine pre-event conditions at critical times prior to event initiation, including an assessment of reliability margins in the pre-event time frame.
- Analyze data from phasor measurement units, high-speed data recorders, digital fault recorders, digital relays, and system relay targets.[4]
- Analyze generator and load performance, including underfrequency and undervoltage relay actions.
- Use the model information and sequence of events to dynamically model the trigger events and the outage sequence. Identify the system phenomena that propagated the failure. Provide graphical results showing the nature of the cascade. Conduct additional analyses as initial findings identify the need for further study.

d. Findings, Conclusions, and Recommendations

- Identify and assess failures contributing to the event, including possible instability conditions, system protection mis-operations, generator actions, etc.
- Either identify or rule out man-made/criminal cyber or physical attacks on the electric system.
- Determine if the system was being operated within equipment and system design criteria at the time of the outage.
- Assess the qualifications, training, SCADA/EMS tools, and communications available to system operators and reliability coordinators, and how effective these were leading up to and during the event.
- Assess the adequacy of communications system and communications among system operators.
- Identify any issues regarding maintenance or equipment conditions that may have contributed to the outage.
- Determine whether system restoration procedures were available and adequate. Identify any issues that caused unexpected delays in the restoration of generators and loads.
- Identify the root causes[5] and contributing factors of the cascading outage.
- Recommend actions to prevent cascading outages in the future and to improve system reliability.
- Determine whether the system is adequately designed.
- All compliance issues will be referred to the NERC Director of Compliance.

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[3] NERC is developing standards for data and model validation that will facilitate modeling activities in future blackout analyses.

[4] NERC is developing standards for dynamic monitoring equipment and the deployment of such equipment at critical locations in the bulk electric system.

[5] NERC will rely on root cause analysis experts, both from within the industry and outside consultants, to conduct these analyses.

Phase 4 — Follow-up on Recommendations

For Phase 4 NERC and the regional entities will follow up on specific recommendations coming from all analyses, whether done at the regional entity or NERC level. In certain cases, where government agencies have taken a direct role in the analysis, reports will be made to those agencies on progress in addressing the recommendations.

Attachment A

Typical Team Assignments for Analysis of Blackouts or Disturbances[6]

Fact-Finding Teams

- Physical and/or cyber security (if needed)
- On-site interviews
- System data collection (frequency, voltages, generation and loads)[7]
- System protection and control information
- System restoration
- Coordination with regional entity teams

Assessment and Analysis Teams

- Performance of generation and transmission protection systems
- Frequency analysis
- Equipment maintenance
- SCADA/EMS/Tools
- Operator training
- Standards compliance
- System planning
- System operation
- System restoration
- Root cause analysis
- System simulation
- Interregional coordination
- Vegetation management
- Recommendations for future actions
- Security and law enforcement liaison

Data Management Teams

- Data requests
- Data collection
- Data warehouse – entry, logging, retention, and maintenance[8]
- Data release[9]

Report Writing Teams

- Text
- Graphics
- Presentations

[6] The analysis team leader will specify the tasks required of each team.
[7] Standard forms and procedures for the collection of data and information will be adapted for particular circumstances.
[8] Experience with data warehousing and access procedures gained during the investigation of the August 2003 blackout will be used in future investigations.
[9] Data release procedures will prevent inappropriate disclosure of information.

Communications Teams

- Press releases
- Interface with government agencies
- Interviews

Attachment B

NERC Blackout and Disturbance Response Procedures
Guidelines for Analysis Team Scopes

Each blackout or disturbance is unique and will therefore demand a customized approach to its analysis. The following guidelines for analysis team scopes are suggestive rather than definitive. Not all the teams listed may be needed for a particular analysis.

Data Requests and Management — This team organizes large volumes of raw data and value-added information produced by analysts in support of the blackout analysis into a data warehouse. The team issues data requests from affected entities, catalogs and stores all data received, and provides secure and confidential access to teams and personnel supporting the analysis. The team serves as the single point for issuing data requests, receiving and storing data, and managing data queries by the analysts, and is responsible for assuring consistency, security, and confidentiality of the data and minimizing redundant data requests.

