**UNITED STATES OF AMERICA**
**FEDERAL ENERGY REGULATORY COMMISSION**

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| **Grid Resilience in Regional Transmission Organizations and Independent System Operators** | **)<br>)<br>)** | **Docket No. AD18-7-000** |

**JOINT COMMENTS OF THE ELECTRIC RELIABILITY COUNCIL OF TEXAS, INC. AND THE PUBLIC UTILITY COMMISSION OF TEXAS**

Electric Reliability Council of Texas, Inc. (ERCOT), in conjunction with the Public Utility Commission of Texas (PUCT), files these comments in response to the January 8, 2018 request of the Federal Energy Regulatory Commission (Commission or FERC) seeking information from each regional transmission organization (RTO) and independent system operator (ISO) concerning activities related to ensuring the resilience of the bulk-power system.

## I. COMMENTS

### A. Introduction

On October 2, 2017, the Commission issued a notice seeking comments on a rule proposed by the Secretary of Energy that would require RTOs and ISOs subject to the Commission's jurisdiction under section 206 of the Federal Power Act (FPA) to modify their Commission-filed tariffs to provide full cost recovery for certain generators capable of maintaining a ninety-day on-site fuel supply.[1] On January 8, 2018, the Commission issued an order terminating that proceeding, finding that the proposed rule did not satisfy the requirements of FPA section 206.[2] In that same order, the Commission nevertheless determined that the concerns of bulk-power system resilience underlying the proposed rule warranted further inquiry.[3]

As an initial step in this inquiry, the Commission has directed RTOs and ISOs to provide detailed information regarding a number of resilience-related activities, and has also sought input on the meaning of *resilience* in the first instance.[4] While ERCOT is conventionally recognized as an independent system operator, ERCOT is aware that it does not come within the Federal

[1] *Grid Resiliency Pricing Rule*, 82 Fed. Reg. 46,940 (Oct. 10, 2017).
[2] *Grid Reliability and Resilience Pricing*, Docket Nos. RM18-1-000, AD18-7-000, 162 FERC ¶ 61,012, Jan. 8, 2018.
[3] *Id.*
[4] *Id.*

Power Act's definition of either the term *RTO* or *ISO*,[5] and therefore does not fall within the coverage of the Commission's order. Nevertheless, ERCOT and its state regulator, the PUCT, see great value in providing input to the Commission on resilience-related activities in the ERCOT Interconnection, not only because such input could inform the Commission's possible application of its authority over public utility tariffs under sections 205 and 206 of the FPA, as originally proposed in Docket RM18-1-000, but also because it could impact the potential development of reliability standards by the North American Electric Reliability Corporation (NERC) that, by virtue of section 215 of the FPA, would govern the conduct of ERCOT and other users, owners, and operators of the bulk-power system in the ERCOT Interconnection. Accordingly, while the Commission's request for comments does not strictly apply to ERCOT, ERCOT and the PUCT respectfully request that the Commission allow submission of these limited comments as part of the initial set of responses from FERC-jurisdictional ISOs and RTOs.

**B. Resilience and Reliability Concepts**

ERCOT and the PUCT agree with the Commission's proposed definition of *resilience*, which reflects a conventional understanding of the term—namely, the ability to withstand or recover from some disturbance. Because any disturbance to the bulk-power system that impairs the continuous provision of electric service has, to that same extent, impaired reliability, ERCOT and the PUCT view resilience as an important subset of their existing reliability responsibilities.

As with the other North American ISOs, ERCOT's principal purpose is ensuring bulk-power system reliability. The Texas statute authorizing the PUCT to designate ERCOT as an ISO broadly mandates that the organization must "ensure the reliability and adequacy of the regional electrical network."[6] Anticipating and responding to foreseeable bulk-power system disturbances is therefore already an essential part of ERCOT's defined mission. As discussed in greater detail below, ERCOT and the PUCT have always taken action, when appropriate and feasible, to ensure the ERCOT system is able to withstand foreseeable system disturbances. Whether the concerns are large-scale shifts in the wholesale market such as the integration of large amounts of wind generation or the retirement of fossil-fuel units, extreme weather events such as ice storms or hurricanes, or common operational issues such as the loss of generation or

[5] *See* 16 U.S.C. §§ 796(27), (28) (requiring that an RTO and ISO must be "approved by the Commission.")
[6] Tex. Util. Code § 39.151(a)(2).

transmission facilities, the resilience of the bulk-power system has always been an essential part of ERCOT's and the PUCT's larger public mission to ensure adequate and continuous service to consumers in the ERCOT region of Texas.

