NERC

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Measure 7 Analysis

System Analysis and Modeling Subcommittee

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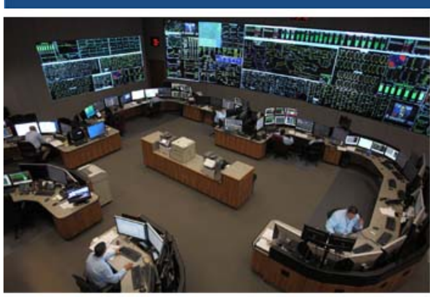
RELIABILITY | ACCOUNTABILITY

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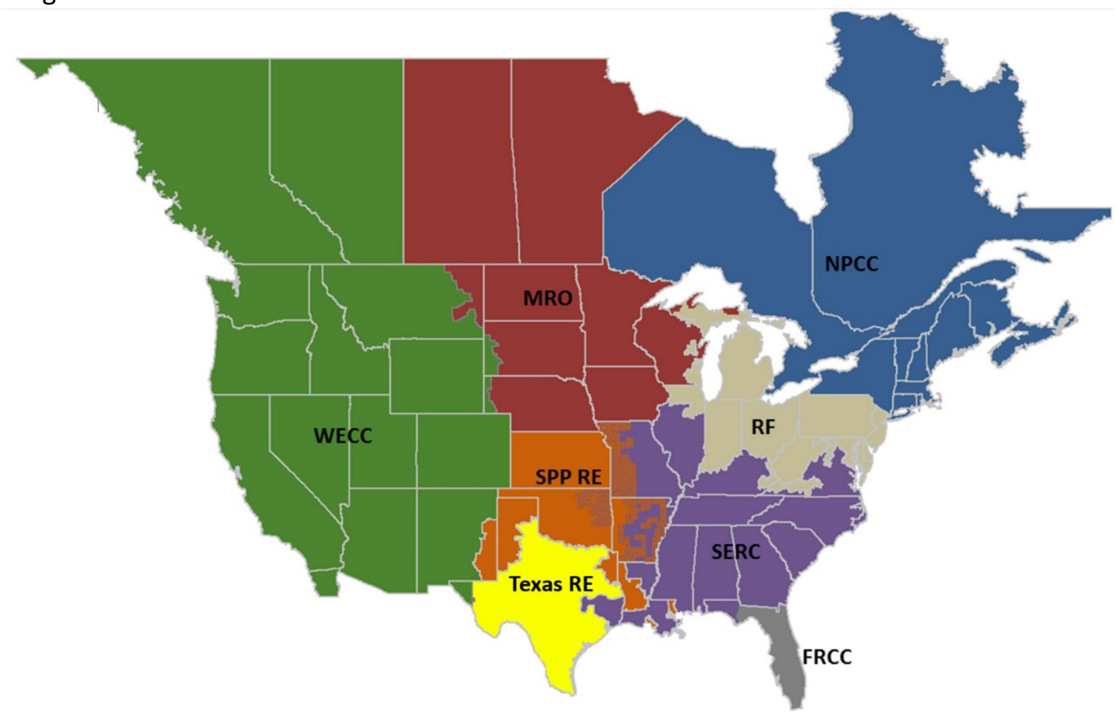
Preface

The North American Electric Reliability Corporation (NERC) is a not-for-profit international regulatory authority whose mission is to assure the reliability of the bulk power system (BPS) in North America. NERC develops and enforces Reliability Standards; annually assesses seasonal and long-term reliability; monitors the BPS through system awareness; and educates, trains, and certifies industry personnel. NERC's area of responsibility spans the continental United States, Canada, and the northern portion of Baja California, Mexico. NERC is the electric reliability organization (ERO) for North America, subject to oversight by the Federal Energy Regulatory Commission (FERC) and governmental authorities in Canada. NERC's jurisdiction includes users, owners, and operators of the BPS, which serves more than 334 million people.