Sequence of Events — A precise, accurate sequence of events is a building block for all other aspects of the analysis, and is a starting point for the root cause analysis. It is the basis for developing computer models to simulate system conditions and evaluate steady state and stability conditions in the period leading to blackout. The sequence of events is the foundation of facts upon which all other aspects of the analysis can proceed.

System Modeling and Simulation Analysis — System modeling and simulation allows the investigators to replicate system conditions leading up to the blackout. While the sequence of events provides a precise description of discrete events, it does not describe the overall state of the electric system and how close it was to various steady state, voltage stability, and power angle stability limits. An accurate computer model of the system, benchmarked to actual conditions at selected critical times, allows analysts to conduct a series of sensitivity studies to determine if the system was stable and within limits at each point in time leading up to the blackout, and at what point the system became unstable. It also allows analysts to test different solutions to prevent cascading. Although it is not possible recreate the entire blackout sequence, simulation methods will reveal the mode(s) of failure initiating the blackout and propagating through the system.

Root Cause Analysis — Root cause analysis guides the overall analysis process by providing a systematic approach to evaluating root causes and contributing factors leading to the blackout or disturbance. This team works closely with the technical analysis teams and draws on other data sources as needed to record verified facts regarding conditions and actions (or inactions) that contributed to the blackout or disturbance. The root cause analysis guides the overall analysis by indicating areas requiring further inquiry and other areas that may be of interest regarding lessons learned, but are not causal to the blackout. Root cause analysis enables the analysis process develop a factual record leading to logical and defensible conclusions in the final report regarding the causes of the blackout.

Operations Tools, SCADA/EMS, Communications, and Operations Planning — This team will assess the observability of the electric system to operators and reliability coordinators, and the availability and effectiveness of operational (real-time and day-ahead) reliability assessment tools, including redundancy of views and the ability to observe the "big picture" regarding bulk electric system conditions. The team also investigates the operating practices and effectiveness of those practices of operating entities and reliability coordinators in the affected area. This team investigates all aspects of the blackout related to operator and reliability coordinator knowledge of system conditions, action or inactions, and communications.

Frequency/ACE — This team will analyze potential frequency anomalies that may have occurred, as compared to typical interconnection operations, to determine if there were any unusual issues with control performance and frequency and any effects they may have had related to the blackout.

System Planning, Design, and Studies — This team will analyze the responsibilities, procedures, and design criteria used in setting system operating limits, and compare them to good utility practice. The team will review the actual limits in effect on day of the blackout and whether these limits were being observed. The team will review voltage schedules and guides, and reactive management practices in the affected areas, including use of static and dynamic reactive reserves. The team will analyze the tagged and scheduled transactions to determine if inter-regional transfer limits were understood and observed. The team will analyze system planning and design studies completed in the affected areas to determine if operating conditions were consistent with the assumptions of those studies and whether the planning and design studies were sufficient and effective.

Transmission System Performance, Protection, Control, Maintenance, and Damage — This team investigates the causes of all transmission facility automatic operations (trips and reclosures) leading up to the blackout on all facilities greater than 100 kV. This review includes relay protection and remedial action schemes, identifying the cause of each operation, and any misoperations that may have occurred. The team also assesses transmission facility maintenance practices in the affected area as compared to good utility practice and identifies any transmission equipment that was damaged in any way as a result of the blackout. The team will assess transmission line rating practices and the impact that ambient temperature and wind speeds had on the transmission line performance in terms of the design temperature of the transmission conductors. The team shall report any patterns and conclusions regarding what caused transmission facilities to trip; why the blackout extended as far as it did and not further into other systems; why the transmission separated where it did; any misoperations and the effect those misoperations had on the blackout; and any transmission equipment damage. The team will also report on the transmission facility maintenance practices of entities in the affected area compared to good utility practice. Vegetation management practices are excluded here and covered in a different team.