At the federal level, the identification and mitigation of resilience risks falls within the scope of NERC's existing responsibilities as the FERC-approved electric reliability organization (ERO). The FPA provides that the ERO must have authority to "develop and enforce . . . reliability standards that provide for an adequate level of reliability of the bulk-power system" and explicitly requires the ERO to "conduct periodic assessments of the reliability and adequacy of the bulk-power system in North America."[7] NERC fulfills these obligations by conducting its own evaluations of risks to system reliability and by hosting industry forums to identify and evaluate various potential reliability risks. One of the most important of these forums is the Reliability Issues Steering Committee (RISC), whose basic purpose is to "triage key reliability risks and propose solutions to manage those risks."[8] RISC's most recently posted report identifies nine different risk areas—for example, "changing resource mix" and "extreme natural events"—and includes recommendations for addressing each one.[9]

Based on evaluations of various risks, NERC and members of industry may propose reliability standards that would mandate actions to mitigate those risks. In its role as the ERO, NERC has approved a number of standards that require evaluation and mitigation of resilience risks, including, for example, risks posed by geomagnetic disturbances and cyberattacks.[10] It is therefore apparent that the concept of grid resilience is understood to be a critical component of bulk-power system reliability under the Federal Power Act.

Although the term *resilience* has often been used in recent contexts to more narrowly refer to a system's ability to withstand "high-impact, low-frequency events" such as cyber-attacks, fuel-supply disruptions, and extreme weather events (as several of the questions in the Commission's order might suggest), there are clearly other events of greater frequency and lower impact that remain credible threats to the bulk-power system and that merit policy consideration. In ERCOT's and the PUCT's view, the ultimate goal of policymakers should be to ensure that *all*

[7] 16 U.S.C. §§ 824o(c)(1), (g).
[8] Reliability Issues Steering Committee Charter at 1 (May 7, 2015)
[9] *See ERO Reliability Risk Priorities* (Feb. 2018), pp. 14-29, available at http://www.nerc.com/comm/RISC/Related%20Files%20DL/ERO-Reliability-_Risk_Priorities-Report_Board_Accepted_February_2018.pdf.
[10] *See* NERC Reliability Standards TPL-007-1; CIP-003-7; CIP-005-5; CIP-006-6.

foreseeable threats to the reliability of the bulk-power system are identified and addressed in the most cost-effective way.

These comments summarize the efforts and methods that ERCOT and the PUCT undertake to identify and address various potential disturbances affecting the ERCOT system. Because the Commission's order is concerned with the practices of RTOs and ISOs, this comment focuses more on ERCOT's practices, although it also notes several key rules and practices of the PUCT that are relevant to resilience. However, there are additional protective measures provided in the rules of the PUCT which are not discussed herein.

### C. Resilience and Market Design

As an initial matter, ERCOT and the PUCT wish to underscore the importance of market design to ensuring system resilience. Market design is inextricably linked to long-term system reliability, given the fundamental need to ensure the sufficiency of generation supply to serve future load. Consistent with the Commission's approved design of other American wholesale energy markets, the PUCT has designed the ERCOT market to ensure resource adequacy—including the reliable service of load in a variety of future operating scenarios—by compensating generators for remaining available during conditions of energy scarcity. In February 2011, when extremely cold temperatures caused equipment failures that forced some generators off-line, prices in the region rose to the maximum amount—then \$3,000 per megawatt-hour (MWh)—for approximately six hours, reflecting that scarcity. This resulted in severe financial consequences to generators with day-ahead commitments that failed to generate in real time, just as it greatly rewarded those generators that stayed online during the event. When ERCOT faced similar system-wide temperatures in January 2017 and January 2018, improvements in plant weatherization across the fleet resulted in substantially fewer generators suffering equipment failures. One of the most important factors contributing to this improvement is ERCOT's robust scarcity pricing.[11]

PUCT rules now allow wholesale prices for electricity in the ERCOT Interconnection to rise as high as \$9,000 per MWh—substantially higher than in other RTO-ISO regions—based on scarcity. And in 2014, at the direction of the PUCT, ERCOT became the first ISO to implement

[11] The ability of the ERCOT generation fleet to withstand severe cold may have been improved by market participant discussions on weatherization practices, the initiation of site visits by ERCOT staff, and the adoption of rules requiring generators to assess weatherization twice each year—all of which measures were developed as a consequence of the February 2011 cold-weather event.

an operating reserve demand curve (ORDC), which allows system-wide energy prices to rise in proportion to the scarcity of operating reserves.[12] Like other American wholesale markets, ERCOT also uses locational pricing to ensure that the prices generators are paid reflect the relative need for energy at each point in the system. These scarcity-based pricing mechanisms not only encourage sufficient long-term investment in generation, but also help to ensure that generation owners maintain their units to maximize availability during a variety of possible system disturbances. In short, ERCOT's scarcity pricing mechanisms are designed to alleviate the need for many resilience-based regulatory controls.

### D. Ensuring Resilience in Operating and Planning the ERCOT System

Apart from market design, ERCOT and the PUCT routinely undertake a number of measures to ensure resilience of the ERCOT system as part of their broader reliability obligations. Although many of these mechanisms are similar to those employed by other ISOs, others are different because of ERCOT's relative size to the other two U.S. interconnections, the greater penetration of renewable resources in ERCOT compared with most other ISOs, and ERCOT's greater vulnerability to certain extreme weather events.

