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Donna L. Nelson
Chairman

Kenneth W. Anderson, Jr.
Commissioner

Rolando Pablos
Commissioner

Brian H. Lloyd
Executive Director



Public Utility Commission of Texas

Rick Perry
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September 28, 2012

Honorable Members of the Eighty-Second Texas Legislature:

We respectfully submit the Report on Extreme Weather Preparedness Best Practices prepared by Quanta Technology, as required by Section 186.007 of the Utilities Code. This report addresses the four main requirements set by the Legislature to: 1) review the emergency operations plans currently on file with the commission; 2) analyze and determine the ability of the electric grid to withstand extreme weather events in the upcoming year; 3) consider the anticipated weather patterns for the upcoming year as forecasted by the National Weather Service or any similar state or national agency; and 4) make recommendations on improving emergency operations plans and procedures in order to ensure the continuity of electric service.

In addition to the areas covered by the statute, the Commission also tasked Quanta to develop a list of best practices for extreme weather preparedness and protecting facilities against contamination during periods of drought.

The commission anticipates utilizing the findings in this report to amend our substantive rules that pertain to emergency operations plans. If you need any additional information about any issues addressed in this report, please contact us.

Sincerely,

A handwritten signature in black ink, appearing to read "Donna L. Nelson".

Donna L. Nelson
Chairman

A handwritten signature in black ink, appearing to read "Kenneth W. Anderson, Jr.".

Kenneth W. Anderson, Jr.
Commissioner

A handwritten signature in black ink, appearing to read "Rolando Pablos".

Rolando Pablos
Commissioner



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REPORT ON EXTREME WEATHER PREPAREDNESS BEST PRACTICES

Authorized by
Public Utility Regulatory Act, Section 14.001

September 27, 2012

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Prepared For: Public Utility Commission of Texas

Prepared By: Quanta Technology, LLC
A Division of Quanta Services (NYSE:PWR)



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I. BACKGROUND AND INTRODUCTION

In February 2011, the state of Texas experienced extremely frigid weather that led to widespread generation outages. These outages resulted in the available energy falling below the levels necessary to meet actual customer demand, leading to rolling customer outages to maintain load-generation balance. As a result of these impactful events, on May 23, 2011, the Texas Legislature passed Senate Bill No. 1133, attached in Appendix 1, requiring the Public Utility Commission of Texas (PUCT) to develop a "Weather Emergency Preparedness Report" as follows:

The commission shall analyze emergency operations plans developed by electric utilities as defined by Section 31.002, power generation companies, municipally owned utilities, and electric cooperatives that operate generation facilities in this state and prepare a weather emergency preparedness report on power generation weatherization preparedness. In preparing the report, the commission shall:

- (1) Review the emergency operations plans (EOPs) currently on file with the commission;*
- (2) Analyze and determine the ability of the electric grid to withstand extreme weather events in the upcoming year;*
- (3) Consider the anticipated weather patterns for the upcoming year as forecasted by the National Weather Service or any similar state or national agency; and*
- (4) Make recommendations on improving emergency operations plans and procedures in order to ensure the continuity of electric service.*

The PUCT selected Quanta Technology, LLC to develop this report.

Quanta Technology's objectives in performing this analysis were to:

- Perform a review of the emergency operations plans submitted by generating entities in Texas, with specific emphasis on the elements required to be included in the plan per P.U.C. Subst. R.25.53;
- Identify best practices for generating entities regarding weatherization practices and to compare these elements against the submitted EOPs to determine current state and opportunities for improvement;
- Analyze the robustness of the Texas grid to deliver power under projected peak season conditions, in terms of transmission system reliability and to ensure resource adequacy to meet projected seasonal demands in 2012-2013;
- Using the preceding analysis, to identify areas within Texas as priority areas to ensure generating entities have developed and implemented highly effective and complete EOPs; and to identify best practices regarding equipment contamination management.



This report to the PUCT is intended to supplement the exhaustive efforts of those at the PUCT, the Electric Reliability Council of Texas (ERCOT), the Texas Reliability Entity (TRE), and the many stakeholders who operate within Texas who have already taken a significant number of actions to address the recommendations resulting from the analysis of the February 2011 events. These actions fall in the broad categories of planning and reserves, coordination with generator owners and operators, winterization, communications, and load shedding as tracked by TRE in the spreadsheet included as Appendix 2. Some of the actions pertinent to the content of this report include:

- ERCOT-hosted workshops on generator weatherization and load shedding
- TRE survey of transmission and generator owners regarding winter preparedness and subsequent webinar
- ERCOT winter assessment survey
- PUCT workshop on Resource Adequacy and Shortage Pricing
- The inclusion of sensitivity analysis into ERCOT's seasonal assessments resulting in a new report, the Seasonal Assessment of Resource Adequacy (SARA)
- Modifying rules for regulation service, vastly increasing resource outage approval timeframes, reinforcing authority to secure additional responsive reserves as needed
- ERCOT procedural changes to verify resources are implementing weatherization practices including fuel switching during projected and actual extreme weather events
- Changes to permit ERCOT to verify blackstart capabilities by random testing
- Obtaining and factoring ambient temperature unit design specifications and extreme forced outage rates into resource adequacy assessments
- Establishing points of contact with regulatory agencies to discuss removal of emissions limits on generators during emergency conditions
- Major enhancements to communication protocols and information access between ERCOT, market participants, and the PUCT during emergency conditions
- Clarifying roles and responsibilities of participants implementing emergency procedures

For more than a year, entities in Texas have been improving their overall state of extreme weather preparedness through these activities. In some cases, these changes have already manifested themselves in updated emergency plans; in some cases, perhaps not. The focus of this activity is to review the current state of those emergency plans directed to be provided by the PUCT relative to the compendium of lessons learned from the February 2011 events.



Review of Emergency Operations Plans (EOPs)

The PUCT adopted §25.53 (see Appendix 3) on December 17, 2007, requiring each market entity¹ to file with the PUCT a copy of its full EOP or a comprehensive summary of its EOP. At a minimum, the EOPs shall be available for PUCT or staff inspection at the market entities' main office. The rule also applies to electric cooperatives. Municipally owned utilities were not required to submit EOPs; however, some municipally owned utilities have historically provided information regarding emergency operations to the PUCT on a voluntary basis, and were encouraged to provide their plans as well. These entities were required to submit an initial comprehensive EOP or summary of the EOP by May 1, 2008 and to provide revisions to the PUCT within 30 days of significant changes to the plan.

In its rule, the PUCT specified that the contents of the EOPs for electric utilities and transmission and distribution utilities (TDUs) shall include the following:

- Registry of critical load customers
- Communications plan
- Curtailment priorities, procedures for shedding load, rotating black-outs, and planned interruptions
- Priorities for restoration of service
- Pandemic plan
- Hurricane plan
- An affidavit indicating that all relevant operating personnel are familiar within the contents of the EOP and will follow it in the event of a system-wide or local emergency except to the extent deviations are appropriate based on the circumstances;
- Annual drill with an effectiveness review

For electric utilities that own or operate electric generation facilities and power generation companies (PGCs), requirements include:

- Summary of power plant weatherization plans and procedures
- Summary of alternative fuel and storage capacity
- Priorities for recovery of generation capacity
- Pandemic plan
- Hurricane plan

¹ Market entities are defined as electric utilities, transmission and distribution utilities (TDUs), power generation companies (PGCs), retail electric providers (REPs), and the Electric Reliability Council of Texas (ERCOT).



- An affidavit indicating that all relevant operating personnel are familiar within the contents of the EOP and will follow it in the event of a system-wide or local emergency except to the extent deviations are appropriate based on the circumstances;
- Annual drill with an effectiveness review

In addition, a retail electric provider (REP) shall include in its plan an affidavit affirming it has a business continuity plan. Electric Reliability Council of Texas (ERCOT) is required to attest it has a Crisis Communication Plan, a business continuity plan, and a pandemic preparedness plan.

Market entities are required to exercise their emergency procedures every 12 months via actual implementation or through drills, and provide and maintain an emergency contact with the PUCT. Additionally, they must provide the PUCT with updates on the status of operations, outages, and restoration efforts during declared emergency events until all outages are restored or otherwise notified by the PUCT staff. The rule requires electric cooperatives to submit the same information for their areas of responsibility.

Quanta Technology specifically focused its EOP review on the generating companies' weatherization plans and procedures, and compared the content of the complete plans with the list of extreme weather generator best practices, also identified in this report. Quanta Technology also reviewed other key provisions, including if the plans address hurricanes, etc. as required by the PUCT.

Analysis of Texas Electric System Reliability

Quanta Technology utilized a three-part approach to analyze the robustness of the bulk electric grid in Texas. The first component is an analysis to evaluate the risk that the available generating capacity will be inadequate to meet the demand during 2012 seasonal peak conditions. This analysis included a sensitivity of expected capacity and demand to extreme temperature conditions; increases in generator forced outage rates; and increased forced outages due to drought conditions. Quanta Technology utilized existing NERC and ERCOT resource adequacy evaluations as the baseline for this review and sensitivity analysis.

The second component of the analysis involved the use of a Vulnerability Assessment Tool (VAT) to identify critical locations on the Texas transmission system. VAT is a proprietary tool designed to identify the most critical substations and areas in an interconnected bulk power system and to numerically rank them in proportion to their potential to impact the reliability of the bulk power network. VAT is used to identify trigger points on the system that are not manifest by classic contingency analyses. The VAT program was used to identify "hot spots" on the transmission system at which there was either a concentration of transmission facilities or generation, the outage of which would impact system performance on the aggregate. The ERCOT Transmission Network map was used to identify groupings of transmission lines whose routes were in reasonable proximity to each other where it is reasonable to consider the facilities a common corridor susceptible to a common mode outage related to a severe weather event. A targeted power flow analysis was then performed on these targeted "critical" areas to identify system reliability concerns.



The final component of this analysis is the evaluation of the transfer capability of the Texas transmission network to supply concentrated load pockets (e.g. major cities) that might occur due to localized generation deficiencies. The first contingency incremental transfer capability (FCITC) is the amount of power incremental above normal power transfers that can be reliably transferred over the transmission system in a reliable manner, ensuring that the system remains within emergency limits following the loss of any single electric system element.

Texas has been subjected to severe drought conditions over the past two years in particular. The most apparent visible environmental impacts include withering agriculture, depleted lakes and reservoirs, and generally dry, dusty conditions. Less obvious but equally devastating is the impact of the decrease in lake and river levels and increased water temperature in the depleted reservoirs of generating plants, while in the midst of serving peak customer demands. Quanta Technology included a sensitivity analysis on these effects specifically in the context of its resource adequacy analysis and more generally in the study of the Texas grid.

Extreme Weather Best Practices for Generators

Much effort has been devoted to identifying the contributing causes of major electric system outages that have occurred from time to time. Periodically, these events are in part caused by generators who are inadequately prepared for extreme weather events, such as extended cold spells. Whereas, generating facilities are designed in northern climates to routinely handle these circumstances, facilities in the southern climates are sometimes not designed for these infrequent climatic extremes. As a result, a myriad of operating procedures and temporary actions are employed to better protect these facilities when extreme weather conditions occur. Quanta Technology performed a review of the recommendations of various extreme weather events that have occurred and identified a concise list of best practices that generating facilities should incorporate into their own extreme weather preparation framework to more effectively manage these situations. Using this list of practices, Quanta Technology also evaluated the contents of the existing full EOPs to identify the current state of the plans relative to those practices. While most of the identified practices are not burdensome or complex, more impetus may be needed to ensure generating facilities institutionalize these practices going forward. While not a technical solution, this may be the ultimate best practice.

Contamination

Establishing a program to effectively address electric facility contamination is a regular component of the facility owner's equipment maintenance strategy. These programs need to be flexible to address the changing environmental conditions such as those created by the extended drought conditions in Texas, as well as manage the expected environmental conditions in which the facilities routinely operate. Quanta Technology conducted a review of recent contamination events in Texas and available literature regarding facility contamination management, including a compendium of current best practices (developed by a team that included Quanta Technology personnel) and proposes a framework for entities to utilize to analyze its current state and improve its contamination management practices.