Generator Performance, Protection, Controls, Maintenance and Damage — This team will investigate the cause of generator trips for all generators with a 10 MW or greater nameplate rating leading to and through the end of the blackout. The review shall include the cause for the generator trips, relay targets, unit power runbacks, and voltage/reactive power excursions. The team shall report any generator equipment that was damaged as a result of the blackout. The team shall report on patterns and conclusions regarding what caused generation facilities to trip. The team shall identify any unexpected performance anomalies or unexplained events. The team shall assess generator maintenance practices in the affected area as compared to good utility practice. The team will analyze the coordination of generator under-frequency settings with transmission settings, such as under-frequency load shedding. The team will gather and analyze data on affected nuclear units and work with the Nuclear Regulatory Commission to address nuclear unit issues.

Vegetation/ROW — This team investigates the practices of transmission facility owners in the affected areas for vegetation management and ROW maintenance. These practices will be compared with accepted utility practices in general, and with NERC Reliability Standards. The team will evaluate whether the affected parties were within their defined procedures at the time of the blackout and will investigate historical patterns in the area related to outages caused by contact with vegetation.

Analysis Process and Procedures Review — This team will review the process and procedures used in the analysis of the blackout, make recommendations for improvement, and develop recommendations for appropriate processes, procedures, forms, etc. to guide and expedite future analyses including coordination and cooperation between NERC, its regional entities, and government agencies.

Restoration Review — All entities operating portions of the bulk electric system in North America are required by NERC Reliability Standards to maintain System Restoration Plans and Black Start Plans, and Reliability Coordinators are required to coordinate the implementation of those plans. This team will review the appropriateness and effectiveness of the restoration plans implemented and the effectiveness of the coordination of these plans.

NERC and RE Standards/Procedures and Compliance — This team reviews the adequacy of NERC Reliability Standards, regional entity standards and procedures, and the compliance monitoring program to address issues leading to the blackout. The team also reviews the compliance of the affected operating entities with Reliability Standards. For less significant event analyses, this tea may not be needed. However, all compliance issues will be referred to the NERC Director of Compliance.

Attachment C

NERC CONFIDENTIALITY AGREEMENT FOR ANALYSIS OF BLACKOUTS AND DISTURBANCES

This Confidentiality Agreement ("Agreement"), dated _______________, is between the North American Electric Reliability Corporation ("NERC"), and

____, a member of the NERC Event Analysis Team ("Team Member")(collectively referred to as "Parties").

WHEREAS, NERC is conducting an analysis of the power event that occurred in ___________________________ on ____________________ and related matters ("Event"); and

WHEREAS, NERC has established a team to carry out that analysis ("Event Analysis Team"); and

WHEREAS, in order for the Event Analysis Team to fulfill its objectives, it is necessary for the Event Analysis Team have access to confidential or business sensitive information from operating entities within the _______________ and to be able to conduct open and unconstrained discussions among team members,

The Parties therefore agree as follows:

1. The term "Event Analysis Information" means all information related in any way to the Event that operating entities within the _____________________ or their representatives have furnished or are furnishing to NERC in connection with NERC's analysis of the Event, whether furnished before or after the date of this Agreement, whether tangible or intangible, and in whatever form or medium provided (including, without limitation, oral communications), as well as all information generated by the Event Analysis Team or its representatives that contains, reflects or is derived from the furnished Event Analysis Information; provided, however, the term "Event Analysis Information" shall not include information that (i) is or becomes generally available to the public other than as a result of acts by the undersigned Parties or anyone to whom the undersigned Parties supply the Information, or (ii) is known to or acquired by the Team Member separate from receiving the information from the Event Analysis Team.

2. The Team Member understands and agrees that the Event Analysis Information is being made available solely for purposes of the Event Analysis and that the Event Analysis Information shall not be used in any manner to further the commercial interests of any person or entity. The Team Member further understands and agrees that he or she will not disclose Event Analysis Information to any person who has not signed this Agreement except as such disclosure may be required by law or judicial or regulatory order.

3. If Team Member's employing organization has signed the NERC Confidentiality Agreement for Electric System Security Data ("NERC Security Data Agreement"), paragraph 2 shall not be deemed to prohibit Team Member from disclosing Event Analysis Information to

other employees of that organization, but only to the extent that “security data” as defined in the NERC Security Data Agreement is shared within the organization.