#### 1. Mechanisms for Identifying Resilience Concerns

As the ISO responsible for both the day-to-day and long-term reliability of the bulk-power system covering most of Texas, ERCOT employs a number of mechanisms to identify potential resilience concerns. Ultimate responsibility for identifying and mitigating reliability risks in the ERCOT Interconnection resides with ERCOT's Board of Directors, which by law comprises executives from various industry segments as well as independent experts, each of whom brings a distinct expertise for identifying vulnerabilities.[13] Every five years, the ERCOT Board develops a strategic plan outlining various initiatives to address a number of key trends impacting operations in the region. Trends identified in the last strategic plan—published in 2013 and due to be revised this year—include single fuel dependency, gas and electric market

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[12] *See Scarcity Pricing in ERCOT*, slide 4, presented at June 27-29, 2016 FERC Technical Conference, available at https://www.ferc.gov/CalendarFiles/20160629114652-3%20-%20FERC2016_Scarcity%20Pricing_ERCOT_Resmi%20Surendran.pdf; see also *Methodology for Implementing Operating Reserve Demand Curve (ORDC) to Calculate Real-Time Reserve Price Adder*, available at http://www.ercot.com/mktinfo/rtm/kd/Methodology_for_Implementing_Operating_Reserve_Demand_Curve_.doc.

[13] *See* Tex. Util. Code § 39.151(g).

coordination issues, and an increased need for flexible resources due to the incorporation of large amounts of intermittent renewable resources.[14]

In addition to the strategic plan, ERCOT's executive management annually develops a confidential risk matrix identifying the most critical risks to ERCOT, including current or future reliability risks to the ERCOT system. Concerns identified in the risk matrix are prioritized and communicated to the ERCOT Board.

Potential reliability risks are also routinely identified by other ERCOT stakeholder groups, including ERCOT's Technical Advisory Committee, Reliability and Operations Subcommittee, and Regional Planning Group. The ERCOT Technical Advisory Committee annually develops its own list of key market and reliability objectives for the various stakeholder subcommittees that operate under the Technical Advisory Committee's oversight. In 2017, these objectives included addressing the growth of distributed energy resources, providing greater clarity in rules regarding grid-switchable generation, and improving ERCOT's planning processes. As the primary stakeholder body under the ERCOT Board, the Technical Advisory Committee oversees the handling of these initiatives by ERCOT staff and by other stakeholder subcommittees. Operations or planning concerns—and measures to address them—are routinely discussed at meetings of the ERCOT Reliability and Operations Subcommittee and at the various task forces and working groups that report to it. ERCOT's Regional Planning Group provides a forum for ERCOT staff to work with its stakeholders to develop future system scenarios that will be studied in both the near-term and long-term planning horizons. For example, the most recent meeting of the Regional Planning Group included a panel discussion on the impacts of growing electric vehicle penetration on the ERCOT system.[15]

ERCOT staff also play a critical role in identifying resilience concerns. Issues occurring during real-time operations may be identified by any of ERCOT's control center operators or by its operations support staff, both of whom monitor system conditions around the clock, 365 days a year. Control room operators will take all necessary actions to address any operating issues that arise. These issues may be discussed with other operators or with operations support staff. Outside of real-time operations, planning or operational studies that identify potential system vulnerabilities are shared with appropriate departments in ERCOT and with stakeholder groups.

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[14] *See* ERCOT's 2014-2018 Strategic Plan at 10-11, available at http://www.ercot.com/content/news/presentations/2016/ERCOT%20Strat%20Plan%20FINAL%20112213.pdf.

[15] http://www.ercot.com/calendar/2018/1/30/138669-RPG.

Structural issues bearing on system resilience may also be identified by the PUCT or the Texas Legislature. The PUCT has primary enforcement authority over standards governing operations in the ERCOT Interconnection.[16] The PUCT may learn of reliability concerns directly from ERCOT, from market participants, or from the PUCT's designated reliability monitor, Texas Reliability Entity, Inc., which also serves as the NERC regional entity for the Texas region. The PUCT may then decide whether to gather more information by conducting a workshop or opening a project. Such information may ultimately result in the development of rules that affect planning or operations activities in ERCOT. For example, following the extreme hot and cold weather events in ERCOT in 2011, the PUC initiated a proceeding that resulted in rules giving ERCOT authority to conduct site visits to generation facilities to examine weatherization preparations and that required ERCOT to conduct an annual assessment of system reliability in extreme hot and cold conditions.[17] Similarly, the Texas Legislature has held hearings to gather information on issues such as resource adequacy and geomagnetic disturbances and has considered legislation on these topics.