II. REVIEW AND EVALUATION OF EMERGENCY OPERATIONS PLANS

Quanta Technology performed a two-stage review of the EOPs required to be maintained by market entities and electric cooperatives per §25.53. In accordance with Senate Bill 1133, the PUCT established tasks to: 1) review and evaluate the EOPs previously submitted to the PUCT by electric utilities, transmission and distribution utilities (TDUs), power generation companies (PGCs), retail electric providers (REPs), the Electric Reliability Council of Texas (ERCOT) and electric cooperatives; and, 2) make recommendations on how each plan should be improved if a plan is identified to be lacking in sufficient detail.

In the initial phase, Quanta Technology reviewed 130 summary EOPs² (or affidavits thereof) submitted to the PUCT to evaluate whether the entities incorporated the weatherization practices and procedures identified in the final Federal Energy Regulation Commission-North American Electric Reliability Corporation's (NERC-FERC) report analyzing the February 2011 extreme weather event. For the second part, Quanta Technology reviewed 119³ detailed EOPs submitted to ERCOT by the market entities and electric cooperatives (and municipal utilities who submitted on a voluntary basis) to assess the inclusion of those weatherization practices and procedures identified in this report. Many of the complete EOPs had been recently updated indicating that generating entities had recognized and incorporated lessons learned from the February 2011 cold weather event. The findings from this two-part review are summarized in the tables included as Appendices 4 and 6 in the confidential version of the report.

In the original review, Quanta Technology evaluated the summary EOPs based on several key criteria. These criteria were developed by reviewing and evaluating the findings and lessons learned⁴ from the February 1-5, 2011 cold weather event and associated outages. These criteria focused on weatherization practices for electric generating entities only, as required by Senate Bill 1133.

² In addition, some entities filed EOP updates in 2011 as part of a separate PUCT project, which were not provided for this project. The listing of entities who provided EOP updates as part of this corollary project are listed in Appendix 3a.

³ Since §25.53 allowed utilities to submit summaries of their plans to the PUCT, most electric utilities, TDUs, and PGCs filed a summary of the plan, which permitted Quanta Technology to review only an overview of a company's EOP. In many cases, the "comprehensive summary" of the company's EOP provided assurance that the specific PUCT plan requirement was being met while excluding specific details. The PUCT, using authority provided in Senate Bill 1133, requested generating entities to submit their full EOPs to ERCOT to enable a more thoughtful and complete review of the EOPs.

⁴ These include FERC's August 2011 report, NERC's Lessons Learned, ERCOT's Weatherization Workshop June 2011, Texas Regional Entities November 2011 presentation, and El Paso Electric's May 2011 report on the February event. In other cases, not enough detail was available to render a judgment.



Criteria #1- Awareness of plant (generator and plant equipment) weather design limits

The first criterion was to determine if the plan recognized the generating plants design limits regarding weather. While there are many components to a generating plant that can fail during extreme weather, knowing the actual design limit is essential to developing a plan for operating during extreme weather. For example, certain pieces of equipment may not be expected to operate below 20 degrees Fahrenheit and will require external heat such as heat tracing or other heat sources. This criterion includes all weather-related design parameters such as high temperatures, wind, ice, lightning, etc.

Criteria #2 – Understanding of the critical failure points within the plant

The second criterion was to determine if the plan recognized the specific critical failure points in the plant. During the cold weather event in February 2011, numerous failures were the result of not understanding the critical failure points. These included, for example, instrumentation, compressor drains, etc. To ensure the plant is prepared to operate through an extreme weather event, understanding the specific critical elements to be addressed is required, such as any instrumentation whose failure can trip the unit.

Criteria # 3 – Address if the plant expects to operate during extreme weather

The third criterion was to determine if the plant, recognizing the limits and the critical failure points, expected to operate during extreme weather conditions. For example, most wind turbine generators stated the plant would automatically shut down above or below certain temperatures. An additional key element is to ensure generator owners convey to their associated generator operators and transmission operators these design limitations, especially if the units will shutdown beyond certain extremes.

Criteria # 4 – Did the plan provide specific checklists for plant personnel

The fourth criterion was to determine if specific checklists for plant personnel were provided to ensure that all critical failure points were checked, prepared, and monitored for the extreme weather events. Checklists provide a repeatable and documented framework for ensuring all critical failure points are addressed prior to and during the onset of extreme weather. Checklists can also be used during the extreme weather event to ensure on-going actions are taken to prevent critical component failures during the event.

Criteria # 5 - Process for identification of imminent weather events

The fifth criterion was to determine if the plan included a process for the identification of imminent weather events. While weather forecasting provides the basis to identify imminent weather events, a process for recognizing the imminent weather event and proactively implementing the EOP for the event is necessary.



Criteria #6 – Inventory of pre-arranged supplies for extreme weather events

The sixth criterion was to determine if the plan included a list of supplies that should be on-hand in advance of extreme weather events and a process for ensuring those supplies are indeed available. This can include replacement parts, additional heat tracing material, heaters, fuel for heaters, tarps, heat lamps, etc.

Criteria # 7 – Training for extreme weather events

The seventh criterion was to determine if the plant personnel were provided training for extreme weather events. Regular training can ensure employees fully understand the plant operations and limitations, their roles and responsibilities during extreme weather events, personnel safety, and that they are prepared to recognize problems and address issues.

Criteria # 8 – Drills for extreme weather conditions

The eighth criterion was to determine if the plant conducted extreme weather drills. Such drills can provide value by identifying gaps in the EOP and allow plant personnel to make the necessary adjustments. Drills also reinforce the training provided for extreme weather operation to confirm personnel fully understand their roles and responsibilities during an extreme weather event.

Criteria # 9 – Alternative fuel testing

The ninth criterion was to determine if the plan required the plant to periodically test the use of alternate fuel, if available. The infrequent use of alternate fuel (such as fuel oil) and the potential for the alternate fuel systems to be affected by extreme weather needs to be addressed in the event part of the EOP expects the possible use of alternate fuel during an event.

Criteria # 10 – Staffing levels during an extreme weather event

The tenth criterion was to determine if the plan addressed staffing during an extreme weather event. During extreme weather events, additional staffing may be necessary to execute the plan, and maintain extreme weather remediation such as heaters, etc.

Criteria # 11 – Review of actual extreme weather events for lessons learned

The eleventh criterion was to determine if the plan called for the review of the extreme weather event for lessons learned and improvement opportunities to the overall plan itself. Every event will likely provide lessons and opportunities for improvement and an effective plan will capture those lessons and opportunities to allow improved implementation during the next extreme weather event.

Appendix 6, included in the confidential version of this report, provides a summary of the evaluation of submitted EOPs based on the criteria identified above.



Findings

Quanta Technology identified several key observations with respect to the EOP-related documents that were on file with the PUCT and at ERCOT, both the summary EOPs originally reviewed and the complete EOPs provided upon later request. These observations served as the foundation of the recommendations contained later in this section. Because many opportunities for improvement when reviewing the individual EOPs, the observations and recommendations listed below, while not specific to any one company's EOP, address overall possible improvements that should be considered by the PUCT in light of recent extreme weather events.

Observation # 1 – EOP Summaries Provided To PUCT Lack Detail for Evaluation

The PUCT has a limited number of complete EOPs in their files for review.

Most companies submitted "comprehensive summaries" of their EOPs to the PUCT, permissible by its rule. These summaries often included statements that addressed each of the required EOP items identified in the rule. In some cases, the company provided a table of contents or referenced where the specific requirement was covered in their plan. Where only plan summaries were provided, insufficient detail existed to assess the plan itself, although the more comprehensive plan may in fact contain the desired components.

The rule also indicates that entities are also required to have a complete plan, which in many cases was provided upon request. As discussed later in the report, a majority of the steam generating and combustion turbine plant owners demonstrated at minimum a framework for and general awareness of the need for weatherization preparedness in these EOPs.

Observation # 2 – Some EOPs Not Available at the PUCT

The PUCT did not have an EOP for all entities to whom the rule applied.

P.U.C. SUBST. R.25.53 required each market entity to file with the commission a copy of its plan or a comprehensive summary of its emergency operations plan by May 1, 2008 and file a revised plan or a revision to the comprehensive summary that appropriately addresses significant changes to the plan no later than 30 days after such changes take effect. A majority of entities are in compliance with this rule. The PUCT maintained EOPs or summaries therein for the entities identified in Appendices 4 and 5 (included in the confidential version); however, plans for all entities were not identified. This does not suggest they do not exist; rather, they were not available for review.

Additionally, the PUCT does not have jurisdiction over municipal utilities although several voluntarily provided their EOPs as part of this or a corollary project.



Observation # 3 – Emergency Operations vs. Emergency Preparedness

Emergency operation plans at many generating facilities addressed fire, chemical spills, bomb threats, etc. but not extreme weather preparedness. Those that did address extreme weather focused on personnel and plant safety, not plant availability.

The plans or summaries thereof provided to the PUCT are EOPs, covering operations during emergency conditions. In many cases, the plans focused on operation during a system outage or emergency versus preparing to operate a facility to ensure its availability during extreme weather conditions. In numerous cases, the EOPs for generating facilities addressed fire, chemical spills, bomb threats, etc. In nearly all cases, the company indicated there was a plan in the event of a pandemic. However, not all of the plans for generators included the PUCT weatherization requirements listed in the rule and outlined in the report introduction.

The entities that did address extreme weather preparation varied in the approach and content of the EOPs. The rule did not define the contents of EOPs in terms of weather preparedness to better guide entities in developing their plans for severe weather, cold weather, hot weather, or for any other possible weather extremes. As such, different owners provided plans for differing conditions.

Furthermore, a number of the EOPs focused on severe weather from the perspective of protection of personnel and plant equipment. The plans addressed operation or preparing to operate during lightning storms, tornado warnings, hurricanes, high winds, flooding, ice and snow (from the perspective of removal), and earthquakes. The primary focus in these plans is on items that can become flying debris and on other hazards from a personnel safety point of view.

Some plans did include winter weatherization checklists and staffing to implement winter weatherization and operation practices. Where these plans included such checklists, they were generally very detailed and included freeze protection procedures such as heat trace verification, insulation checking, checking drains, installation of tarps, and use of heaters and their available supply of oil to name a few.

It is important to understand that although the full EOPs (or the summary descriptions thereof) may not have included explicit extreme weather practices as discussed in this report, the entities may (and oftentimes do) have these procedures maintained elsewhere in their procedures and practices. The PUCT may, for consistency, want to standardize what should be included in EOPs in the future.

Observation # 4– Understanding plant operating limitations

Plants, other than wind generators, generally did not include any extreme weather operating limits in their plans.

In some cases, the EOPs provided specific information regarding the plants' weather-related operating limitations. However, this information was primarily identified in the plans for wind



turbines, which generally operate between -4 degrees Celsius and 40 degrees Celsius, and shutdown above certain wind speeds. Other types of plants did not often provide any operating temperature or other weather-related limitations, although such limits may be appropriate. For example, some combustion turbine generators have limits based on ambient air temperature that may result in de-ratings of the units, coal plants may have limits due to cooling water temperature limitations, and other units may have limits when using alternate fuel such as fuel oil. These should be documented in the EOPs.

Observation #5– Checklists for personnel

Most entities with generation that can be protected provided checklists for personnel to that addressed at least cold weather operation.

Approximately 47% of the detailed plans reviewed contain some type of checklist for plant personnel related to minimum cold weather operations. Although checklists were not included in some EOPs, entities often maintain separate preparedness procedures for these activities apart from the EOPs. The PUCT may wish to require their inclusion in the EOPs to ensure consistency among generators.

Because most wind turbine generators indicate they do not have realistic capability to operate beyond manufacturer design tolerances, there is a high percentage of these generating plants noted with a less comprehensive checklist, because those units would not be expected to be online anyway given their temperature constraints.