4. The Parties expressly agree that Event Analysis Information shall otherwise only be disclosed through official releases and reports as authorized by NERC.

5. It shall not be a violation of the NERC Confidentiality Agreement for Electric System Security Data for a Reliability Coordinator to furnish Event Analysis Information to an Event Analysis Team Member who has signed this Agreement.

6. This Agreement shall be for sole benefit of the parties hereto. This Agreement may be modified or waived only by a separate writing signed by the Parties. If any clause or provision of this Agreement is illegal, or unenforceable, then it is the intention of the Parties hereto that the remainder of this Agreement shall not be affected thereby, and it is also the intention of the Parties that in lieu of each clause or provision that is illegal, invalid or unenforceable, there be added as part of this Agreement a clause or provision as similar in terms to such illegal, invalid or unenforceable clause or provision as may be possible and be legal, valid and enforceable. This Agreement will be governed and construed in accordance with the laws of the State of New Jersey, except for any choice of law requirement that otherwise may apply the law from another jurisdiction.

7. This Agreement shall have a term of two (2) years from the date hereof, except that the obligations of paragraphs 2, 3, and 4 shall continue for five (5) years from the date hereof.

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

By: ______________________________________

Printed: __________________________________

Title: ____________________________________

NERC EVENT ANALYSIS TEAM MEMBER

Signed: ___________________________________

Printed: ___________________________________

Attachment D

NERC Blackout and Disturbance Analysis Objectives, Analysis Approach, Schedule, and Status

Analysis Objective	Analysis Approach	Schedule	Status
Pre-Event Conditions			
1. What was the precursor sequence of events leading to the event?	• Assemble data/alarm logs and time-stamped sequence information. • Develop and maintain an expanding database of log and time-stamped sequence information. • Develop a precursor sequence of high-level, events relevant to, and leading to event initiation. • Reconcile the precursor sequence of events with those emerging from REs, RTOs, and operating entities.		
2. What time frames are relevant for pre-event assessment of system conditions? What points in time should be used to establish a baseline set of study conditions when the system was last known to be stable and within normal operating criteria?	• Referencing precursor sequence of events, determine relevant times to develop base case conditions (stable and within normal operating criteria). • Verify relevant time horizons and availability of system data at those times with REs organizations, RTOS, and operating entities.		
3. What models and data can best simulate system conditions prior to and during the event? What is the relevant scope of the system for detailed study (what is considered the boundary of the study system and what is considered neighboring or external systems?)	• Identify up-to-date power system model(s) appropriate for powerflow and transient and dynamic simulations (determine if detailed eastern interconnection model is needed or multi-regional model(s) are needed. • Identify what models are available in REs, RTOs, and operating entities. • Identify who will actually perform power flow, transient and dynamic simulations; hire contractor(s) as needed. • Identify and assemble data required for these models. • Develop and maintain a system data repository.		

Analysis Objective	Analysis Approach	Schedule	Status
4. What system conditions existed in the precursor time horizon leading up to the event (at the times identified in 1.)?	• Obtain and manage data for powerflow: system configuration, planned and unplanned outages, unit commitment and dispatch, interchange schedules, congestion conditions, reserves, loads, state estimator snapshots, deratings and limitations, frequency, etc. Identify who will maintain and run powerflow simulations. • Work with REs, RTOs, and operating entities to develop powerflow cases defining the base conditions for each relevant time, ensuring the powerflows model each critical juncture leading up to the event. • Identify and review results of additional studies completed by reliability coordinators, RTOs and operating entities. • Assess the powerflow results with respect to steady state operating criteria (was the system within all known limits at each precursor time)?		
5. Were there any prior-existing abnormalities, instabilities, reliability criteria violations, or reliability issues in the precursor sequence time horizon? Prior to event initiation were there any latent instability conditions that would suggest the system was at risk? Were the precursor conditions ones that had been previously studied by the entities involved? Were there adequate reserves with effective distribution? Were planned outages effectively coordinated?	• Work with REs, RTOs, and operating entities to obtain and manage transient and dynamic models for simulations. • Identify who will conduct transient and dynamic simulations and if external contractor(s) are required. • Conduct transient and dynamic simulations at each of the precursor study times. • Assess the stability of the system at each of these times and identify any latent reliability issues prior to blackout initiation. • Consider creating a visual map of system conditions. • Document the limitations and assumptions of simulations affecting the certainty of the simulation results.		
Blackout Sequence of Events			
6. What was the sequence of system events leading to and directly triggering the blackout?	• Evaluate data logs, fault recorder data disturbance recorder data, and synchro-phasor measurement to establish a detailed sequence of events that initiated the event. • Identify the sequence of events that directly led to the event. • Review and reconcile these trigger events with REs, RTO, and operating entity analyses.		
7. What was the sequence of events during the event?	• Evaluate logs and disturbance recorder data to establish sequence during the blackout. (The event sequence may follow multiple tracks.) • Review and reconcile this sequence with those constructed by REs, RTOs, and operating entities. • Consider developing 3-D, time-lapse visualization of the blackout (U. of Minnesota and/or U. of Wisconsin).		