The North American BPS is divided into eight Regional Entity (RE) boundaries as shown in the map and corresponding table below.



The North American BPS is divided into eight Regional Entity (RE) boundaries. The highlighted areas denote overlap as some load-serving entities participate in one Region while associated transmission owners/operators participate in another.

FRCC	Florida Reliability Coordinating Council
MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst Corporation
SERC	SERC Reliability Corporation
SPP RE	Southwest Power Pool Regional Entity
Texas RE	Texas Reliability Entity
WECC	Western Electricity Coordinating Council

Executive Summary

The NERC System Analysis and Modeling Subcommittee (SAMS) was initially tasked with analyzing the Essential Reliability Services Task Force (ERSTF) Measure 7 data collected from Balancing Authorities (BAs) for peak, shoulder, and light load levels. The SAMS analysis was a "proof of concept" to determine the effectiveness of Measure 7 data in understanding trends in reactive power support and voltage regulation across the system.

The NERC Performance Analysis Subcommittee (PAS) was tasked with collecting a complete set of Measure 7 data from the registered BAs. The collection process was voluntary. Data collected included three prior years of actual data from energy management system (EMS) archives for years 2013, 2014, and 2015, as well as three future years' data from planning base cases for years 2016, 2017, and 2020. Because this was a "proof of concept", PAS opted to only collect the data for summer peak hour conditions. The data collected focuses on generator and dynamic reactive capability, static reactive capability, and load power factor. Additionally, not all BAs provided both planning and operating data. The partial data was not included in the analysis performed by SAMS.

The SAMS analysis of the data identified a number of observations that varied in subject and significance. The following is a summary of the key observations:

1. The significant number of variables and uncertainties in the data nullifies the desired benefit of Measure 7 data to provide useful or valuable information pertaining to how the changing resource mix affects reactive capability on the BPS.
2. Data, related to reactive capability and system voltage needs, collected at the BA level does not provide useful information since reactive power needs are a relatively localized issue. Stated another way, a specific area deficient in reactive capability most likely would be overlooked if the BA metric indicated acceptable reactive capability at its level.
3. FERC issued Order 827, subsequent to the development of Measure 7, which requires non-synchronous resources to provide dynamic reactive power capability and voltage control similar to synchronous resources. Order 827 will likely alleviate some of the concerns of reactive deficiency due to a changing resource mix.
4. A noticeable variance in some areas was observed between the operations and planning data. This variance appears to stem from the means in which the data is accounted for in operations and planning (e.g., how the planning cases are built compared with actual system operating conditions, BA-level data collection in the model as compared with how data is pulled from the data historian from actual data, etc.).
5. The "Normalized BA Total Dynamic MVAR" was the closest metric to something useful since it normalizes any dynamic capability with demand level. However, this metric is not sufficient, as it does not capture how area dependency or contingency dependency relate to reactive reserves.

The following is a summary of the recommendations resulting from the SAMS analysis of the Measure 7 data.

1. Discontinue the use of Measure 7 data collection based on the failure of the "proof of concept" analysis to demonstrate any effectiveness in developing cogent trends in reactive power support and voltage regulation.
2. Use a combination of the Essential Reliability Services Whitepaper on Sufficiency Guidelines (use of sub-areas within a BA) and the Reliability Guideline for Reactive Power Planning to advocate reliable reactive power planning practices. NERC SAMS developed the Reliability Guideline to provide a comprehensive overview of reactive power planning practices to ensure reliable voltages and operation of the BPS.

Introduction

In 2014, NERC Planning and Operating Committees jointly created the Essential Reliability Services Task Force (ERSTF) to identify essential services for reliability of the bulk power system BPS. The ERSTF created three technical sub-teams to develop Essential Reliability Services (ERS) measures – frequency support, ramping capability, and voltage support. The sub-teams originally developed ten ERS measures. One of the measures proposed from the voltage sub-team was Measure 7 which is related to the static and dynamic reactive power reserve available to regulate voltage across the system. The sub-team requested and obtained data from a pilot group of select ERSWG members; however, to fully validate the proposed measure, the measure needed to be extended to a broader audience. Every BA/Region has its diverse resource mix and unique challenges with maintaining sufficient levels of ERSs and reliability, so it is important to analyze the measures across a wide array of entities.