Observation #6–Some generators automatically shut down during weather extremes

Wind generators often automatically shut down during weather extremes.

Most wind generators reported that their plants had specific high and low temperature operating limits. A number of those plants indicated the turbines would automatically shut down beyond those operating points. Grid operators should be informed in advance of these limitations with follow-up communication expected from the facility owners/operators when those limitations are likely to be exceeded.

Observation #7– Emergency operations plans do not yet consistently address the recommendations and lessons learned from the February 2011 event.

The emergency operations plans on file with the PUCT did not yet consistently address the issues identified in the FERC report on the February 2011 cold weather event and associated NERC Lessons Learned.

In August 2011, the FERC issued its report on the February 2011 cold weather event, which contained 26 recommendations for the electric industry. NERC also issued numerous “Lessons Learned” related to the event, with additional lessons learned available based on other historical cold weather events. ERCOT and the Texas Regional Entity (TRE) both held workshops on



weatherization of generators. Quanta Technology reviewed this material and developed evaluation criteria that included the key elements from these recommendations and lessons learned.

NERC, ERCOT, the TRE, and generating plant owners have conducted a number of reviews of “lessons learned” and discussions of best practices related to cold weather preparation. Based on survey information collected by TRE, significant work has been undertaken to understand and implement best practices and plans. The EOPs on file with the PUCT do not yet consistently apply these lessons learned, although it is believed that many generators have implemented them. The EOPs on file with the PUCT should be updated reflecting the application of these lessons.

It is important to note that the PUCT does not have regulatory authority over a generator’s failure to properly implement its EOP. However, the PUCT does exercise regulatory authority over an entity’s actual performance during all events, including extreme weather events, to the extent an entity is deemed to have violated either the PUCT rules or ERCOT protocols.

Recommendations

The EOPs previously submitted to the PUCT were often summaries or affidavits attesting to their completion that in many cases lack sufficient detail to determine if the generating facilities have specific weatherization plans in place. Other information available, including survey information collected by the TRE, indicates that significant work has recently been undertaken to understand and implement plans that address extreme weather operation. Quanta Technology staff reviewed each of the detailed EOPs based on eleven key criteria developed from the recommendations, lessons learned, and best practices provided by FERC, NERC, ERCOT, and TRE.

Recommendations are focused on supporting the needs of the PUCT to ensure that generation owners are fully prepared for extreme weather operations. Many of these recommendations will ensure the work already undertaken by the generation owners is incorporated in their EOPs. Recommendations also focus on the actions that can be taken by the PUCT to assist those who have not included cold or hot weather preparations in their EOPs to ensure those entities have formalized those plans. Implementation of these recommendations will establish a consistent level of power generation weatherization preparedness to help ensure the continuity of electric service is maintained during potential extreme weather conditions.

Recommendation 1

The PUCT should consider standardizing information to be prepared and filed as part of the EOPs. The eleven following areas should be considered areas to be addressed in the form determined appropriate by the PUCT.

- *Awareness of plant (generator and plant equipment) weather design limits*
- *Understanding of the critical failure points within the plant*



- *Address if the plant expects to operate during extreme weather*
- *Did the plan provide specific checklists for plant personnel*
- *Process for identification of imminent weather events*
- *Inventory of pre-arranged supplies for extreme weather events*
- *Training for extreme weather events*
- *Drills for extreme weather conditions*
- *Alternative fuel testing*
- *Staffing levels during an extreme weather event*
- *Review of actual extreme weather events for lessons learned*

The current rule requires PGCs, electric utilities and electric cooperatives that own or operate electric generation facilities to include in their plans:

- A summary of power plant weatherization plans and procedures
- A summary of alternative fuel and storage capacity
- Priorities for recovery of generation capacity

The rule does not contain specific requirements defining the severe weather events that should be addressed in an EOP. It states that the plan should address power plant weatherization plans and procedures. To establish a more consistent level of power generation weatherization preparedness throughout the EOPs, the plans should include plans and procedures to ensure the continuity of electric service during potential extreme weather, including extreme cold weather, extreme hot weather, or for any other possible weather extremes of interest such as high-winds, ice, etc.

As presently structured, the plans often lacked weatherization plans related to extreme cold or hot weather. The eleven specific criteria developed to evaluate the current EOPs should serve as a basis for developing those requirements. The PUCT could undertake a rulemaking and through that process identify the specific items to be included in future EOPs and a timeframe for updating the plans accordingly.

The PUCT should consider this recommendation with full consideration that generators, in ERCOT's energy only market design, are highly incentivized to maintain availability at all times. Generators must offer their units and respond when called to service in order to receive compensation in ERCOT's market. Especially during extreme weather events such as that experienced in February 2011 when ERCOT attempted to maintain load-energy balance in the midst of dwindling operating reserves, market prices for generation typically soar to the market cap level, \$3,000/MWh⁵, creating great economic opportunities for those units able to remain on-

⁵ As of August, 2012, the market cap price increased \$4,500/MWh.



line. In this context, while the PUCT may wish to consider more specific requirements for extreme weather preparedness as outlined in this report, it must balance this need against the powerful market incentives that already exist for generating entities to take whatever steps are appropriate to maintain optimal availability.

As discussed in greater detail later in this report, the generating entities should carefully review and consider the following best practices regarding extreme weather preparedness when updating and revising its EOPs:

Cold Weather

- Documented plan in place for primary best practices.
 - Adequate heat tracing, especially for potentially exposed instrumentation sensing lines and transmitters,
 - Adequate insulation and lagging,
 - Thermal enclosures,
 - Detailed maintenance and testing plan for freeze protection components,
 - Temperature design limit criteria complete and up to date for all temperature sensitive plant components,
 - Portable air compressors available to provide backup instrument air in remote areas as needed,
 - For turbine generator peaking units, consider periodic starting and equipment warm up prior to actual dispatch,
 - Keep auxiliary boilers on hot standby where applicable.
- Documented plan in place for secondary best practices.
 - Closing roll-up doors,
 - Spot applications of temporary insulation,
 - Deployment of fuel oil heaters to help protect exposed equipment,
 - Isolating and draining non-essential water lines,
 - Installing fabric or plastic windbreaks or temporary enclosures around exposed equipment
 - Letting unprotected but essential water lines drip.
- Mechanisms in place to execute preparedness activities.
 - Execution of preparedness activities is accomplished through a documented process.
 - Verify fuel switching capabilities as appropriate.
 - Review fuel supplies to assess potential for curtailment, especially natural gas.
- Weatherization Supplies



Hot Weather

- Documented plan in place.
 - Clearly documented cooling capacity limits, regulatory requirements for water withdrawal in certain lakes/reservoirs within watersheds, maximum discharge temperature limits, and current priority for water rights during drought conditions.
 - Adequate water supplies for cooling towers
 - Adequate cooling capacity of the water supplies to the cooling tower heat exchangers
 - Perform preventive maintenance on the cooling equipment prior to the forecasted high temperature.
 - Consider temporary measures where applicable to help remove heat
 - Redundant HVAC equipment to computer/IT equipment
 - Plan to conserve available cooling capacity for application during extreme weather conditions
- Mechanisms in place to execute preparedness activities.
 - Execution of preparedness activities is accomplished through a documented process

Recommendation 2

To the extent the legislature believes this is an important endeavor, the legislature could consider extending the PUCT's jurisdiction over MOUs that own generation and require them to file EOPs. This will help to ensure all EOPs address the specific areas of weatherization required to ensure extreme weather preparedness and equipment reliability.

The importance of having all generation available during extreme weather conditions requires that all generator owners be optimally prepared by addressing the eleven criteria and implementing extreme weather preparedness best practices. Several municipal utilities voluntarily filed their EOPs with the PUCT as part of a corollary collection effort, which permitted the analysis of their extreme weather emergency preparedness. Notwithstanding the outstanding voluntary support received by the municipal utilities throughout the response to the extreme weather events in 2011, as the PUCT determines what recommendations, lessons learned, and best practices should be included in future EOPs in Texas, having the authority to regularly include the municipal utilities with generation in this effort will be an important addition.

Recommendation 3

The PUCT should consider how best to ensure that all entities have appropriate EOPs, whether by filing complete plans, allowing a more detailed summary, or affidavits indicating the plan is complete.



P.U.C. SUBST. R. 25.53 requires certain entities to file their EOPs, or a detailed summary of the plan, with the PUCT. The information at the PUCT revealed that the summaries provided were of limited value for this review. The PUCT should consider if continued filings of detailed summaries of the plans (or affidavits) are appropriate in lieu of providing the complete EOP. If deemed appropriate to continue to provide summaries, the PUCT should specify the level of detail required in the summaries.

Conclusion

Quanta Technology reached a number of conclusions based on the review of generating entity EOPs provided by the PUCT. Most importantly, absent specific requirements defining the severe weather (extreme heat, cold, drought, wind, ice, etc.) to be addressed in an EOP along with the specific requirements to be addressed, plans provided to the PUCT were not consistent in content and often did not consider the issues of extreme weather preparedness for plant operation based on the recommendations, lessons learned, and best practices identified as a result of the February 2011 cold weather event and other events. Incorporating these recommendations into EOPs will help ensure the continuity of electric service to citizens of Texas during extreme weather conditions.



III. ABILITY OF THE TEXAS GRID TO WITHSTAND EXTREME WEATHER EVENTS

Quanta Technology conducted a review of the reliability of the Texas grid in terms of two key aspects: transmission grid robustness and resource adequacy. To assess transmission grid robustness, Quanta Technology performed a two-part analysis to assess the ability of the Texas grid to withstand extreme weather events – an initial vulnerability assessment to identify critical locations accompanied by power flow analysis to identify the grid's ability to meet the power delivery needs in those areas, and a first contingency incremental transfer analysis to assess the ability of the grid to meet the needs of large load centers under generator outage conditions. The transmission grid review was supplemented by a further review and analysis of the adequacy of Texas' generating resources to meet projected customer demands under expected conditions in 2012 and 2013 as well as under alternate scenarios that included greater than expected generator outages as a result of impacts from extreme conditions such as drought, and from greater than expected customer demand as would be possible during extreme weather conditions.

Outlined below is a summary description of the analyses followed by a detailed discussion of the methodology that Quanta Technology employed to perform these multiple analyses. Because the resource adequacy analysis is based on publically available information, the results of this analysis will be included herein. Conversely, the Texas transmission grid assessment is based on power flow modeling information that is considered highly sensitive, and as the results of this analysis identifies potential areas of vulnerability, Quanta Technology will generalize its findings in the discussion that follows for inclusion in the public version of the report. Any specific facility and location-specific details will be included in Appendix 9 in the confidential version of the report.

Summary of Analyses

Several seasonal NERC and ERCOT assessments were used to identify the most probable resource adequacy scenario for the winter 2012-2013 and summer 2013 timeframes. Under these conditions, ERCOT expects to have ample generating reserves to meet the customer demand and effectively respond to unanticipated generator outages.

Quanta Technology then performed sensitivity analyses against the expected conditions to consider lower probability events, at first individually and then in combination. An evaluation was conducted to assess resource adequacy with increased customer demand – using approximately 1 in 10 demand conditions (90th percentile), 1 in 20 (95th percentile), and 1 in 50 conditions (98th percentile). Only in this last most extreme case for the summer 2012, ERCOT would have approached resource constraints that necessitated implementation of an energy emergency alert (EEA). As the net available resources are projected to increase in 2013, this concern is alleviated. No such issues exist for the winter analyses in this or any of the remaining sensitivity analyses.



Next, greater than expected generator outages are then assessed. Forced generator outages in a bandwidth around the 90th percentile (10% probability) were considered in combination with outages of at-risk generation due to drought conditions at a level in excess of 50% of the at-risk generation identified by ERCOT. Whereas no resource adequacy issues are identified in the winter, resource constraints appear in the most extreme summer scenario for 2013 – that is, 95th percentile forced outage levels (less than 5% probability) coupled with the outage of up to 50% of the at-risk generation due to drought. Rotating customer outages would be required in this scenario.