Analysis Objective	Analysis Approach	Schedule	Status
8. What was the cause of the event in terms of electrical conditions and other related events? Generally describe any system breakups, islanding, etc. Were there conditions of voltage or frequency collapse, or unstable oscillations? Was the sequence strictly a sequential "domino" effect of facility trips? What were the system conditions (snapshots) at key points during the event?	• Assess triggering sequence and blackout sequence to establish the causes for the blackout in terms of electrical conditions and events. • Select key points in sequence for simulation that are relevant for study and that can be accurately modeled. (It may not be possible to reconcile data sufficiently to recreate system conditions during the blackout.) • To the extent possible, conduct simulations and assess results at each point during the blackout. • Review and reconcile results with REs, and operating entities.		
9. Why did the event extend as far as it did? What arrested the event from extending further into other systems?	• Using advanced analysis techniques, assess where and why the event was arrested.		
10. How did affected non-nuclear generators respond during the event? Were trips as expected and required by procedures and standards? Did non-nuclear generators remain connected and support the power system in the manner they should have? Did any generator action, generator control functions, or generator protection systems contribute to the event?	• Prepare a table of affected generators and actions they made leading up to and during the event, including time-stamped unit trips, relays initiating unit trips, MW and MVar outputs, voltages, and frequency, etc. • Analyze the automatic (including relay trips) and operator-initiated actions of non-nuclear generators to determine whether actions were correct under the conditions or not. • Reconcile non-nuclear generator data and analysis with that of the REs, RTOs, and operating entities.		
11. How did nuclear generators respond leading up to and during the blackout? Were trips as expected and required by procedures and standards? Were there any nuclear safety issues identified?	• Work with NRC to develop a table of sequence of actions and issues regarding affected nuclear generators (both ones that tripped and those that did not). • Refer nuclear issues to NRC for analysis, assisting in their analyses where appropriate.		
12. What was the sequence and amount of load lost? What directly caused load loss (e.g. under-frequency load shed, loss of transmission source, voltage collapse, relay actions, under/over frequency protection or stalls, etc.)	• Work REs, RTOs, and operating entities to develop a description of load lost/impacted, by area. • Analyze and report the cause for load loss in each area.		
13. How did system protection and automated controls operate during the event? Did they operate correctly or not?	• Assess each automatic trip of a transmission or generator facility for proper or improper relay actions. • Assemble and review RE and operating entity reviews of logs, disturbance reports, and relay targets/logs and reconcile with NERC data.		