### 2. Resilience in System Planning

#### a. Planning Assessments

One of the most critical elements of system resilience is ensuring that the transmission system is planned in such a way as to ensure continued operations following an unexpected outage of one or more generators or transmission elements. Consistent with the governing NERC reliability standard, TPL-001, ERCOT evaluates a number of various planning scenarios in the near-term and long-term planning horizons. Among other scenarios, these scenarios include the loss of a single transmission element (N-1), the loss of a single transmission element followed by adjustments and then by the loss of a generator (N-1 + G-1), and the outage of a single transmission element followed by adjustments and then by the loss of another transmission element (N-1-1). ERCOT must develop a corrective action plan to address any reliability criteria violations that arise in these contingency scenarios. This corrective action plan typically involves building new transmission facilities. Notably, ERCOT employs a more conservative practice than that required by the NERC standard. ERCOT considers an outage of multiple lines sharing the same tower for more than a contiguous half-mile to be only a single

[16] Tex. Util. Code §§ 39.151(d), (j); 15.023(a).
[17] 16 Tex. Admin. Code §§ 25.53, 25.362(i)(2)(H).

contingency (N-1), and ERCOT's criteria do not allow the loss of load following such a contingency. Thus, ERCOT's planning criteria promote system resilience.

NERC reliability standard TPL-001 also requires ERCOT to consider a variety of extreme events in its planning analysis: for example, the loss of a tower with three or more circuits, the loss of all transmission lines in a common right-of-way or a switching station or substation, and the loss of all generating units at a single generating station. Because these extreme scenarios are generally thought to be less likely to occur and would often require substantially greater cost to address, the NERC reliability standard does not mandate that planners address these issues through a corrective action plan. However, these studies do allow ERCOT to identify critical contingencies on the ERCOT system and to develop a mitigation plan which can be implemented if the contingencies occur. These studies may also provide information that can influence ERCOT's selection of preferred transmission projects under its established planning criteria.

When planning new transmission projects, ERCOT strives to build greater resilience into the system. This includes considering the geographic diversity of transmission lines serving a load center. For example, when ERCOT was considering options for the construction of a third 345-kilovolt (kV) line to serve the Lower Rio Grande Valley, ERCOT ultimately endorsed the option that was furthest from the coast because the two existing 345-kV lines serving the area were relatively close to the Texas coast and therefore susceptible to outages due to hurricanes and tropical storms. When appropriate, ERCOT has also conducted additional studies to determine the potential contingency impacts of placing a proposed line in a common right-of-way with one or more existing transmission lines.

Given Texas' susceptibility to hurricanes and tropical storms from the Gulf of Mexico, it is also essential to consider storm-hardening measures for transmission facilities located in coastal areas. PUCT rules require utilities to develop storm-hardening plans to address a number of key areas, including construction standards, vegetation-management plans, and damage assessments.[18] Among other things, these plans typically provide that utilities will use transmission towers designed to withstand hurricane-force winds in appropriate areas. These measures add resilience to the bulk-power system in ERCOT.

[18] 16 Tex. Admin. Code § 25.95(e).

ERCOT's planning practices must also consider the high penetration of wind generation in the ERCOT Interconnection. ERCOT presently has over 20,000 megawatts (MW) of installed wind generation capacity, with more in the interconnection queue. ERCOT's annual planning assessment uses historical wind output values in future planning years. However, because wind generation is intermittent and may not be available in peak demand conditions, ERCOT also performs a sensitivity study to determine the system needs if wind generation is at zero real- and reactive-power output. Following the South Australia blackout event in 2016 involving the loss of a number of wind generators after multiple voltage events within a short period of time, ERCOT conducted a survey to understand the capability of wind generators in ERCOT to ride through multiple voltage events. Based on the survey feedback, ERCOT is currently working on a formal assessment considering multiple voltage events to determine the system response under extremely stressed system conditions.

Furthermore, as the resource mix in the ERCOT Interconnection evolves to include more inverter-based resources, dynamic stability and low system strength have presented a new challenge. To ensure system resilience, ERCOT has adopted—and continues to pursue—new study techniques and computational improvements. For example, conventional transient stability models and analysis techniques alone are no longer suitable to perform renewable integration studies under low system-strength configurations. ERCOT now supplements these models and techniques with studies that can provide results of higher granularity, improving overall study results and allowing ERCOT to more accurately determine appropriate power transfer limits across the region.

In addition to near-term planning assessments, ERCOT also conducts a long-term system assessment (LTSA) focusing on possible developments 10 to 15 years in the future. ERCOT works with its stakeholders in the Regional Planning Group to devise a number of different load- and generation-development scenarios used in the LTSA. Among other factors, these scenarios have considered the following:

- different locations and rates of growth in consumer load;
- different locations and rates of growth in solar and wind generation development, depending on price of inputs; and
- thermal generator retirements based on market factors or environmental regulations.

The goal of using these different scenarios is to identify upgrades that provide resilience across a range of situations or that might provide greater economic benefit than the upgrades that would be determined considering only near-term needs.

**b. Load forecasting**

Load forecasting is an integral part of the daily operation of the system, as it forms the basis for a series of subsequent operational and planning decisions. When weather events threaten reliability, load forecasting scenarios become increasingly important as they represent a range of possible load outcomes. Understanding the range of possible impacts that a winter storm or hurricane can have on load and formulating a potential response is critical to system resilience. To this end, ERCOT has developed a variety of short-term, mid-term, and long-term forecasts.

