NERC

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

March 2018

The vision for the Electric Reliability Organization (ERO) Enterprise, which is comprised of the North American Electric Reliability Corporation (NERC) and the eight Regional Entities (REs), is a highly reliable and secure North American bulk power system (BPS). Our mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid.

The North American BPS is divided into eight RE boundaries

The purpose of this report is to provide an analysis of Hurricane HarØeè⇩s impact on the BPS to ensure a complete, coherent review and documentation of the event and restoration efforts. The report focuses on preparation before the storm, operations during the event, and restoration recovery efforts. The report is an independent assessment by ERO staff and summarizes the event for the entire storm area. For any questions about the contents of this report, including corrections, improvements, and any suggestions, please contact NERC.EventAnalysis@nerc.net

Hurricane Harvey made landfall as a Category 4 hurricane on August 25, 2017, at 10:00 p.m. Central with winds in excess of 130 MPH and a record-breaking storm surge. The storm inflicted massive disruptions on the electric power system in the Corpus Christi, Houston/Galveston, and Beaumont/Port Arthur areas of Texas. As Harvey moved inland, the storm stalled, causing excessive rain (40ς50 inches) in parts of Southeastern Texas and flooding large areas of Houston and inland as far as Austin.

NERC REs, independent system operators (ISOs), and the potentially affected registered entities continually monitored weather developments and exchanged projections. Lines and generators on maintenance returned to service. Unit commitment and generator dispatch decisions postured the system to withstand the impact of the storm and recover promptly afterward. Equipment status and capabilities were confirmed. Transmission Owners (TOs) and Transmission Operators (TOPs) preemptively shut down several local load networks in a controlled fashion to prevent damage to equipment and speed restoration. Generator Owners