Analysis Objective	Analysis Approach	Schedule	Status
14. Was any equipment damaged during the event?	• Request information from REs, and companies on equipment damage, as appropriate. • Assess any transmission or generation facilities sustaining damage during the event, and extent of damage.		
15. Did SCADA/EMS and data communications systems operate correctly during the event? What problems were noted?	• Request information from REs, and companies. • Identify and analyze any problems with SCADA/EMS and data communications at regional and company levels.		
Reliability Standards/Procedures			
16. What NERC reliability standards were applicable to the event? What violations occurred? Were NERC standards and policies sufficient?	• Compliance staff review NERC standards relevant to the event and perform a compliance review.		
17. What RE reliability standards were applicable to the event? What violations occurred? Were RE standards and policies sufficient?	• Request REs to review applicable standards and report compliance with those standards during the event.		
18. Were any special operating procedures or other operating guidelines in effect and being observed leading up to the event? Were these procedures sufficient?	• Review and analyze loop flow procedures with involved REs and companies, and report analysis results.		
19. What other RTO, TO, CA procedures were applicable? What violations occurred? Were the procedures sufficient?	• Request RTOs, TOs, CAs to review applicable standards and compliance with existing reliability procedures and standards during the event, and report results.		
Maintenance			
20. Are there any indications that maintenance of transmission or generation facilities may have contributed to the event?	• Assess whether equipment or maintenance issues (e.g. tree trimming) contributed to the blackout and investigate specifics in areas of concern. • Review RE assessments of maintenance issues that may have contributed to the event.		

Personnel, Procedures, and Communications			
21. What conditions were operators and reliability coordinators aware of leading up to and during the event? What information did they have to warn them of unsafe system conditions? What problems or concerns did they have? What did they observe during the event? Were human errors made that contributed to the event? If there were, what were the causes of the errors?	• Develop an interview guide to address procedural and operational issues. • Conduct onsite interviews with operating personnel and reliability coordinators involved. • Analyze interview data to corroborate with technical data and report conclusions.		
22. Were lines of authority clearly understood and respected in the time leading up to and during the event, as well as during the restoration period?	• Identify critical instructions given and evaluate results. • Review documentation and effectiveness of assignments of operating and reliability authorities.		
23. What communications occurred among operating entities?	• Review voice communications logs. • Evaluate logs relevant to the blackout and identify key interactions. Report conclusions.		
24. What were the qualifications (including certification status) and training of all operating personnel involved in the event and their supervisors?	• Request certification status of all operating personnel from involved operating entities. • Conduct onsite review of training materials and records. • Conduct onsite review of operating procedures and tools		
25. Was the role and performance of the reliability coordinators as expected?	• Review the adequacy of reliability plans for the affected REs. • Review the actions of the affected reliability coordinators to determine if they performed according to plans. • Assess whether inter-area communications were effective, both at the control area and reliability coordinator levels.		
System Restoration			
26. Were black start and restoration procedures available and adequate in each area? Were they followed and were they adequate to the restoration task? Were pre-defined authorities respected during the restoration?	• Onsite audit of blackstart and restoration procedures and plans. • Analyze whether the plans and procedures were used and whether they were sufficient for this outage.		
27. What issues were encountered in the restoration that created unexpected challenges or delays? What lessons were learned in the restoration (both things that went well and things that did not).	• Solicit information from operating entities and REs regarding unexpected challenges and delays in restoration, and lessons learned. • Analyze what worked well and what did not in the restoration.		

System Planning and Design			
28. Were the conditions leading up to the event within the design and planning criteria for the transmission systems involved?	• Request transmission owners and REs involved to report any violations of design or planning criteria prior to or leading up to the blackout.		
Conclusions and Recommendations			
29. From a technical perspective, what are the root causes of this event? What additional technical factors contributed to making the event possible?	• Conduct a root cause analysis on the findings and data. Categorize results as “root cause” or “contributing factor”. Focus on technical aspects.		
30. What are the significant findings and lessons learned resulting from the analysis regarding technical failures leading to the event? What actions are recommended to avoid similar future events and improve bulk electric system reliability? What issues may be inconclusive and require future analysis?	• Draft report of significant findings, lessons learned, and recommendations.		
31. Final Report	• Prepare and coordinate publication of final report.		