ERCOT's long-term demand forecast predicts demand and energy levels for the next ten years. This forecast is based on a set of econometric models predicting hourly load as a function of premise counts for given customer classes, weather variables such as temperature, cloud cover, and wind speed, and calendar variables such as the day of the week and whether it is a holiday. The forecast is used as an input to ERCOT's transmission planning processes (along with utility-provided forecasts) and is also a potential source of information for developers of generation.

ERCOT also uses six unique mid-term forecasts to project system load over the next ten days. Each forecast is based on weather-forecast feeds from one or a combination of four vendors. ERCOT also employs an in-house meteorologist to provide an internal weather forecast. ERCOT tracks weather forecast and model error on a daily basis and also daily calculates model bias over the past seven days. The mid-term forecasts provide ERCOT with a range of possible outcomes for high-risk events such as hurricanes.

Finally, ERCOT develops a short-term load forecast consisting of two separate models that run every five minutes to forecast load for the next two hours. These models use the same weather data that the mid-term forecast uses. Day-to-day telemetry data is filtered to reduce the effects of anomalous load events, which allows the forecast software to continue to run in the case of bad or missing data. During extreme events such as a hurricane or severe winter weather, when load may be less predictable, the mid-term and short-term forecasts can be adjusted using different established methods to more accurately predict system load.

**c. Renewable Energy Forecasting**

In addition to predicting load patterns, ensuring reliability also requires ERCOT to have reasonably accurate forecasts of wind and solar generation. Consequently, ERCOT has developed forecasts that project hourly wind and solar output for each wind and solar generation site over each of the next 168 hours. These models are used as inputs in ERCOT's day-ahead studies and in real-time operations. Experience with different conditions, such as the presence of ice on turbine blades during winter storms, has allowed ERCOT to refine its models to more accurately predict generator behavior. In their current state, these models have generally been very accurate and have played a critical role in ensuring system reliability.

**d. Resource Adequacy Assessments**

ERCOT conducts a variety of assessments of the sufficiency of resources to meet projected future load. The two principal assessments are the capacity, demand, and reserves report (CDR) and the seasonal assessment of resource adequacy (SARA). The CDR, which is generally published in May and updated in December each year as required by PUC rules,[19] provides a deterministic forecast of the planning reserve margin for each of the next ten years according to a stakeholder-approved formula set out in ERCOT protocols. Essentially, the reserve margin is calculated as the percentage by which ERCOT's total generation and load resources exceed forecasted firm load. ERCOT's SARA determines the amount of operating reserves available to meet the forecasted peak demand for an upcoming season. Each seasonal report illustrates the range of resource adequacy outcomes based on a set of possible peak demand and resource availability scenarios, providing ERCOT's operational planners and market participants information about potential system-wide capacity shortage conditions. NERC is considering modifying its own seasonal reliability assessments using ERCOT's SARA reports as a model.

ERCOT also considers impacts of drought on the bulk-power system, since Texas has historically been prone to extended periods of little rainfall. In 2013, ERCOT developed a drought risk assessment model that determines the number of months before reservoir and groundwater supplies of cooling water for thermal generation plants decrease to the point where operators are likely to consider implementing risk mitigation measures. Water sources and associated generating units for which drought impacts are expected within six months are

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[19] *See* 16 Tex. Admin. Code §§ 25.505(c); 25.362(i)(2)(D).

included on a watch list for enhanced monitoring and communications with the plant operators. ERCOT also uses the model to construct periodic reports on the aggregate amount of generating capacity and production that is at risk in each of various areas in the ERCOT Interconnection.

#### e. Reliability Must-Run Evaluations

Grid resilience can also be impacted by retirements of generation. Under long-established procedures, when a generator in the ERCOT Interconnection announces its intention to retire or mothball, ERCOT must conduct a study of these impacts.[20] If ERCOT determines that the retirement would cause a violation of ERCOT's operating criteria, then ERCOT may seek to negotiate a reliability-must-run (RMR) agreement with the generation owner.[21] The PUCT recently amended its rules to require generator owners to provide 150 days' notice of such retirements to ERCOT, rather than the 90 days previously required, and to explicitly recognize ERCOT's right to consider less-costly alternatives—such as demand response or new generators—that would address any reliability concern identified.[22] The availability of RMR agreements thus provides an important reliability backstop in the ERCOT wholesale energy market.

### 3. Resilience in System Operations

ERCOT has adopted a number of practices and standards to ensure that its system is operated reliably even when experiencing any of a number of disturbances. These practices begin months in advance of the operating day and extend to real-time operations.

#### a. Outage Coordination

Like other ISOs, ERCOT coordinates planned outages of generators and transmission facilities to ensure reliability during both normal conditions and conditions involving potential system disturbances. ERCOT has an extensive outage-coordination process that includes a seasonal review, six different approval timelines, and a separate process to identify high-impact outages for special treatment. Because of the high degree of wind penetration in ERCOT and the uncertainty of wind output at the time of a given outage, certain outages in or near high-wind areas must be evaluated using both seasonal wind averages and low-wind conditions. ERCOT must limit its approval of outages to account for these uncertainties. Nevertheless, when outages are requested in these areas or in areas of high congestion, ERCOT outage coordinators work

[20] *See* 16 Tex. Admin. Code § 25.502(e).
[21] *Id.*
[22] *See id.*

diligently with transmission providers to shorten restoration times or even allow work to be done while the lines are energized in an effort to maintain maximum system availability. Should a need arise or a contingency occur on the system, the ability for transmission operators to quickly restore maintenance outages increases the resilience of the system.