51.88 inches maximum rainfall recorded in Cedar Bayou near Highlands, Texas

938 millibars at landfall, tying for 16th lowest pressure hurricane on record

Category 4 near Port Aransas, Texas

Tropical storm in Cameron, Louisiana

132 mph near Port Aransas

More than 42,000

50

over 2.02 million

over 850

over 6,200

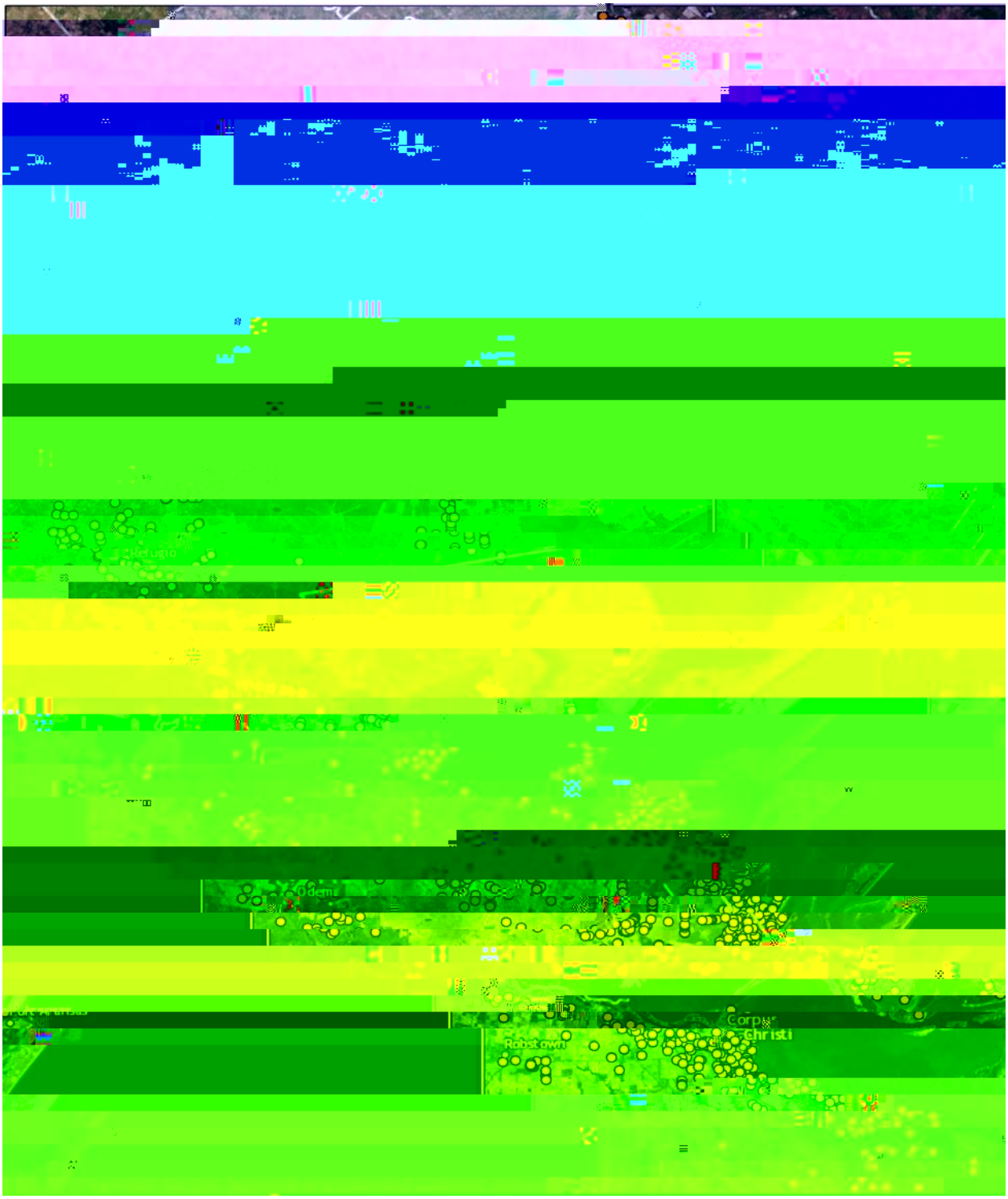
over 800 miles

Pre-existing conditions for all areas were considered normal for late August, which is a peak season for the Texas RE Interconnection and the SERC Regions. During these times, TOs and GOs are typically restricted from taking facility outages due to high system demand.

Hurricane Harvey began as a tropical wave that emerged from the African coast in early August (see

Emergency r

American Electric Power's impacted service area included Corpus Christi, Port Aransas, Aransas Pass, Rockport, Fulton, Refugio, Port Lavaca, Bay City, and Victoria. Dots represent broken or damaged poles (See). shows ERCOT transmission outages.



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ERCOT contacted the TOs, TOPs, GOs, Generator Operators (GOPs), and other registered entities within the forecasted hurricane impact zone to discuss potential storm impacts and coordinate emergency plans. Entities worked to ensure that sufficient numbers of additional field operation crews were scheduled and available to respond to the expected storm disruptions.

Where possible, previously scheduled transmission and generation outages were restored or postponed to ensure that facilities would be available during the event. Transmission companies were advised of expectations during the storm, which included the testing of primary and backup communications, management of potential high voltage conditions, and communication of transmission outages to ERCOT. Generators were advised of expectations to be prepared to reduce output due to anticipated load loss and to respond to voltage support instructions. Gas pipeline companies were also contacted to review the potential for possible curtailments.

Concerns regarding potential impacts of the coming storm included the following:

- The unpredictable nature of the impending load loss
- The potential for high voltages due to the load loss
- The potential for substation flooding along the Texas coast
- The potential for gas curtailments to power plants
- The potential for reduction in generator output due to loss of load

Entities resourced various staff to address additional requirements before, during, and after the storm. Some of these included the following:

- Assigning additional operators and supervisors to shifts
- Assigning director-level management to control locations
- Requesting and receiving assistance from mutual assistance crews
- Requesting and receiving substation support from various manufacturers and contractors

The majority of increased staffing was in the restoration area (i.e. vegetation management crews, substation crews, and line crews). Additional areas that received increased staffing were operations centers, primary control centers, backup control centers, and customer service centers.