Guidelines for NERC Reports on Blackouts and Disturbances[10]

Introduction and Purpose

Executive Summary of Blackout or Disturbance

Conclusions & Recommendations

Actions to Minimize the Possibility of Future Blackouts and Disturbances

Detailed Analysis of Event

1. **Sequence of Events**
   - 1.1. Sequence of transmission and generation events
     - 1.1.1. Reasons for each trip
     - 1.1.2. Sequence of loss of load
     - 1.1.3. Description of cascading and islanding

2. **System Modeling**
   - 2.1. Model and assumptions
     - 2.1.1. Equipment ratings and limits
     - 2.1.2. Steady state, system dynamics, and other analyses
     - 2.1.3. Degree of simulation success
     - 2.1.4. Simulation results
     - 2.1.5. Conclusions and lessons learned

   - 2.2. Pre-event Conditions
     - 2.2.1. Load levels
       - 2.2.1.1. Forecast vs. Actual
       - 2.2.1.2. Comparison with planning and operational models
     - 2.2.2. Generation dispatch
       - 2.2.2.1. Forecast vs. actual
       - 2.2.2.2. Comparison with day ahead studies
       - 2.2.2.3. Reporting of scheduled and forced outages
     - 2.2.3. Reserve capacity
       - 2.2.3.1. Location of MW reserves
       - 2.2.3.2. Planned vs. actual
     - 2.2.4. Transmission configurations
       - 2.2.4.1. Planned vs. actual
       - 2.2.4.2. Comparison with day ahead studies
       - 2.2.4.3. Reporting of scheduled and forced outages

[10] Each blackout or disturbance is unique and will therefore demand a customized approach to its investigation and reporting. These guidelines for NERC reports are suggestive rather than definitive. Not all investigations and reports will require covering all of these topics.

2.2.5. Interregional transactions
2.2.5.1. Calculated transfer limits
2.2.5.2. Basis for limits – thermal, voltage, and stability
2.2.5.3. Seasonal assessments – Assumptions vs. actual
2.2.5.4. Actual schedules vs. Tagged schedules
2.2.5.4.1. AIE Survey
2.2.5.4.2. Tag Survey
2.2.6. System voltages (profile) and reactive supplies
2.2.6.1. Coordination of reactive supplies and voltage schedules
2.2.6.2. Reactive supply with power transfers

2.3. Event Key Parameters
2.3.1. System voltages (profile) and reactive supplies
2.3.2. Power flows and equipment loadings
2.3.3. System dynamic effects

3. Transmission system performance

3.1. Equipment ratings
3.2. Protective relay actions
3.3. Equipment maintenance
3.4. Equipment damage

4. Generator performance

4.1. Generator control actions
4.2. Generator protection
4.2.1. Underfrequency
4.2.2. Overspeed
4.2.3. Excitation systems
4.2.4. Other systems
4.3. Equipment maintenance
4.4. Equipment protection
4.5. Dynamic effects of generators

5. System frequency

5.1. Frequency excursions – pre event
5.1.1. Analysis of frequency anomalies
5.1.2. Effect of time error correction
5.2. Frequency analysis of the event
5.2.1. Remaining interconnection
5.2.2. Islands remaining

6. Operations

6.1. Operational visibility and actions
6.1.1. Reliability Coordinators
6.1.1.1. Delegation and authority
6.1.1.2. Monitoring capabilities
6.1.1.2.1. Scope of coverage and system visibility

6.1.1.2.2. Monitoring tools
6.1.1.2.3. Data availability and use
6.1.1.3. Operations planning capability
6.1.1.3.1. Operational planning tools
6.1.1.3.2. Coordination
6.1.1.4. Operating procedures
6.1.1.4.1. Emergency operations
6.1.1.4.2. Loss of monitoring system or components
6.1.1.4.3. Communication procedures
6.1.1.5. Operating qualifications and training
6.1.1.5.1. Qualification of operators
6.1.1.5.2. Training provided
6.1.1.5.3. Simulation of emergencies
6.1.2. Transmission Operators
6.1.2.1. Authority to take action
6.1.2.2. Monitoring capabilities
6.1.2.2.1. Scope of coverage and system visibility
6.1.2.2.2. Monitoring tools
6.1.2.2.3. Data availability and use
6.1.2.3. Operations planning capability
6.1.2.3.1. Operational planning tools
6.1.2.3.2. Coordination
6.1.2.4. Operating procedures
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6.1.2.4.3. Communication procedures
6.1.2.5. Operating qualifications and training
6.1.2.5.1. Qualification of operators
6.1.2.5.2. Training provided
6.1.2.5.3. Simulation of emergencies