When the impact of extreme customer demand conditions is added to the extreme generator outage scenario described above, as expected, there is an inadequate level of projected resources, which would result in the need for rotating customer outages. Fortunately, drought conditions have substantially abated in 2012 such that the likelihood of drought-related generator outages has greatly diminished, decreasing but not totally eliminating, the possibility that rotating customer outages would be required in these extreme scenarios.

Using a specialized grid vulnerability assessment tool to assess the impacts of common mode failures, Quanta Technology determined that, in general, the Texas grid is quite sturdy. This analysis, when combined with probability of various extreme weather impacts across Texas, resulted in the identification of 18 counties that merit increased attention with respect to extreme weather preparedness and enhanced system analyses for common mode failures.

Resource Adequacy Assessment and Sensitivity Analysis

Quanta Technology performed a review of several key reports regarding generator resource expectations in Texas for the upcoming winter and summer periods. These included ERCOT's fall, 2011, summer, 2012, and fall, 2012 editions of the Seasonal Assessment of Resource Adequacy (SARA) report, ERCOT's Capacity, Demand, and Reserves (CDR) report, also from fall, 2011 and summer, 2012, the Drought Review Survey, the ERCOT, SERC, and SPP seasonal assessments in the NERC Winter Reliability Assessment 2011/2012 and 2012 Summer Reliability Assessment, as well as the 10-year outlook contained in NERC's 2011 Long-Term Reliability Assessment. The summaries from the NERC seasonal and long-term assessments are contained in Appendix 8 in the confidential version of the report.

In particular, the ERCOT SARA reports provide an excellent framework for ERCOT to proactively assess potential threats to the grid seasonally, including trending any longer-term issues that proceed through multiple seasons. ERCOT should continue to take advantage of that opportunity as it has done with respect to drought conditions in the SARA reports evaluated for purposes of this report.

In addition, Quanta Technology referred to the "Analysis of Drought Impacts on Electricity Production in the Western and Texas Interconnections of the United States" issued in December 2011 by the U.S. Department of Energy - Argonne National Laboratory (DOE Report).



The data from these various sources was used to evaluate the capacity resources available in Texas at a baseline level, followed by a sensitivity analysis to determine the impact of higher than expected forced generator outages, forecasted load, and additional capacity reductions due to drought conditions. For purposes of this analysis, extreme weather is considered that which can create common mode outages (e.g. hurricanes, tornadoes, etc.) or temperatures that result in loads at or above the 90th percentile (equivalent to a 1 in 10 scenario or greater).

As discussed in the various assessments, ERCOT summer 2012 and 2013 operations will be acceptable if:

- Normal weather patterns are experienced;
- Generator forced outages approximate average historical forced outage rates; and
- Extended drought conditions do not further impact thermal generating capability.

However, prolonged periods of extreme temperature will drive up customer demand; cause higher than expected generator forced outage rates; and in particular, the loss of generating capacity due to the continuing drought conditions could erode the available reserve levels resulting in the need for energy management procedures that could include rolling customer outages. Importantly, since 2011 when Texas was in the midst of an extreme drought in many areas, drought conditions have significantly lessened such that the potential impacts are not expected to manifest in 2012 or 2013.

Capacity resources in the winter peak season are less of an issue in ERCOT as noted in the winter seasonal assessments.

Sensitivity Assumptions – Summer 2012 and 2013

Quanta Technology used the 2012 summer baseline values for demand and resources from 2011 CDR Report in the ERCOT Region to assess conditions for 2013 summer based on the projections for 2012. Table 1 reflects the sensitivity analyses pertaining to the summer 2012 conditions. As an initial sensitivity, the demand forecast for summer was increased by 3%, 6%, and 9%, respectively (Table 1 - Column B) to reflect extreme temperature conditions. Based on planning experience, it was assumed that summer peak demand would increase by 6% should peak conditions be at the 90th percentile rather than the more traditional 50th percentile used in resource adequacy assessments. Sensitivity analysis considering +/-50% of this adjusted level was then considered.

For this scenario in 2012, ERCOT's reserves would drop below 2,300 MW, the level at which an Energy Emergency Alert (EEA) would be initiated, if the summer peak loads exceed forecast levels by 9%. This represents an estimated 95-99th percentile load, or less than a 5% probability of occurrence. Note that this adequacy assessment is considering capacity versus operating reserve targets as compared to capacity reserve margin targets since we are evaluating reserves at the time of peak operation. However, in 2013, there is a projected net increase of approximately



2,000 MWs of reserves, which would increase the levels such that EEA declaration would not be expected.

As a separate sensitivity, increased generator forced outage rates above those normally expected were considered. The sensitivity incorporated a generator forced outage rate at the 90th percentile (using the 50th percentile as the normal forced outage rate), and at 50% above and below the 90th percentile rate, reflecting an excessive forced outage rate compared to the average. In addition, outages to generating units affected by drought were identified separately based on the capacity considered at risk due to drought conditions as noted in the resource drought survey. The aggregate capacity identified in the survey was considered at 100%, 300% and 600% of the reported values. Note that these drought-outage values are still below the maximum at-risk values (11,000 MWs or about 15% of total capacity) identified by ERCOT in its evaluation in the fall, 2011. The probability of this scenario is significantly less than the 1 in 10 expectation that served as the initial assumption for the sensitivity.

The results of this analysis for 2012 are identified in Column C of Table 1. Note that these calculations only include adjustments to capacity resources due to extraordinary outages associated with higher than normal forced outages and drought-related capacity reductions. Normal generation forced outages are addressed through the provision of targeted operating reserves. These results indicate that reserve levels could drop marginally below the 2,300 MW operating reserve margin, which would require an EEA declaration. This is based on extraordinary forced outages at the 90th percentile levels and at 300% of the reported values for drought-impacted generation. Under the most extreme outage scenario evaluated, it is likely rotating customer outages would be necessary as there is a projected 2,300 MW capacity deficiency. With the projected 2,000 MW reserve increase projected in 2013, the need for the EEA would be eliminated but rotating customer outages would still be projected in the most extreme outage scenario.

Note that the DOE report identified a significant percentage of at-risk thermoelectric generation in the Texas Gulf basin, in excess of 70% total capacity, potentially affected by drought. Although additional detailed study is required, the worst-case projected loss of thermal generation in a severe/extreme drought scenario could approach 25% of total capacity. Thus, the current drought impacts, actually experienced and at-risk per ERCOT's projections, have been significantly less than the worst-case scenario presented in the DOE report. These effects have been mitigated by the improved drought conditions in 2012 such that the extreme scenario would likely not materialize if drought levels remained constant or continued to improve.

Combining these two sensitivities in a most extreme scenario – higher than projected customer demand (as outlined in Column B) coupled with higher than expected forced outage rates specifically impacted by drought conditions (as outlined Column C) – yields the results in Column D. For the summer 2012 period, capacity deficiencies exist in the moderate and extreme sensitivities. The moderate sensitivity is classified as a 6% increase in customer demand, 90th percentile forced outage rates, and 300% of drought-impacted resources outaged. This combination results in a nearly 1,900 MW resource deficiency.



This deficiency spirals to over 8,100 MWs in the summer period with a 9% increase over projected demand, a forced outage rate at 50% higher than the 90th percentile value, and with 600% of the drought-impacted resources based on the drought survey outaged. (Refer to Column D of Table 1) These results do not materially change for the projected demand and resources in 2013.

In practice, ERCOT did not experience the conditions in the summer, 2012 that resulted in the need to implement EEAs. ERCOT's summer, 2013 forecasted conditions based on the summer 2012 CDR report indicate an improved posture relative to the 2012 assessment. Although load is projected to increase by over 1,000 MWs from the 2012 forecast, an additional 3,000 MWs of resources are projected to be available to offset this increase, and position ERCOT more favorably in the 2013 summer period.

Sensitivity Assumptions – Winter 2012/2013

For 2012/2013 winter conditions, the demand forecast for winter was increased by 6%, 12%, and 18% to reflect extreme temperature conditions, reflecting 90th, 95th, and greater than 95th percentile loads, respectively. The medial value for the 2012/2013 winter was taken from the December 2011 CDR and SARA presentation. The median value and associated range are sufficient to capture the historic extreme temperature demand that occurred during the February 2011 cold spell in which loads experienced were approximately 10% above the normally forecast levels. However, higher than forecast loads alone would not trigger an EEA event in the winter as the expected capacity is well above the 2,300 MW operating reserve target. Furthermore, higher than forecast outage rates alone would not trigger an EEA event in the winter as evidenced in Column C of Table 2. Lastly, in all combined sensitivity winter scenarios, projected reserve levels are maintained above the 2,300 MW threshold indicating that no EEA declaration would be projected to occur as outlined in Column D of Table 2.

In looking ahead to the winter 2012/2013, projected demand and resource increases are comparable yielding generally similar sensitivity results.



Table 1: 2012 Summer Capacity Reserve Margin Sensitivity

	No Adjustments Baseline (A)	Higher than Forecast Loads (3%, 6%, 9%) (B)			Higher than Forecast Outages (C)			Higher than Forecast Loads and Outages (D)		
Adjusted load forecast	64,618	64,618	64,618	64,618	64,618	64,618	64,618	64,618	64,618	64,618
Increase: Extreme Temperature	0	1,939	3,877	5,816	0	0	0	1,939	3,877	5,816
Modified Load	64,618	66,557	68,495	70,434	64,618	64,618	64,618	66,557	68,495	70,434
Available Capacity	72,444	72,444	72,444	72,444	72,444	72,444	72,444	72,444	72,444	72,444
90th Percentile FOR	0	0	0	0	-1449	-2898	-4347	-1449	-2898	-4347
FOR due to Drought	0	0	0	0	-975	-2925	-5850	-975	-2925	-5850
Modified Resources	72,444	72,444	72,444	72,444	70,020	66,621	62,247	70,020	66,621	62,247
Capacity Reserve Margin	12.1%	8.8%	5.8%	2.9%	8.4%	3.1%	-3.7%	5.2%	-2.7%	-11.6%
Available Operating Reserves	7,826	5,887	3,949	2,010	5,402	2,003	-2,371	3,464	-1,874	-8,186

Table 2: 2012/2013 Winter Capacity Reserve Margin Sensitivity

	No Adjustments Baseline (A)	Higher than Forecast Loads (6%, 9%, 15%) (B)			Higher than Forecast Outages (C)			Higher than Forecast Loads and Outages (D)		
Adjusted load forecast	49,558	49,558	49,558	49,558	49,558	49,558	49,558	49,558	49,558	49,558
Increase: Extreme Temperature	0	2,973	5,947	8,920	0	0	0	2,973	5,947	8,920
Modified Load	49,558	52,531	55,505	58,478	49,558	49,558	49,558	52,531	55,505	58,478
Available Capacity	76,808	76,808	76,808	76,808	76,808	76,808	76,808	76,808	76,808	76,808
Maintenance Outages	-5,268	-5,268	-5,268	-5,268	-5,268	-5,268	-5,268	-5,268	-5,268	-5,268
90th Percentile FOR	0	0	0	0	-1323	-2645	-3968	-1323	-2645	-3968
FOR due to Drought	0	0	0	0	-975	-2925	-5850	-975	-2925	-5850
Modified Resources	71,540	71,540	71,540	71,540	69,243	65,970	61,723	69,243	65,970	61,723
Capacity Reserve Margin	44.4%	36.2%	28.9%	22.3%	39.7%	33.1%	24.5%	31.8%	18.9%	5.5%
Available Operating Reserves	21,982	19,009	16,035	13,062	19,685	16,412	12,165	16,711	10,465	3,244



Conclusions

The capacity reserve margin forecast for ERCOT in summer of 2012 with normal weather and typical outage conditions is approximately 12% and the winter reserve margin is over 40%. However, higher than expected demand **or** forced outage rates, caused by extremes of weather and/or drought conditions, could erode the summer reserve margin to between 3% and 6%. Winter reserve margins should be adequate for higher than expected loads or outages. A worst case scenario with higher than forecast loads **and** increased generator forced outages **and** capacity restrictions due to drought could cause a shortfall in capacity in the summer and strain capacity in the winter. Operating reserves should be adequate for winter peak conditions with the assumed levels of sensitivity. Drought-related outages at levels identified in the SARA report (11,000 MWs) could cause operating reserves to drop below 2,300 MW in the winter scenarios.