ERCOT staffed both its primary and alternate control centers during the storm, including adding additional operators at the alternate control center and 24-hour on-

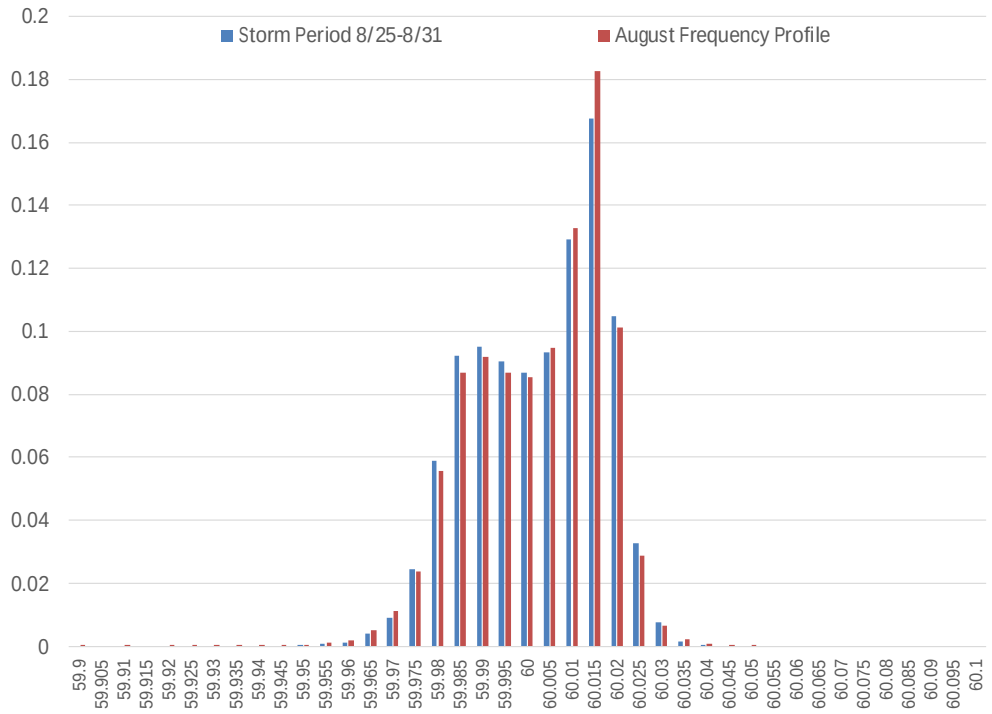
On August 8, the loss of a 138 kV line created a 30 MW island for an industrial facility private use network (PUN). This island also carried 2 MW of ERCOT load in addition to the PUN load.

Generation was limited at a second facility due to damage to four transmission circuit breakers at the power plant switchyard.

Several generation operation risks were identified during the storm. These include the following:

- Unavailability of three blackstart units as a result of the transmission system outages
- Increased potential for loss of off-site power to nuclear facilities
- Loss of generation due to switchyard damage
- Loss of generation due to damage to cooling towers
- Precipitator fly ash buildup and higher gas flow pressure due to operating without auxiliary feeds
- Curtailments due to wet coal
- Danger from the loss of building siding
- Potential lack of fuel due to damage to the fuel proØiderÛs facilities or loss or reduction of pressure in gas supply lines

Many of the entities affected by the storm implemented emergency procedures or entered a conservative operations



In general, the ERCOT operational assessment tools had minimal issues during the event. All of the energy management system (EMS) real-time assessment tools remained fully functional during Hurricane Harvey. The state estimator (SE) was able to continue solving during the loss of telemetry from multiple entities. On-site engineering support monitored the areas affected and watched for issues based on surrounding telemetry that remained available. SE solved with 100 percent convergence from 4:00 p.m. to midnight on August 25. The only time frames of note were on August 26 at 1:00 a.m. and 4:00 a.m. where SE solved with excessive mismatch around 1:00 a.m., which contributed to a 92.3 percent SE convergence for that hour due to growing telemetry failures.