7. System Planning and Design

7.1. Establishing operating limits
7.1.1. Responsibility for setting limits
7.1.2. ATC and TTC calculations
7.1.3. Planning studies
7.1.3.1. ·Wide-area simultaneous transfer limits
7.1.3.1.1. Determination of limits
7.1.3.1.2. Monitoring of limits
7.1.3.1.3. Basis for limits – thermal, voltage, and stability
7.1.3.1.4. RE assessments
7.1.3.1.5. Other system studies in affected areas
7.1.3.2. Reactive planning
7.1.3.2.1. Reactive reserve planning
7.1.3.2.2. Active vs. static resources
7.1.3.2.3. Voltage stability analysis
7.1.3.3. RE criteria and/or NERC standards used for planning

7.1.3.3.1. Compliance to these planning criteria and/or standards

8. Reliability Standards and Compliance

8.1. Audits
8.1.1. Reliability Coordinators
8.1.1.1. Previous audits and results
8.1.1.1.1. Compliance with NERC standards
8.1.1.2. Updated findings based on analysis
8.1.1.3. Post blackout audit results and findings
8.1.1.4. Recommendations for future audits
8.1.2. Balancing Authorities
8.1.2.1. RE audits
8.1.2.1.1. Compliance with NERC and RE standards
8.1.2.2. Updated findings based on analysis
8.1.2.3. Post blackout audit results and findings
8.1.2.4. Recommendations for future audits
8.2. RE criteria and/or NERC Reliability Standards used for operations
8.2.1. Compliance to these operating criteria and/or standards
8.3. Reliability Standards
8.3.1. Improvements needed
8.3.2. Potential new standards

9. Actions to Minimize the Possibility of Future Widespread Events

9.1. Reliability Standards and Compliance to Standards
9.2. Availability of Planned Facilities as Scheduled
9.3. Automatic Load Shedding Programs
9.4. Controlled Separation and Islanding
9.5. Improved Data Collection and System Monitoring
9.6. Studies of Impacts of Severe Events

10. Restoration of Service

10.1. Restoration Procedures
10.1.1. RTOs and ISOs
10.1.2. Transmission operators
10.1.3. Generator operators
10.1.4. Distribution providers

10.2. Restoring service
10.2.1. Transmission Line Restoration
10.2.1.1. Within control area/ISO/RTO
10.2.1.2. Interarea tie lines
10.2.1.3. Impediments and other issues
10.2.2. Generation Restoration
10.2.2.1. Utility-owned generation
10.2.2.2. Independent generation
10.2.2.3. Fuel supply adequacy
10.2.2.4. Fossil units

10.2.2.5. Nuclear units
10.2.2.6. Capacity reserves
10.2.2.7. Coordination with transmission
10.2.2.8. Coordination with load and other generation
10.2.2.9. Impediments and other issues
10.2.3. Coordination and Communications
10.2.3.1. Within control area/ISO/RTO
10.2.3.2. With outside control areas/ISOs/RTOs
10.2.3.3. Wide-area coverage
10.2.3.4. Impediments and other issues

10.3. Review of Restoration Procedures
10.3.1. Time to restore customers
10.3.2. Need for modifications
10.3.3. Availability of procedures to necessary participants
10.3.4. Need for training and practice drills
10.3.5. Comparison with other control areas/ISOs/RTOs

11. Analysis Process

11.1. Description of process
11.1.1. Organization
11.1.2. Coordination with US-Canada Task force
11.1.3. Coordination with RE and RTOs
11.1.4. Recommended process improvements
11.1.4.1. Use for other events – near misses, etc.
11.2. Data Management
11.2.1. Data collection processes
11.2.1.1. Data request process
11.2.1.2. Data forms used
11.2.2. Data received
11.2.2.1. Quality and usefulness of data
11.2.3. Data warehousing
11.2.3.1. Data warehouse structure
11.2.3.2. Accessibility of data
11.2.4. Data forms and process for future analyses