It will be incumbent on generation owners to prepare their units to be available should extreme weather conditions occur. Good maintenance practices, precautionary emergency plan implementation, and due diligence to sustain maximum availability are key to assuring that resources are adequate during high load periods and under extreme environmental conditions.

Units that may be susceptible to limited cooling capacity caused by extended drought conditions should take precautionary steps to conserve their energy output. Limited operations except during periods of critical demand can conserve limited thermal cooling capacity and increase the possibility that this limited capacity could be available during periods of extreme demand. This could be accomplished, for example, by reducing output at night to permit reservoir temperatures to decrease in order to achieve full output during the daily peak period. Such precautionary steps can reduce forced outages during periods of high system stress. This option needs to be considered in the context of maintaining water capacity that would also be impacted by natural evaporation.

Recommendations

Recommendation 4

Thermal generation that is susceptible to drought conditions should ensure its extreme hot weather plans as identified in Recommendation 1 are documented and implemented. In addition, owners of these generating plants should proactively evaluate the feasibility of securing additional water resources to mitigate the drought effects, including the following:

- *Securing rights to additional water resources*
- *Access to new groundwater sources*
- *Building pipelines to access to alternate water sources*



Recommendation 5

ERCOT should continue to perform the Seasonal Assessment of Resource Adequacy (SARA) analysis and refine as necessary to proactively evaluate unique events like drought. ERCOT should maintain frequent dialogue with impacted entities to inform its findings.

Transmission Grid Assessment

There are nearly 45,000 miles of transmission lines in Texas. Texas is unique in that its transmission system has facilities in the three major US interconnections and its transmission owners are members of four NERC reliability entities – TRE, SPP, SERC, and WECC. The majority of the transmission, over 40,000 miles, is in ERCOT and constitutes the Texas Interconnection. Entergy operates approximately 2,700 miles of transmission in Texas and is a member of SERC in the Eastern Interconnection. Southwestern Electric Company operates a total of 3,900 miles of transmission in Texas, Louisiana, and Arkansas in the Eastern Interconnection and is a member of SERC. Southwestern Public Service Company operates transmission in the northwestern Texas and is a member of SPP. El Paso Electric operates within the Western Interconnection.

Quanta Technology performed an analytical review of the transmission system within the state of Texas to evaluate its ability to withstand events related to extremes of weather. Considered in this assessment was the outage of multiple transmission lines along common corridors as might result from severe weather events such as hurricanes, tornadoes, ice storms, forest fires, or flooding. Also considered was the outage of generating capacity at large plants as might occur due to fuel interruptions, flooding, lack of cooling water, or storm damage. Finally, incremental transfer capability studies were performed to assess the ability to move power into high density load pockets that might be needed due to generation deficiencies resulting from floods, droughts, or fuel interruptions.

Quanta Technology utilized its proprietary Vulnerability Assessment Tool (VAT) to identify critical locations on the Texas transmission system. VAT is a unique tool designed to identify the most critical substations and areas in the interconnected bulk power system and to numerically rank them in proportion to their potential to impact the reliability of the bulk power network. VAT was used to identify trigger points on the system that are not manifest by classic contingency analysis.

The VAT program was used to identify hot spots on the transmission system, the outage of which would impact system performance. The trigger points identified either were the termination of multiple transmission lines or represented multiple generating units in close proximity to a particular bus or a combination of both. The ERCOT Transmission Network map was used to identify groupings of transmission lines whose routes were in reasonable proximity to each other to be considered a common corridor susceptible to a common mode outage related to a severe weather event.



Quanta Technology also evaluated the ability of the transmission system in Texas to supply concentrated load pockets that might occur due to localized generation deficiencies. First contingency incremental transfer capability was determined for power transfers from generic resources to major load centers, displacing major generating resources as might occur due to weather related curtailments.

Quanta Technology then incorporated its VAT criticality indices into an overall impact matrix that identified the susceptibility of locations to extreme weather events. The resultant matrix identified the areas of concern on the Texas grids with respect to extreme weather vulnerability.

The results of this assessment are listed in the confidential version of the report in Appendix 9.

Conclusions

Based on the results of the VAT, power flow and transfer capability studies, the transmission system serving the state of Texas is very robust and capable of meeting the load serving challenges associated with extreme weather conditions. There is sufficient resiliency in the transmission system to withstand multiple generation or transmission outages that might be the result of storms, floods, or wildfires under the studied scenarios. In addition, major load centers have adequate import capability to transfer power to replace local resources should concurrent outages occur resulting in load pockets.

The VAT analysis of the entire state of Texas identifies only a small number of substations with significant indices. This would suggest a very robust system. There are two buses that are outliers, which represent a potential trigger for a wide-spread event. More detailed study is recommended to fully appreciate the sensitivity of these areas. The VAT indices were then incorporated into an impact matrix that qualitatively considered the impact of extreme weather conditions. Based on this composite set of factors, Quanta Technology identified 18 Texas counties with areas of concern.

Recommendations

Recommendation 6

For the 18 counties identified as areas of concern in the Impact Matrix, the PUCT and ERCOT should consider more frequent engagement with the facility owners in these areas to keep an ongoing pulse on the state of the electric system and entity emergency preparedness. This could include near real-time system-health monitoring for the areas potentially at-risk with respect to the common mode impacts considered in the impact analysis.

Recommendation 7

Facility owners in the 18 areas of concern should ensure their emergency preparedness plans for extreme weather are up to date and incorporate the appropriate best practices as identified in this report.



Recommendation 8

The PUCT should initiate a more detailed review of the two "outlier" buses and associated areas as determined by the VAT indices to ensure a complete understanding of the current state of readiness for extreme weather events.

Recommendation 9

Transmission planners should routinely consider multiple contingency events on buses and surrounding areas identified as the higher ranked facilities from the VAT analyses in their planning analyses.



IV. EXTREME WEATHER GENERATOR BEST PRACTICES

The extreme cold weather that impacted Texas from February 1-4, 2011, while severe in terms of temperature, wind, and length of the event, was not unprecedented, as other cold weather events occurred from time to time throughout the 1980s and 2000s. The impact on the availability of generating facilities in Texas was extreme, with nearly one-third of the generating fleet in ERCOT unavailable at some point during the event and two-thirds of these outages directly attributable to extreme cold weather impacts. These losses resulted in the need for widespread rotating customer outages to balance customer demand with available energy resources.

The PUCT, TRE, ERCOT, and Texas entities in general have taken the extreme weather preparedness issue very seriously since these events occurred. Though there are still additional opportunities for improvement, much progress has been made in addressing and incorporating the best practices and procedures into the fabric of entities' preparedness strategies seasonally and when extreme weather threatens.

The list of best practices for extreme weather preparedness was developed based on the empirical experiences of entities involved in these events in Texas and elsewhere as identified in the lessons learned from those events that included:

- The Texas Reliability Entity best practices for winter preparation and lessons learned from February 2011 survey and associated presentation. These practices are based on the information provided by 103 responding entities in ERCOT comprising a mix of various types of generating resources, including both equipment owners and operators.
- The Electric Utility Response to the Winter Freeze of December 21 to 23, 1989 in Texas.
- FERC/NERC Outages and Curtailments during the Southwest Cold Weather Event of February 1-5, 2011 report.
- NERC Lessons Learned resulting from the February 2011 investigation.

This review was combined with Quanta Technology staff's direct experience with operation of generating facilities in Texas and specifically with respect to cold weather generator preparedness measures.

The lessons learned from this and other similarly significant extreme weather events point to the need for generating entities to institutionalize extreme weather practices, proactively plan for operation during extreme weather conditions, train its personnel on these practices and plans, and then execute these extreme weather strategies as appropriate. Successful strategies exist for keeping generating facilities on line during cold weather, and Texas generating facilities should leverage these proven "best" practices to avoid future capacity shortages. Whereas many entities have taken significant steps to improve its extreme weather preparedness, they should be incorporated into the current EOPs on file with the PUCT.



Cold Weather Preparedness

While the abnormally cold temperatures of February 2011 were extraordinary for Texas, they were relatively mild when compared to the normal low temperatures experienced in more northern climates. Failures in both freeze protection equipment and processes played a significant role in the weather-related capacity shortages in Texas. Successful strategies exist for keeping generating facilities on line during cold weather, and ERCOT facilities can and should leverage some of these proven practices to avoid future capacity shortages.

As discussed in the review of the generating entities' full EOPs, there are significant opportunities for improvement in the quality and content of the EOPs relative to the items specified below, and in the routine practice of these plans whether through actual implementation or through seasonal preparedness training. In some cases, entities have identified improvements that may not have been manifested in the EOPs to this point.

Deficient Freeze Protection Systems

What is obvious from the extreme weather event of February 2011 is that some generation facilities were caught by surprise, exposing staff and equipment to conditions with which they were unfamiliar and for which they were unprepared. These facilities, while designed correctly for a certain bandwidth of high and low temperatures, did not address possible extremes. When actual conditions breached the design parameters, some owners and operators were not properly equipped to effectively manage the impacts to maintain their units in operating condition. Owners of generating facilities, especially those who found themselves without adequate freeze protection equipment (as opposed to having equipment that malfunctioned or was defective), should clearly identify the design parameters for their equipment susceptible to extreme conditions and conduct a detailed review of the risk of their facilities operating outside these parameters. Some of this risk data will be empirical from their 2011 experiences, and some will result from scenario projections of even colder temperatures than those experienced. Once the risks have been quantified, the owners should develop appropriate mitigation strategies that could include items that are discussed later in this section. At a minimum, these owners should update their EOPs to address these risks in the short-term, while considering the long-term remedies in the plan.

The following best practices are designed to ensure continuity of operation under conditions where freezing temperatures can threaten the process of critical plant components essential to the operation of the facility.

Primary protection:

- Electric trace heating, also known as electric heat tracing, heat tape or surface heating, is a system used to maintain or raise the temperature of pipes and vessels. Trace heating takes the form of an electrical heating element run in physical contact along the length of a pipe. The pipe must then be covered with thermal insulation to retain heat losses from the pipe. Heat generated by the element then maintains the temperature of the pipe. Trace



heating may be used to protect pipes from freezing, or to maintain process temperatures for piping that must transport substances that solidify at ambient temperatures. Electric trace heating cables are an alternative to steam trace heating where steam is not available or is unwanted. Adequate heat tracing, especially for potentially exposed instrumentation sensing lines and transmitters is critical to a successful freeze protection program.

- In addition to heat tracing, fiberglass insulation is used to enclose specific piping in the power plant to not only retain process heat but to protect against freezing during periods of cold weather when the plant processes may be suspended for planned or unplanned outages. As fiberglass itself is vulnerable to compromise and degradation from elements such as rain and fog, the fiberglass enclosed pipes are then wrapped in aluminum sheets formed to fit the shape of the piping and secured with bands and screws. Periodic inspection of the lagging and underlying fiberglass insulation, and the repair of any gaps or missing material should be performed.
- Thermal enclosures should be periodically inspected for operability and structural compromise. Thermal enclosures are often used where clusters of small instrumentation lines and measuring devices are commonly located, and by their size and structure do lend themselves to heat tracing or insulation. In this application the instrument clusters are completely enclosed and held to a temperature well above freezing by a small space heater within the enclosure.
- Valve and gate actuators on process piping are often driven by the plant instrument air system. Segments of instrument air systems can freeze if the moisture drains are faulty. Freeze protection preparedness should include an inspection of the drains on the air systems to ensure proper operation in extreme weather. Portable air compressors should be available to provide backup instrument air to critical actuators if the primary instrument air system fails.