**b. Ancillary Services**

As in the markets regulated by the Commission, ERCOT procures ancillary services to ensure recovery from the sudden loss of generation or from unexpected increases or decreases in system demand, and to control frequency within certain established tolerances. Ancillary services thus play a critical role in ensuring system resilience. Because the ERCOT Interconnection is much smaller than either the Eastern or Western Interconnection, and because a large percentage of ERCOT's generation fleet is intermittent wind generation, ancillary services are of utmost importance to ensure system reliability.

ERCOT procures three primary ancillary services in the day before each operating day: Non-Spinning Reserve Service (NSRS), Responsive Reserve Service (RRS), and Regulation Service. Each December, ERCOT determines the minimum quantities of these services that are to be procured for each hour of each operating day. These minimum quantities are established in part to accommodate the observed uncertainty of various conditions on the ERCOT system. If ERCOT determines that operating conditions are such that additional ancillary services should be procured on a given operating day, it may increase the quantity from the minimum amount previously posted.

NSRS is an ancillary service that helps to ensure ERCOT will have sufficient generation even with large forecasting errors or inclement weather conditions by requiring obligated generators to make the procured amount of capacity available within 30 minutes of being called. The highest quantities are procured when risk of net-load[23] (load minus wind) ramp-up is highest, based on historical net-forecast error. In hours with a higher risk of net-load ramp, the NSRS requirement is based on the 95th percentile of net-forecast error. In hours with low risk of net-load ramp, the minimum quantity of NSRS is based on the 70th percentile of net-forecast

[23] The substantial growth of wind generation in the ERCOT Interconnection has resulted in the need to calculate net load, which expresses in a single figure the combined impact of the two most significant uncontrollable factors affecting generator dispatch: system load and total wind generation. ERCOT has developed a suite of tools to forecast both load and wind generation to ensure that the system can accurately match the net load.

error. In 2018, ERCOT adjusted the NSRS minimum quantities to account for the additional over-forecast uncertainty associated with the projected increase in installed wind capacity.

ERCOT procures RRS to guard against sudden frequency excursions typically caused by unit trips. RRS is provided either by frequency-responsive generators or by load resources using high-set under frequency relays that are armed to trip at 59.7 hertz (Hz). ERCOT procures at least enough RRS to protect against the simultaneous loss of the two largest generation units (a total of 2,750 MW). ERCOT may establish a higher minimum quantity for any given hour if necessary to ensure that the frequency will not fall below 59.4 Hz or to offset an expected lack of system inertia if thermal generation is projected to constitute a lower percentage of the on-line generation. While RRS is a compensated service that requires a generator owner to keep its unit online with the obligated RRS quantity reserved for use, all generators in the ERCOT Interconnection are required, when online, to provide primary frequency response—i.e., to have a governor in service set to respond to frequency changes that exceed a defined dead-band and in accordance with a defined droop setting. Indeed, because of the importance of governor response in the ERCOT interconnection, NERC has approved a region-specific standard, BAL-001-TRE-1, that codifies these requirements.[24] ERCOT is the only region with a NERC standard that dictates specific governor settings and minimum generator performance measurements for compliance.

ERCOT also procures a third ancillary service, Regulation Service, which is typically used to correct small deviations in frequency by moving generation up or down every four seconds. ERCOT procures sufficient Regulation Service to cover the 95th percentile of deployed regulation or net load variability. Because the exact system frequency cannot be accurately predicted, Regulation Service primarily helps to smooth out the system frequency. However, Regulation Service may also provide some assistance in recovering from unexpected frequency disturbances, such as unit trips.

Where a resource with an ancillary service obligation is unexpectedly unable to provide that service, ERCOT may conduct a supplemental ancillary-services-market auction to procure any needed quantities. If otherwise necessary, ERCOT can also resort to its Reliability Unit Commitment (RUC) authority to require a unit to provide a necessary ancillary service.

[24] *See* NERC Reliability Standard BAL-001-TRE-1, R6.1, R6.2.

In addition to its procurement of the three primary ancillary services, ERCOT also conducts a biennial procurement of black-start generators, which must be capable of starting themselves without any electrical support from the system. These resources provide resilience by enabling restoration of the ERCOT system in the event of a partial or complete loss of power. Before each black-start procurement cycle, ERCOT identifies resources that are eligible to provide the service and conducts studies to determine which of those eligible resources provide the greatest stability and speed of system restoration. ERCOT has procured 13 generators to provide black-start service for the current biennial cycle. Last month, ERCOT was presented with a Technology Transfer Award from the Electric Power Research Institute for its use of a new software tool that determines optimal cranking paths for black-start generators.