The NERC PAS was responsible for Measure 7 data collection from BAs as a "proof of concept" analysis. SAMS was tasked with analyzing the collected data to evaluate trends and to make recommendations on the effectiveness of this data in understanding trends in reactive power support and voltage regulation. SAMS, if necessary, worked with industry stakeholders and PAS to understand the observed trends in the data supplied and correct any issues with the data.

The Summer Peak hour data collected includes three prior years of actual data from energy management system (EMS) archives for years 2013, 2014, and 2015, as well as three future years' data from planning base cases for years 2016, 2017, and 2020. The data collected focuses on generator and dynamic reactive capability, static reactive capability, and load power factor. The supplied data was extracted and standardized plots are provided for each BA based on the data received.

This report provides the analysis of the eighteen BAs that responded (note that data collection was voluntary and not all BAs provided data) for the proof of concept data collection and identifies and relevant trends in system reactive capability. It also provides overall observations and recommendations by SAMS for future ERS Measure 7 trending.

Observations and Recommendations

The following overall observations and recommendations are made based on analysis of the Measure 7 data.

- The original intent of ERSTF Measure 7 was to identify trends in the reactive capability of the system due to the changing resource mix, particularly related to dynamic and static reactive capability within a BA. Due to the significant number of variables and uncertainties in the data, Measure 7 data does not provide the necessary information to develop useful trends in how the changing resource mix impacts reactive capability on the BPS.
- Measure 7 data is collected on a BA level. While the BA was chosen based on availability of data and existing reporting capabilities, collecting data related to reactive capability and system voltage needs at that broad of a level does not necessarily provide useful information since reactive power needs are a relatively localized issue.
  - Reactive deficiencies to maintain adequate and reliable voltage profiles across the system are identified through Planning Assessments and interconnection studies[1] and those issues are addressed through local solutions.
  - Planners and operators often perform reactive planning on a sub-area level or interface-level as part of the Planning Assessments completed for the TPL-001-4 standard requirements. Reactive planning is not performed using metrics and should not be treated as such. This planning requires detailed engineering studies such as PV analysis, QV analysis, contingency analysis, etc., with solutions to meet specific needs of the system.
- The ERSTF Voltage and Reactive sub-group developed the Voltage Support section of the Essential Reliability Services Whitepaper on Sufficiency Guidelines which explained and recommended the concept of creating distinct voltage sub-areas within a larger BA footprint.
- The NERC SAMS developed a Reliability Guideline that provides a relatively comprehensive overview of reactive power planning practices to ensure reliable voltages and operation of the BPS. It also describes reactive power planning practices for a number of large utilities across North America. It is recommended to use this guideline to advocate reliable reactive power planning practices rather than rely on metrics that do not accurately capture the data that was intended.
- The recent FERC Order 827 will likely alleviate some of the concerns of reactive deficiency due to a changing resource mix. FERC Order 827 requires non-synchronous resources to also provide dynamic reactive power capability and voltage control similar to synchronous resources. Previously, this requirement was dependent on system impact studies during the generation interconnection process. However, as NERC SAMS has discussed and advocated in the past, not all voltage and reactive issues are identified during these interconnection studies. Once in the operations horizon with addition elements out of service, resources providing additional energy to the BPS beyond their capacity payment, etc., it is critical that these resources have the capability to help maintain reliable operating voltages and hold a voltage set point as determined by the Transmission Operator. The remaining issue is that many of the