Secondary protection:

- Spot applications of temporary insulation
- Installing fabric or plastic windbreaks or temporary enclosures around exposed equipment

Processes for Winter Preparedness

While good examples of winterization plans were submitted as part of the PUCT data request, the full plans reviewed varied widely in the degree of detail and methods of implementation. In this regard, a required level of detail and content should be developed to address the best practices identified herein. Additionally, these winterization plans should be elevated to critical status in the hierarchy of plant maintenance activities to ensure proper attention and resources are devoted to the effort, with executive management support.



Extreme weather preparedness plans are only effective if they are maintained and executed successfully. In the current paradigm of mandatory reliability standards for bulk electric system reliability, significant impetus exists for the weather preparedness plans (EOPs) to be incorporated for Generation Owners and/or Generation Operators, thus establishing them as requirements. The features of entities' compliance programs such as periodic self-evaluations, subject matter expert designations, annual reviews of the program, and incorporation of "lessons learned" would provide an excellent framework for the execution of extreme weather preparedness measures as identified herein.

The following best practices regarding weatherization processes are designed to ensure adequate preparations for the onset of extreme cold weather events so as to ensure continuity of operation:

Primary protection:

- Clearly identify critical equipment and freeze protection areas.
- Temperature design limit criteria should be reviewed, complete and up to date for all temperature sensitive plant components, including freeze protection apparatus. This includes the intended level of protection afforded by heat tracing and thermal enclosures which may be inadequate in extreme weather. Additional measures such as supplemental heating with space heaters or thermal blankets may be required.
- Detailed maintenance and testing plans for freeze protection components should be maintained and executed well before the onset of cold weather. Such testing and inspection is often managed through the facility maintenance management program where work orders for the inspection and testing are issued, executed, and documented. This should include a thorough review of the integrity of existing freeze protection such as quality of exposed pipe insulation, etc.
- Evaluation of plant electrical circuits to ensure they have enough capacity to handle electrical heaters.
- Monitor/inspect circuits providing freeze protection to ensure their operating integrity, especially those with ground fault interrupters (GFIs), to ensure they have not tripped.
- Place thermometers in rooms containing equipment sensitive to cold temperatures and monitor in order to be able to take action when temperatures approach the equipment's design limits.
- For turbine generator peaking units, consider periodic starting and equipment warm up prior to actual dispatch and prior to the onset of extreme weather.
- Keep auxiliary boilers on hot standby where applicable prior to the onset of extreme weather.

Secondary protection:

- Close roll-up doors.



- Deploy fuel oil heaters to help protect exposed equipment.
- Isolate and drain any non-critical service water lines.
- Let unprotected but essential water lines drip.
- Ensure that a cache of the following supplies is secured in advance for deployment in advance of and during extreme cold weather events:
 - Extension cords
 - Portable generators
 - Insulation material and fleece blankets
 - Electrical heat trace
 - Heat guns
 - Plastic rolls
 - Heat lamps and portable heaters
 - Copper instrumentation tubing
 - Propane heaters and propane bottles
 - Handheld welding torches
 - Heat lamps
- Plan to add extra personnel at the plant site or in hotels near the plant so as to have access to individuals to keep the plant operating and to minimize travel on icy roads. This would include preparation for all associated logistics such as meals, etc.
- Seasonally train all impacted plant personnel on the exercise and performance of its extreme weather preparedness strategies as documented in its EOP.

Generating entities should consider the integration of these extreme weather best practices into their existing EOPs as appropriate. Of critical importance, extreme weather preparedness should receive a level of attention commensurate with the risk posed by other situations that threaten the ability of the plant to remain operating and on-line. As these extreme weather events are generally infrequent, the importance of continued vigilance in maintaining and implementing adequate EOPs tends to diminish as time passes for many reasons. As a result, it would be prudent for the PUCT to consider how to codify these expectations for generating entities to maintain sufficiently detailed EOPs and routinely practice their implementation in order to be adequately prepared for maintaining operating integrity during extreme cold weather events.

Extreme Hot Weather Preparedness

Hot weather effects on electric power plants can manifest themselves in several ways as discussed below. Generally, similar recommendations are offered with regard to understanding extreme hot weather design limitations of temperature sensitive critical equipment/systems as was stated for extreme cold weather conditions. However, generating entities in Texas are generally more acutely aware of the hot weather potential and have designed and built their facilities to maintain operating integrity during these events. This is evidenced by the ability of the grid operators in Texas to maintain system and customer reliability during the sweltering heat of the past several summer months. That being the case, it is prudent for generating entities to



consider and institutionalize its practices for managing extreme hot weather activities, and incorporate these activities in its EOP for consistency in expectations. The following list identifies concerns and mitigation strategies for consideration during hot weather conditions:

1. Maintain adequate water supplies for cooling towers which remove residual heat from the steam cycle and return condensate to the heating cycle.

Mitigation – if water source and storage water is available, fill the plant cooling reservoir as near to its high level limit prior to forecasted high temperatures.

2. Maintain adequate cooling capacity of the water supplies to the cooling tower heat exchangers. During prolonged hot weather periods, cooling water reservoir temperatures can climb to the point where the efficiency of the cooling towers is diminished, resulting in a degradation of condenser back pressure and a resulting derate in the efficiency and ability to produce full power.

Mitigation –there is little to be done about this situation other than preparing for it and anticipating the reduced capacity in near term operating plans.

3. Cooled enclosures for IT equipment will be stressed by higher than normal temperatures.

Mitigation – Perform preventive maintenance on the cooling equipment prior to the forecasted high temperature. Consider having backup air conditioners on hand and ready to deploy in the case of a primary cooling device failure.

4. Heat exchangers for air compressors, generator hydrogen cooling and various auxiliary equipment could be impacted by the reduced efficiency of the plant cooling water system.

Mitigation – Consider temporary measures such as electric fans, air horns or external service water flow over the heat exchanger elements where applicable to help remove heat.

5. Hot weather preparedness focuses on planned maintenance of certain cooling equipment like hydrogen coolers and heat exchangers. Loss of cooling to computer/IT equipment can also be problematic.

Mitigation - Install redundant HVAC equipment in these equipment rooms, supported by portable generators.

6. Wind turbines inoperable above 104° F can produce unexpected capacity reductions.

Mitigation - From a system operator perspective, the tripping of wind generators due to high temperature should be factored in to operating horizon plans and reserve margins. From a design standpoint, wind turbine owners/operators should coordinate with the turbine manufacturers to identify the limiting equipment and identify if strategies exist for maintaining operating integrity in excess of current temperature limits.



Review of Weatherization Best Practice Implementation in Texas

In addition to the review to assess EOPs relative to the eleven criteria based on the February 2011 report findings, Quanta Technology completed an additional review of the best weatherization practices identified in this report for each of the full EOPs provided to ERCOT and the PUCT in response to Senate Bill 1133. The purpose of this review was to determine the extent of the implementation of the best practices for the generators in the ERCOT footprint. This analysis reviewed the implementation of primary and secondary best practices identified above by each of the generating companies who provided an EOP⁶.

Table 3 provides a high level summary of the findings from the review. Quanta Technology utilized the following general criteria to assess the EOPs for best practice incorporation for both hot and cold weather preparedness:

- Entity implemented a majority of the best practices
- Entity did not implement any identifiable best practices
- Entity implemented some limited set of best practices
- Entity documented best practices but lacked clear implementation information
- Best practices do not apply to this type of generator

⁶ In total, 99 EOPs were reviewed. This acknowledges several instances in which a single EOP addressed multiple facilities. This explains the difference in the number of EOPs reviewed in the first evaluation (119) versus this second review.



Table 3: Summary of Best Practice Review of EOP

Practice Segment	Majority of Best Practices Observed	No Best Practices Observed	Limited Best Practices Observed	Best Practice Identified but Lacked Clear Implementation	Best Practices Not Applicable to Generator Type
Extreme Cold - Primary Best Practices	34	7	12	6	40
Extreme Cold - Secondary Best Practices	37	8	8	6	40
Extreme Cold - Plan Execution	34	7	6	12	40
Extreme Cold - Weatherization Plans	40	8	8	3	40
Extreme Hot - Best Practices	11	40	5	3	40
Extreme Hot - Plan Execution	14	39	1	5	40

A detailed breakdown of the review is provided in Appendix 7 in the confidential version of the report.

Findings

Quanta Technology identified several key observations with respect to the review of the full EOPs relative to the best weatherization practices identified in this report.

Observation # 8 – Steam generators and combustion turbines have an extreme weather framework in place.

A majority of the non-wind (steam and combustion turbine) generators have developed a fundamental framework for severe weather preparedness, which indicates a general awareness of the need for weatherization preparedness. Many generators have taken further steps to improve its preparedness in terms of practices and processes based on the response to the extreme weather events of 2011. The content of the EOP could be improved to incorporate these new “lessons learned.”



Observation # 9 – Best practices are generally targeted toward steam generators and combustion turbines.

For the wind turbine generators and certain other non-steam generators, the best practices do not apply as the items included are exclusive to the types of systems and equipment primarily found in steam generators and combustion turbines.

Observation # 10 – Extreme weather preparedness needs to be systematically implemented seasonally.

The best plan is ineffective without a mechanism for implementation in place at the generating plant. Implementation mechanisms should include a date certain for the initiation of preparedness activities each year at the plant. Including the weather preparedness activities in the maintenance management system where work orders are issued, executed and completed well in advance of extreme weather can be considered as a best practice method to ensure the weatherization activities are implemented routinely and completely.

Observation # 11 – Extreme weather preparedness drills that incorporate lessons learned from past events are valuable to increase knowledge of staff expected to implement plans.

Pre and post-severe weather meetings are valuable to review lessons learned from past severe weather periods, to ensure the proper equipment is procured and prepared, and to ensure that all applicable personnel are made aware of their specific duties. Exercises and drills provide a verification that employees know where the weather vulnerabilities exist; how they will be addressed in the plan; and ensure the necessary materials and supplies are on hand and located by the responsible employees prior to the actual onset of extreme weather.

Observation # 12 – An annual EOP review and update is essential to ensure optimal effectiveness.

Entities should complete an annual evaluation of the cold and hot weather preparedness plans for completeness and consistency, and to incorporate any changes in personnel, plan implementation, and lessons learned from previous extreme weather events.

Observation # 13 – Several entities provided excellent EOPs that could serve as models for others.

Several EOPs stood out as excellent plans in that they contained examples of the implantation of the best practices. These included ExxonMobil, Austin Energy, and Topaz Power Holdings. The best practice plans included detailed plans for the scope of equipment to be addressed, timelines for implementation, personnel involved in the preparation activities, and ongoing checks to assure the integrity of the protection processes. Some of these EOPs may also serve as best practice examples that could assist other entities in developing and improving their EOPs should these companies be willing to share their best practices.



Recommendations

Recommendation 10

Generating entities within Texas should develop a comprehensive extreme weather preparedness program that considers and addresses each of the items identified in the best practices discussion identified above.

Recommendation 11

The PUCT is encouraged to explore an effective mechanism that requires entities to analyze and incorporate these best practices and those from future analyses of extreme weather events into a comprehensive extreme weather preparedness plan (EOP). The PUCT should then require these plans to be maintained, updated when necessary, and verification provided that the seasonal preparations, including training, have been executed to sufficiently prepare plant operating personnel for these extreme weather scenarios.

Recommendation 12

PUCT should continue to work with the Texas Regional Entity, ERCOT, SPP, SERC, and WECC to enhance outreach programs for extreme weather preparedness.

Recommendation 13

PUCT should continue to monitor the development of the NERC continent-wide standard for winter weatherization practices.