### c. Operations Planning

ERCOT conducts a number of studies in the days and hours leading up to each operating hour of each day. These studies enable ERCOT to ensure it is well-positioned to reliably serve load and to withstand any unexpected disturbances. Two days before a given operating day, and again in the day before the operating day, ERCOT conducts studies to identify voltage-stability limits and limits on direct-current ties connecting ERCOT to other regions. These assessments dovetail with outage coordination assessments and provide insight to ERCOT system operators of potential reliability issues. The day before the operating day, in preparation for real-time operations, ERCOT performs system assessments to ensure the system can be operated within limits. ERCOT system operators and support engineers often perform off-line, ad-hoc security studies for current and future hours. These studies take into account expected generation patterns, transmission and generation outages, as well as load- and weather-forecast details.

As a further part of preparing for real-time operations, ERCOT also uses a RUC process to commit generation that was not scheduled to run in order to address some identified future real- or reactive-power deficiency or to provide ancillary services. ERCOT runs a day-ahead RUC study and an hour-ahead RUC study. These two RUC review periods ensure that every operating hour is evaluated at least 24 times, providing ERCOT system operators many opportunities to commit generation to meet expected load and congestion needs, if necessary.

In anticipation of severe weather events, ERCOT performs several exercises to ensure adequate preparedness. ERCOT operations support engineers conduct several system assessments to evaluate pre- and post-contingency conditions based on predicted worst-case conditions for the weather event under study. These assessments typically consider more severe system conditions than the standard N-1 security studies performed in the Network Security Analysis. For example, in preparation for Hurricane Harvey, ERCOT conducted assessments considering the loss of a major 345 kV substation near Corpus Christi, where the hurricane was expected to make landfall. These assessments evaluated the impacts of the outage of the 345 kV bus (N-4) together with various credible single contingencies for a variety of load levels based on the anticipated loss of load due to the storm. In the event of cold weather, when the risk of unit trips during start-up is expected to be higher, ERCOT system operators can run future system assessments and use ERCOT's RUC processes to commit generation so that it is on-line and pre-warmed prior to the event.

#### d. Real-Time Operations

The core of ensuring real-time system reliability in ERCOT is the security-constrained economic dispatch (SCED) engine, which optimizes each generator's output to satisfy system load while also observing transmission system limits. SCED sends output levels to each generator every five minutes. In the event of a sudden transmission or generation outage, SCED automatically dispatches available generation to resolve the deficiency. In the uncommon event that SCED is unable to dispatch generation, ERCOT system operators manually dispatch generators to ensure that load and transmission congestion limits are met.

SCED obtains system limits from ERCOT's network security analysis program. This program executes automatically every five minutes, or manually by operator execution, and assesses the entire ERCOT system for both base-case and post-contingency thermal, steady-state voltage, and phase-angle-limit exceedances. ERCOT's Network Security Analysis simulates over 7,100 temporally correct contingencies, including single- and double-circuit contingencies, autotransformer contingencies, single-generator and combined-cycle-train contingencies, and static shunt reactive-device contingencies. In ERCOT operations, just as in planning, ERCOT's N-1 contingency analysis conservatively evaluates the loss of two transmission lines that share a common tower for more than a contiguous half-mile as a single contingency (i.e., an N-1 event representing the loss of a single transmission element), which provides added protection in comparison to other system operators who do not include these contingencies in their analyses.

Every 10 minutes, the Network Security Analysis results are also utilized to perform voltage-stability analyses for specific areas of the ERCOT interconnection where voltage instability can be a concern. ERCOT utilizes an on-line voltage security assessment program to perform this analysis automatically and provides the stability assessment results to ERCOT system operators on a continual basis. ERCOT can also manually perform this analysis at any time.

ERCOT has recently made changes to the staffing in its control room to ensure better real-time capability to address the reliability risks presented by the changing resource mix. In early 2017, ERCOT implemented a new reliability risk desk in its control room to improve the accuracy of renewable-energy forecasts, to ensure the commitment of sufficient frequency responsive capacity and system inertia, and to address forecast errors and net-load ramps. This new desk enables ERCOT to more quickly procure additional ancillary services or commit additional generation to maintain reliability.

#### e. Simulation and Training

One important way that ERCOT ensures system resilience is by conducting simulations of major system disturbances. ERCOT uses an operator training simulator (OTS) to simulate disruptive events as well as the tools operators use in responding to those events. ERCOT coordinates exercises that engage operators and support staff from both ERCOT and its market participants. ERCOT uses the OTS for its standard operator training program, but also for black-start training and severe weather drills. The OTS simulation environment provides an ideal learning platform due to its constant and immediate feedback. Operators participating in simulations are free to make mistakes, learn from them, and apply the lessons learned. When the simulated events actually occur, the operators will make better decisions and improve interconnection resilience.

All NERC-certified, real-time operations personnel within the ERCOT ISO, including personnel from ERCOT and transmission and generator operators in the ERCOT Interconnection, participate in ERCOT's annual black-start training program. The program consists of six separate four-day sessions and seeks to ensure that black-start operators are fully trained to execute their respective black-start plans and that the black-start plans are effective. Operator performance is measured and any deficiencies are noted and addressed. Any outstanding plan and training deficiencies are presented to relevant stakeholder groups for resolution.