[1] Interconnection studies identify a resource's basic reactive requirements, reflecting the degree to which it is interconnecting as a Network Resource (capacity) and/or an Energy Resource. While these studies typically model the resource at nameplate capability, the assumptions for concurrent operation of other resources related to study as a capacity or energy resource may influence the identified reactive requirements. A resource, such as some on-shore wind resources, may have capacity value that is relied upon for system reliability that is much lower than its nameplate capability. Studies may correctly identify the reactive requirements associated with the lower capacity value, which are adequate for system reliability. Real-time system operations will, however, likely encounter energy-based resource dispatch above its capacity value, and may observe different reactive requirements. This may result in energy curtailments which are consistent with and reflect how the resource was interconnected.

non-synchronous resources are located in sub-optimal locations where high wind availability or solar irradiance is available. This may lead to additional system upgrades for both thermal and voltage purposes and these issues will be determined during the generation interconnection studies accordingly.

- Reactive power can be generated from a number of elements on the BPS such as synchronous generators, synchronous condensers, power electronic devices (e.g., Static Synchronous Compensators (STATCOMs), Static Var Compensators (SVCs), and power inverters), and static devices such as shunt capacitors or reactors. Each type of device is used for specific reliability issues related to voltage. The need for dynamic vs. static capacitors is based on transient system response to faults and other disturbances, the timeframes of grid operator actions to maintain reliability, and other important factors. In addition, even the power electronic devices have unique characteristics that drive the contribution of the reactive power based on system characteristics and these often determine what type of resource to install (e.g., the voltage dependency characteristics between a SVC and STATCOM).
- Beyond any ERS related trends or issues, there was a noticeable difference in some areas between the operations and planning data that deserves further investigation. There are fundamentally no differences between the timeframes (the transition between data sets should be relatively fluid and smooth in terms of data collected); however, there are differences in the means in which the data is accounted for in operations and planning (e.g., how the planning cases are built compared with actual system operating conditions, BA-level data collection in the model as compared with how data is pulled from the data historian from actual data, etc.). One key issue that was highlighted was that some entities' data showed significant differences between the operational data and the planning data that is worth noting.
  - Example 1: NYISO data showed that the operational power factor was higher than the planning power factor, which is a conservative assumption and does not cause alarm. This can be due to assumptions made in the planning cases as compared with actual operational conditions on the system.
  - Example 2: SCEG data showed the opposite, with operational power factor lower than planning power factor. This is an optimistic assumption and an area of concern. The planning case is underestimating the amount of reactive power necessary to support the end-use load, which may lead to operational reliability issues that could arise with minimal options for timely mitigation.

Regarding the data collected, the following more detailed observations and analyses are provided.

- Generator reactive reserve for a BA is calculated as the difference between the maximum reactive power output of the generators and the actual reactive power output of the generators. In actuality, it is not simple to compare the planning base case "reserves" with the actual system "reserves" because these are highly dependent on both online and offline resources. In the operations horizon, the available reactive reserve to respond to a contingency is based on the available online resources and their reactive capability. Units are dispatched to ensure sufficient reactive capability following credible, studied contingencies. Conversely, the planning case will dispatch generation to serve the expected demand. Reactive resources are dispatched to support voltage set points across the system. However, the difference is that there may be additional offline resource that *could* be dispatched that simply are not in the base case. So comparing either online resources in both the planning and operations horizons or the online+offline resources in both the planning and operations horizons should not be done. These values are not comparable to one another.
- Further, variations in generator dispatch and demand level can significantly influence the generator reactive reserve. All generators do not affect the entire BA footprint. Specific generation may be dispatched to support more localized areas. This is based on a number of variables such as available resources, maintenance outages, network topology, etc.
- There can be significant system modeling differences that affect reactive capability. For example, some planners may opt to model sub-transmission/distribution while operations may not. This can affect

reactive losses, the size of distinct generation in the case, i.e. capturing smaller resources located on the sub-transmission/distribution, reported net load power factor, etc. This can distort trending between planning and operations.