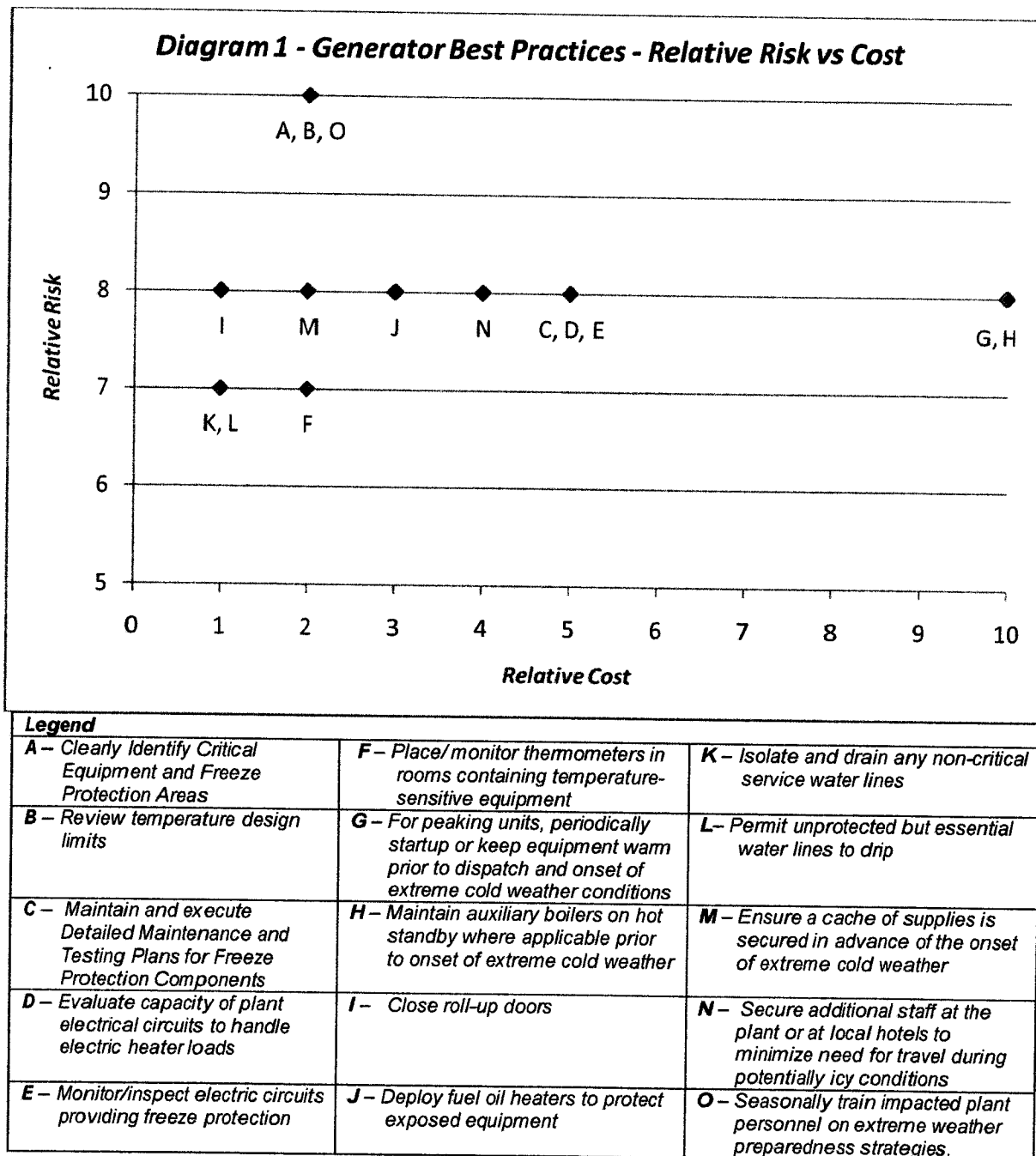
Analysis of Relative Cost versus Benefit for Best Practices

While each of the identified best practices can impact the performance of a generating plant to some extent, there are certain lower cost practices that succeed in being highly effective in reducing the risk of plant shutdown. For comparative purposes, Diagram 1 presents a visual depiction of the primary and secondary practices presented in terms of relative costs versus the potential risk mitigation that is achieved, using a scale of 1-10, with 10 being the highest cost or greatest risk.

For example, Practice A, *Clearly Identify Critical Equipment and Freeze Protection Areas*, is low in cost but high in relative risk. If the location of critical equipment or instrumentation is unknown, then the equipment cannot be monitored and maintained on an ongoing basis. Conversely, any activity that calls for the maintenance of a unit online or in hot standby without being dispatched incurs a high relative cost (Practices G and H). This is coupled with substantial risk mitigation in that there is a much greater probability that the unit or plant would be able to come on-line when requested.



In summary, Practices A, B, and O, pertaining to the understanding of weather sensitive critical equipment and plant design limits, and training all impacted personnel on the implementation of extreme weather preparedness strategies ahead of each peak season, offer the greatest impact at the least cost. Practices C, D, E, I, J, M and N also provide significant risk mitigation at relatively low to moderate cost, as do practices F, K, and L.





Conclusions

The severe cold weather events in Texas in February 2011 and documented in earlier events represent a range of temperatures or an environment in which electric generators can operate continuously and reliably. Similar cold weather remediation strategies pertaining to design and enhanced operating protocols that are available to generators in northern climates are available to generators in Texas. Because generating facilities in Texas are generally designed to operate successfully in extreme hot weather conditions, permanent design solutions that facilitate better extreme cold weather operation may impair extreme hot weather operation, which is more prevalent in Texas. Therefore, careful consideration must be given to striking the appropriate balance for permanent enhancements for maintaining cold weather operating integrity versus temporary deployable strategies that would permit the entities to “ride through” the less frequent extreme cold weather events successfully.

The physical and operational steps that prove successful in assuring more dependable operations in colder climates are not overly burdensome or complex. They have been in use for years and prove to be successful every winter season. What is more problematic, and where the critical path of successful cold weather generator operation in Texas lies, is the development and implementation of plant level procedures that rise to the same level of attention as the NERC mandatory reliability standards, for example, or other highly visible plant maintenance activities. One of the reasons the NERC reliability standards enjoy their current measure of attention is the accompanying potential of a million dollars per day per violation consequence for violating them. NERC currently maintains a suite of emergency operations standards that address various aspects of transmission grid reliability and resource adequacy. Embedded in these plans is the expectation that generators maintain effective emergency operating capability so as not to stress the grid and burden others in the interconnection. However, no specific detail is provided as to how this is to be performed or conducted. Minimizing the potential of unplanned outages as a result of cold weather effects on a generating facility would appear, from an operational perspective, to be closely aligned with minimizing outages as a result of cyber attack, unmaintained protection systems, non-responsiveness to operating directives, or any other circumstance pertaining to emergency operations already contained in the standards. In the end, an outage is an outage, and if it can be avoided it should be. It is illogical to have standards in place to minimize some types of avoidable outages while ignoring others such as caused by extreme weather impacts.

Whether the solution lies with the implementation of a NERC or regional standard, the ultimate best practice may be to ensure known solutions are applied and tracked to ensure a repeat of the February 2011 event is avoided.

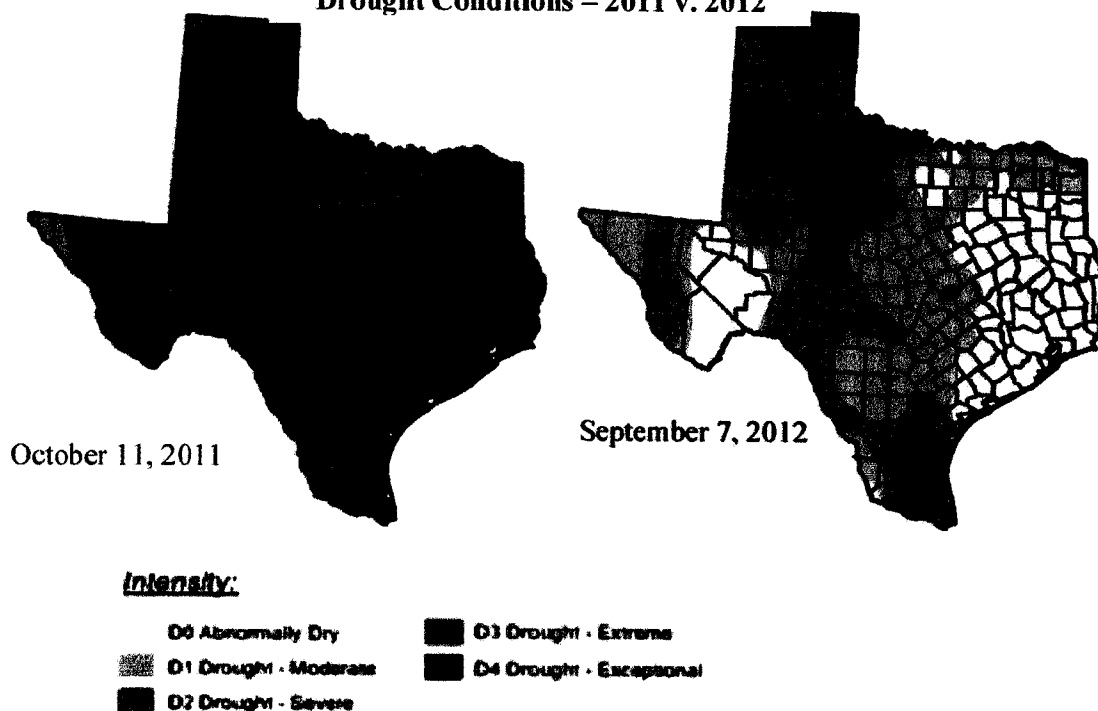


Drought in Texas

For the residents of Texas, 2011 represents the driest season in memory, with much of Texas gripped in extreme drought conditions, as monitored by the US Drought Monitor. Agricultural effects are the most visible evidence of the lack of precipitation, including the loss of thousands of trees across the state stressed to the point of expiration due to the lack of water in combination with the record setting high temperatures. Less obvious, but equally devastating, has been the decrease in surface and groundwater levels during this period, and the concurrent increasing needs of generation facilities for cooling water to support their operations. The record high temperatures correspond to the increased demand for electricity during the peak summer months, increasing the cooling water demands of the power generators in the midst of the drought. Generators that consume fossil fuels are principally the ones impacted by water shortages. These power facilities use the largest share of their water for cooling purposes including open-loop, cooling ponds, cooling towers and air-cooling methods.

The following diagrams indicate the extent of the Texas drought as of October 11, 2011 and then again on September 7, 2012. There has been substantial improvement in terms of rainfall in 2012 such that a good portion of Texas has recovered from the extreme drought conditions. This rainfall activity mitigates the potential for experiencing drought-related outages to generator units due to lack of adequate supply of cooling water or high water intake temperatures, and substantially decreases the contamination issues for owners of electric facilities by virtue of the natural washing effect of rain on the equipment.

**Diagram No. 2 – Comparison of Texas
Drought Conditions – 2011 v. 2012**





Mitigation of the Drought Effects on Electric Generation

Generating entities in Texas have coordinated their activities to identify water shortage mitigation strategies that would assist them maintain unit availability. The resultant actions were documented in the February, 2012 ERCOT drought workshop and included a spectrum of relatively less costly activities such as water conservation and reuse, through what may be initially a more costly solution of dry cooling tower installation.

Generators are designed overall to conserve and minimize water usage, reuse water from one process for another, and return clean water to the source after usage. Generators regularly account for all water withdrawn to regulatory authorities. Many generators utilize salt water or effluent, where practical and regularly maintain equipment to avoid water leakage/wastage. Some generators have installed pipelines to access accumulated (from rain & seepage) water at mine sites and others are re-engineering their water intake structures to allow for deeper water intake levels. ERCOT is also coordinating plans and activities with Texas Commission on Environmental Quality staff and drought response teams along with increasing communication with water permitting entities, users, and stakeholders.

One such stakeholder is the Texas Water Development Board who identified 63,000 acre-feet of potential water shortages for the steam-electric category in 2010, with predictions of nearly a ten-fold increase by 2060. They recommended specific water management strategies to meet water supply needs. This included conservation of existing water supplies, new surface water and groundwater development, additional distribution, water reuse, and others. It was also noted that there a long-term trend in Texas to move away from a reliance on groundwater to surface water.