All generator operators and transmission operators in the ERCOT Interconnection also participate in the annual severe-weather drill. In this drill, the OTS simulates, in alternating years, hurricane conditions and winter weather conditions. The drill seeks to evaluate each operator's ability to assess changing system conditions and to identify the necessary actions and communications required to recover from the event. It also provides an opportunity to test emergency communications between ERCOT and its market participants.

ERCOT also routinely participates in another resilience-focused exercise called *GridEx*. GridEx is a national exercise conducted by NERC that simulates a coordinated cyber or physical attack with operational impacts on electric and other critical infrastructure across North America. The exercise provides an opportunity for various electric industry participants and various national, state, and local government entities to deploy their incident response plans, practice communications, and recognize critical interdependencies and vulnerabilities. Lessons learned from GridEx are integrated into ERCOT's business continuity plans and training and reported to various ERCOT stakeholder groups.

ERCOT expects that the ERCOT Operations Training Department's role in providing training that increases resilience will increase in 2018 when ERCOTs new dedicated training center opens. The facility will be focused on expanding the use of the OTS and facilitating more joint training with market participants.

#### f. Weatherization Checks

ERCOT conducts generator site visits to evaluate generator weatherization practices each winter. After the PUC required generator owners to submit their weatherization plans to ERCOT, ERCOT began evaluating generators' adherence to those plans. ERCOT personnel review documentation and evaluate physical equipment for evidence of weatherization plan implementation. Special attention is given to critical components—those that, if frozen, will de-rate, trip or prevent the unit from starting. Common evaluation procedures include testing of the associated heat-trace circuit, inspection of insulation, transmitter cabinets, and cabinet heaters. For the past several years, ERCOT has averaged seventy to eighty generator site visits. ERCOT's review has historically found that plants are largely following their weatherization plans, although some units have been identified as needing to improve details of their plans and preparation. ERCOT concludes each visit by providing recommendations for improvement based on observed best practices and lessons learned.

### g. Gas and Electric Coordination

As the system fuel mix has shifted to lean more heavily on natural gas, the need for greater coordination between ERCOT and gas pipeline operators has increased. Since 2012, ERCOT has participated in regional and industry-wide forums pertaining to natural gas and electric coordination. ERCOT hosts a Black Start Gas Coordination Working Group that meets twice each year to discuss issues associated with delivery and supply of gas to black start resources. The group's participants include gas pipeline owners, gas-fired generation operators, state government representatives, and other affected stakeholders. ERCOT also participates in the ISO/RTO Council's Gas-Electric Coordination Task Force, exchanging best practices and discussing current issues with other ISOs and gas industry representatives. These efforts have resulted in greater coordination between ERCOT and the gas pipeline companies during gas curtailment events. For example, in the case of extremely cold weather or an impending hurricane, gas pipeline companies in Texas will now communicate expected gas curtailments to ERCOT, and ERCOT then disseminates that information internally to ensure adequate situational awareness.

### 4. Physical and Cybersecurity

To ensure ERCOT's continued ability to perform its core reliability functions, ERCOT must ensure that its physical and cyber assets are protected against malicious attacks. ERCOT has developed highly detailed plans and procedures to ensure resilience of its systems. ERCOT's cybersecurity practices are based on the National Institute of Standards and Technology's *Framework for Improving Critical Infrastructure Cybersecurity* and use multiple layers of protective measures to ensure security. ERCOT's procedures are adopted in accordance with NERC critical infrastructure protection standards. ERCOT actively collaborates with other ISOs and industry participants in evaluating cybersecurity practices, and recently served as chair of the ISO/RTO Council's Security Working Group. ERCOT shares and receives information concerning security threats and attacks via the Electricity Information Sharing and Analysis Center portal. ERCOT also coordinates security strategies as a participant on the Electricity Subsector Coordinating Council's Cyber Mutual Assistance Program.

Like other ISOs, ERCOT employs armed security guards and physical monitoring systems to provide physical protection to its control centers 24 hours a day. ERCOT coordinates with local, state, and federal officials and organizations as necessary to ensure physical security.

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Additionally, ERCOT and other ISOs formed the Physical Security Working Group in 2014 to share best practices and lessons learned in the arena of physical security.

## II. COMMUNICATIONS

ERCOT and the PUCT request that all correspondence and communications regarding this matter be sent to:


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## III. CONCLUSION

Ensuring the resilience of the bulk-power system is a critical part of ERCOT's existing reliability mandate. ERCOT and the PUCT have, and will continue to, address resilience concerns as they become credible threats to system reliability. ERCOT has robust processes in place to ensure the ERCOT system will be operated in a way that can resist and recover from a variety of foreseeable disturbances. These processes will continue to identify other areas for improvement as the system evolves. ERCOT and the PUCT appreciate the Commission's allowance of these comments and look forward to working with the Commission to address any outstanding reliability concerns.

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Respectfully submitted,

*/s/ Chad V. Seely*

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