- While the BA-level reactive reserves may shows thousands of MVARs of reactive capability, the BA may be deficient in reactive capability in one specific area which would be overlooked using this metric. This may portray a false impression that the BA has sufficient reactive resources to maintain voltages.
- The "Normalized BA Total Dynamic MVAR" was the closest metric to something useful since it normalizes any dynamic capability with demand level. However, as previously stated, this metric is not sufficient as it does not capture area dependency or contingency dependency and how it relates to reactive reserves. Therefore, the data illustrated some "interesting" trends and incited some discussion but no useful information was gleaned from the data directly.
- For entities that only supplied either the operational data or planning data but not both data sets, this posed a challenge in drawing any useful conclusions or trends from only three data points. Having only a historical view or forward looking view from the planning model was not useful.

Regarding the specific trends that were requested by ERSTF/ERSWG, some broad observations from the data are described in Table 1.

Table 1: Observations by Category

Category	Observations
Generator Reactive Reserve	• Consistent step change in generator reactive reserve for planning data as compared with operational data. This can be attributed to a number of variables; however, it is assumed that this consistent observation is due to the planning cases having a higher reactive demand than the actual operating conditions, driving the reserve lower. This is a conservative assumption for the planning cases and does not pose a reliability risk. Reactive reserve levels for each BA did not identify any significant concerns.
Power Electronic Reactive Reserve	• For the most part, the data showed steady or increasing trends in power electronic reactive reserve. In particular, in the planning cases, trends were mostly increasing which identified an increased reliance on these types of resources for reactive power needs. • Many entities did not provide any data for power electronic reactive reserve, signifying that these resources may not exist in their system.
Continuous Switched Shunt Reactive Reserve	• For the most part, the data showed steady or increasing trends in continuous switched shunt reactive reserve.
BA Total Dynamic Reactive Reserve	• The normalized metric provides some useful information since it incorporates the total dynamic reactive reserve as well as the load reactive demand. However, without contextualizing this information, it is hard to glean useful observations or takeaways from the data on a BA-level basis.

Table 1: Observations by Category	
Category	**Observations**
Static Capacitor Reactive Reserve	• In general, the reactive production of static capacitors for most entities increases over time. This is expected to ensure sufficient reactive power support across the BA for growing reactive power demand. However, in some areas the static reactive support is decreasing and the power electronic based reactive support is increasing. This signifies an increasing dependence on power electronic based resources in some areas. • Overall, the static capacitor reactive reserves are steady or increasing and do not identify any reliability risks.
Load Power Factor	• Load power factor was relatively consistent and within reasonable levels for most entities. There were no significantly degrading load power factors that caused any reason for alarm.
Load Reactive Power	• This data is necessary to calculate the normalized BA total reactive reserve; however, by itself the data does not provide much information since it is closely tied to load growth and load projections. • The load reactive power can be used to contextualize other trends in the data such as increases, decreases, or sudden spikes in dynamic and static reactive production and reserves.

Measure 7 Analysis: Balancing Authority Data

A complete set of Measure 7 data was supplied from various BAs within the interconnected system. The data collected included three prior years of actual data from energy management system (EMS) archives for years 2013, 2014, and 2015, as well as three future years' data from planning base cases for years 2016, 2017, and 2020. The collected data focuses on generator and dynamic reactive capability, static reactive capability, and load power factor. BAs that only submitted partial (planning only) data were excluded from the SAMS analysis of the data.

The Measure 7 data was used to generate a standardized set of charts to help identify if any trends in the data exists. The standard set of charts are:

- Generator Reactive Reserve
- Power Electronic Reactive Reserve
- Continuous Switched Shunt Reactive Reserve
- BA Total Dynamic MVAR
- Normalized BA Total Dynamic MVAR
- Static Capacitor Reactive Reserve
- Load Power Factor
- Load Reactive Power

Appendix A (*REDACTED*) present the charts generated from the data supplied by each of the BAs. The observations described above from the SAMS "proof of concept" analysis were to determine the effectiveness of Measure 7 data. Hence, observations are based on viewed systemic trends related to the BPS rather than the review of an individual BA.