Potential Solutions

In terms of grid operations and the production of energy to match consumption, the effects of the drought and the potential threat to generation capacity is no different than a capacity shortfall for any reason. Some mitigation steps that address general capacity issues are equally applicable to drought preparedness and management, while other steps address the water supply quality and quantity issues directly.

The most immediate, effective measure to address capacity shortfalls due to drought are energy and water conservation and efficiency measures. In the effort to constantly match generation to increasing load, a decrease in demand is equally effective in maintaining the required balance as an increase in generation. Although water conservation and efficiency measures by themselves may not entirely solve the water shortage problem, they are an important part of both near-term mitigation activities and longer-term water sustainability issues. Reviews of current conservation plans and efficiency measures to identify any adjustments or improvements in advance of the expected high summer loads are highly advised.

A review of cooling tower efficiency and evaporation rates should also be undertaken to assure the peak efficiency is being captured in the evaporative processes. Studies have shown that



Careful management of makeup water can save up to 18% of cooling water makeup requirements. Factors to evaluate include pH management, chemical scale inhibitors, and pre-treatment of makeup water.

Additionally, generators that rely on cooling from reservoirs should evaluate methods to effectively manage water temperatures such that units can be fully available during peak periods and not limited as a result of intake or discharge thermal constraint limits.

Mitigation actions for water management or conservation are listed below, followed by recommendations for generating entities, based on the ERCOT workshop:

1. New Surface Water Supplies

Surface water strategies include stream diversions, new reservoirs, other surface water strategies such as new or expanded contracts or connection of developed supplies, and operational changes.

2. Water Conservation, Reuse and Efficiency Measures

Water conservation focuses on efficiency of use and the reduction of demands on existing water supplies. Conserving water reduces the energy consumption needed for water and wastewater treatment and distribution. Decreasing energy demand reduces the overall amount of water needed for generator cooling. Potential mitigated strategies in this area include.

- a. Water management strategies involving reuse include wastewater effluent reuse projects.
- b. Indirect reuse involves discharge of wastewater into a stream and later routing or diverting it for treatment as water supply.

3. Reallocation of Reservoir Storage

Reallocation of reservoir storage from one approved purpose to another is a strategy that was recommended by some regions in Texas to meet needs from existing reservoirs.

4. Groundwater Management

Groundwater management includes strategies such as 1) installing new wells; 2) increasing production from existing wells; 3) installing supplemental wells; 4) temporarily over-drafting aquifers to supplement supplies; 5) building, expanding, or replacing treatment plants to make groundwater meet water quality standards; and 6) reallocating or transferring groundwater supplies from areas where projections indicate that surplus groundwater will exist to areas with needs.

5. Drought Management

Drought management is a temporary reduction in operating demand based on groundwater or surface water supply levels of a particular utility.



6. Aquifer Storage and Recovery

Aquifer storage and recovery refers to the practice, where possible, of injecting potable water into an aquifer where it is stored for later use.

7. Desalination

Desalination is the process of removing salt from seawater or brackish water. However, it is a very energy-intensive process and power costs may exceed the benefits.

8. Dry Cooling Towers

A typical 600 MW generator conventional cooling tower can consume 60-70,000 gallons of water per day through evaporative cooling and periodic blow down to control water purity. An option, though perhaps not economically attractive, would be either a retrofit for existing thermal generators, or a condition of new thermal generation construction, would be the installation of dry cooling towers, greatly reducing the reliance on water resources. However, the station service supply requirements of a dry cooling tower could be up to 32 MW per hour that would affect a plant's net capability. The construction or retrofit costs, coupled with the higher station service load (and hence less energy available to the grid) could have a dramatic effect on the generator's profitability and grid reliability itself due to increased service demands. Still, the technology exists, and if drought concerns rise to the level of public safety and health considerations, a limited and targeted implementation of the dry cooling tower option might be viable.

Recommendations

Recommendation 14

Identify best practices for conservation for power plants that "Reduce, Recycle and Reuse" water supplies that may include:

- *Non-consumptive versus consumptive water use*
 - *Return once-through cooling water to reservoir for reuse*
 - *Wastewater or recycling systems, allowing:*
 - *Reuse of graywater for flushing toilets or watering landscape*
 - *Recycling of wastewater through purification at a water treatment plant.*
 - *Use storm water runoff where appropriate*
 - *Rainwater harvesting*
- *Conduct water lines leak detection surveys and repair and maintain equipment to minimize water loss*
- *Monitor and optimize water quality and quantity for decreased usage*
- *Remain aware of best management practices by participating in water conservation technical organizations*
- *Evaluate water efficiency processes and technologies when considering capital investments*
- *Ensure water usage optimization by review of standard operating procedures*



- *Minimize cooling water consumption*
- *Use chemical suppressants to minimize water usage for fugitive dust*
- *Use of xeriscaping on facility properties*
- *Continue employee education on water conservation and drought mitigation efforts*

Recommendation 15

Generate and share ideas to prolong existing cooling reservoirs at power plants to include:

- *Uses alternative sources or lower quality of water where feasible*
- *Evaluate pump/piping configurations (placement, arrangement and size) to maximize reservoir capacity and greatest operational range*
- *Build / Improve infrastructure to access remote water sources and improved water storage to minimize transport losses*
- *Procure additional water supply where feasible and support development of additional water sources*
- *Add / Adjust pumping capability and schedule to optimize water sources with variable availability*
- *Evaluate use of municipal effluent as primary or secondary water source*
- *Add / adjust pumping capability and schedule to optimize water sources with variable availability*
- *Evaluate water treatment technologies to allow use of lower quality water sources for certain processes (for example, conductivity controllers)*
- *Upgrade processes to minimize water consumption*
- *Use collected storm water runoff*
- *Coordinate water withdrawal with surrounding entities to ensure adequate supply*
- *Decrease evaporative losses (storage reservoirs)*

Recommendation 16

Generating entities in actual or potentially drought-stricken areas should review their current water conservation plans to identify any needed adjustments or improvements in advance of the upcoming peak season. This evaluation should include a review of cooling tower efficiency, effective management of reservoir water temperatures to optimize availability at peak times, and consider alternate dry cooling tower approaches.



V. FACILITY CONTAMINATION

The reliability of the power delivery systems is affected to a significant degree by the performance of insulators in power substations and on transmission and distribution circuits. Insulator performance has the potential to be negatively impacted by the presence of air-borne contamination that settles on these insulators. The flashover process occurs as follows. A contamination layer is formed on the insulator surface when airborne particles, such as salt and dust settle on the insulating surfaces. Through light rain or drizzle, or through condensation, the layer is moistened and becomes more conductive, increasing the level of leakage current across the insulator. Due to the heating effect of the electric current, dry bands form on the insulator surface which, in turn, results in arcing that may ultimately lead to flashover.

It is generally impractical to prevent the formation of these contamination deposits that may affect the insulator's electrical performance; rather, entities are challenged to design its insulation, especially in vulnerable areas, to withstand the electrical stresses to which it is subjected under all conditions. For under-performing in-service systems, it may be unacceptable to re-design the insulation to achieve more optimal performance; rather, it becomes a matter of implementing mitigating measures to manage the contamination and its impact on the system. An important consideration is to identify whether the outages caused by contamination occur on a regular basis or if they are incidental, which would inform the owner's response strategy. However, it is very difficult to design an optimal maintenance strategy, which is generally site-specific, and to balance the cost and interval of the maintenance activities against the improved performance that results.

- Electrical system outages attributable to contaminated insulating equipment are costly to the customers served, especially if those facilities serve industrial customers, and to the utility in terms of the negative impact to its reliability indices and by virtue of the costs to maintain and/or repair the equipment. Equipment manufacturers, owners, and research organizations have devoted much time and attention over the years to the study of pollution/contamination on insulating equipment with particular emphasis on: adequately measuring and specifying the type and severity of the contaminants present at a particular location; understanding the contamination flashover processes for the various types of insulating equipment and contamination severity levels; developing and/or scoping the optimal type of insulator to be used in a particular environment; monitoring and measuring the level of contamination and the corresponding risk of flashover in real-time operating conditions; establishing appropriate maintenance practices for the equipment; and importantly, identifying the optimal timing of the maintenance cycles to avoid the occurrence of flashovers. In this discussion, it is important to recognize that many of these power systems were designed and installed many years ago using available information and operating experience regarding proper insulation practices. Based on the compendium of analysis, research, and operating experiences over time, as well as changes to the power grid itself and to the environments within which the equipment operates, some equipment owners have realized that its insulating equipment has underperformed and thus requires remediation. This may be the case in certain areas of Texas.



A coalescence of factors has recently contributed to a series of outages that are believed to be related to contamination of insulators, particularly in the Texas City region of Texas. The primary drivers appear to be the extensive drought conditions in 2011 that have permitted the accumulation of a variety of contaminants on insulating equipment, the lack of natural washing mechanism typically provided by rain, and the availability of moisture resulting from the natural condensation processes in early morning that collectively served to defeat the external insulation of the equipment and caused outages on various facilities over time. These events will be discussed generally followed by a discussion on the “best practices for maintaining insulation performance in the case of contamination, which is based on a review of available literature, some of which was developed with the assistance of Quanta Technology subject matter experts.

Discussion of 2011 Events

During the first half of 2011, a number of electrical outages occurred primarily along the Gulf Coast that was attributed to contamination. In May 2011, the PUCT engaged transmission and distribution utilities to better understand the contamination situation and its impacts on the reliability of electric service in those areas, as well as discuss mitigation measures taken to address the concerns. On June 3, 2011, the PUCT staff summarized this information in an internal memorandum that indicated “salt, smoke, dust, and industrial residue” were the primary contaminants and that the humid and dry weather conditions (drought) were key contributors.

Based on survey responses collected on the contamination issue, several participating utilities and associated industrial customers served by these utilities experienced contamination related outages in 2011. Of the ten T&D entities that provided information, six identified they had experienced at least one contamination-related outage that affected customer service and several identified a multitude of outages in the spring 2011 timeframe. This information supports feedback from industrial customers in the Gulf Coast region that identified it had experienced outages due to utility supply issues, as well as outages it had experienced on its own equipment. Four other T&D entities own and/or operate facilities some distance from the Gulf Coast.

As part of its regular maintenance activities and resulting from the increased focus on contamination issues based on their outage experiences, T&D entities have employed a variety of measures, preventive and reactive, to mitigate the impact of contamination. These include the following activities:

Maintenance Activities

- Annual or semi-annual transmission line inspections (aerial and ground-based)
- Semi-annual or monthly infrared or ultra-violet substation inspections, with accelerated inspections during periods of low rainfall/drought
- Accelerated substation inspection cycles in non-coastal areas prone to drought effects that include weekly employee inspections supplemented by monthly inspections by contract personnel



- Ground-based distribution system inspections, including daily patrols/inspections that incorporates night-time visual inspections at some locations, especially in early morning when humidity is highest along the coast
- Annual, monthly, and weekly inspections of electric equipment at generating facilities
- Ground-based and helicopter-based insulator washing with de-mineralized/de-ionized water, especially in coastal areas prone to contamination impacts
- Hand-washing
- Pressure-washing
- Insulator cleaning through blasting with various media (e.g. corn cobs, pulverized limestone)
- Accelerated patrols in response to events or “danger” areas identified through proactive monitoring
- Coordinated with industrial customers to assist in their assessment of contamination on customer-owned equipment

Equipment

- Contamination-prone equipment is identified and being replaced with more contamination-resistant equipment such as that designed for heavy salt contamination
- In prone areas, added porcelain bell insulators to the existing polymer insulators to better mitigate contamination build-up
- Applied silicone-based coatings to insulators at targeted locations

Advanced Technology/R&D

- Trial performance with prototype insulator designs
- Developing and using devices to monitor insulators/equipment to determine need for mitigation
- Participating in contamination studies as part of industry R&D activities

Other

- Using enhanced fault locations methods to shorten response times
- More rigorous design standards in areas prone to contamination
- Planning to secure environmental consultant to complete environmental monitoring at coastal refinery locations