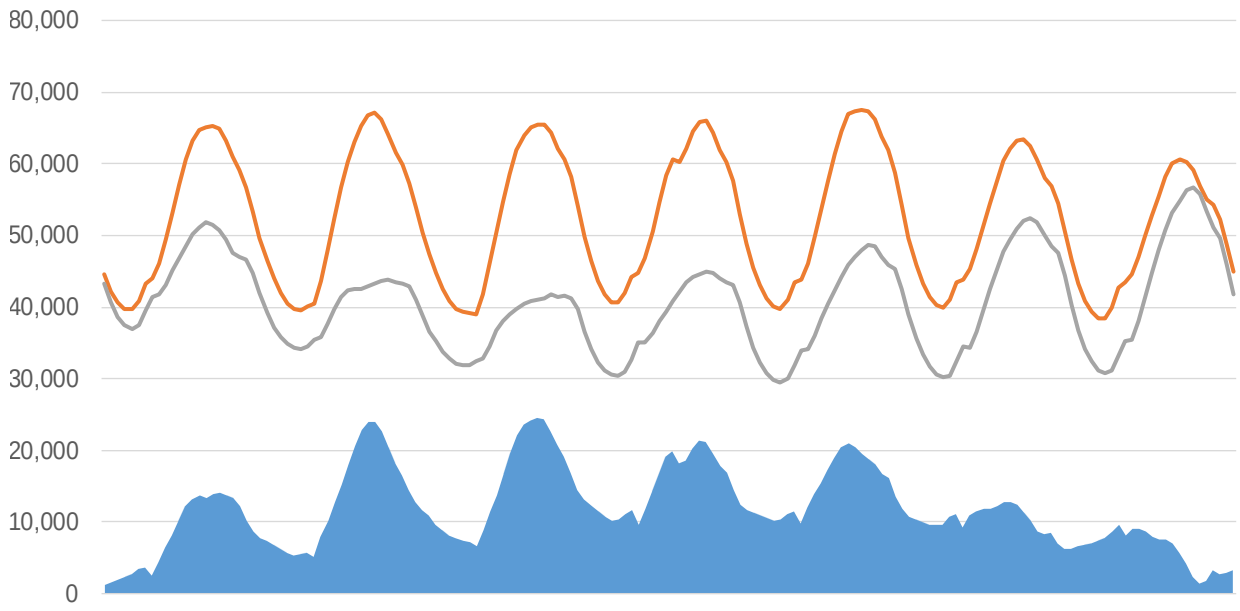
For hour ending 04:00, the convergence performance reduced to approximately 85 percent. At this time, the Inter Control Center Communications Protocol (ICCP) link for one TOP went down. Discrepancies between out of service elements, telemetered MW generation, transmission flows and switching device status caused the SE to yield a άsolved with Excessive Mismatch Solutionέ status. ERCOT Engineering Support personnel were able to utilize the State Estimator Statistical Application to quickly identify MW/Mvar mismatches and topology coherency issues in order to validate the system status. Staff could then manually replace the SCADA value or status in the ERCOT EMS with correct values as needed. This allowed for maximum continuity for SE convergence (See).

Another TOP had intermittent ICCP issues on August 26 and 27 that did not cause any issues due to smaller footprint and actions taken to quickly identify and manage MW/Mvar mismatches and topology coherency issues.

A peak of approximately 338,000 electric customer outages were reported across the impacted area of ERCOT, and the total number of reported customer outages exceeded 2.02 million in Texas, Louisiana, Mississippi, and Arkansas. All customer outages were restored by September 8.

Note: The gap in the customer outage data in on August 30 between 2:00 p.m. and 11:00 p.m. was due to the loss of an entity website.

ERCOT demand during the storm period was approximately 15,000–20,000 MW lo



Demand in the Houston area was 3,000ç5,000 MW lower than normal (See).

The following good industry practices were identified by entities in the affected areas:

Pre-staging of equipment outside of flood-prone areas made the restoration process more effective.

Collaborative efforts with other Texas utilities, ERCOT, and regional mutual assistance groups worked well during this event. It is important to touch base with contract resources and adjacent utilities prior to the storm event to establish communication chains.

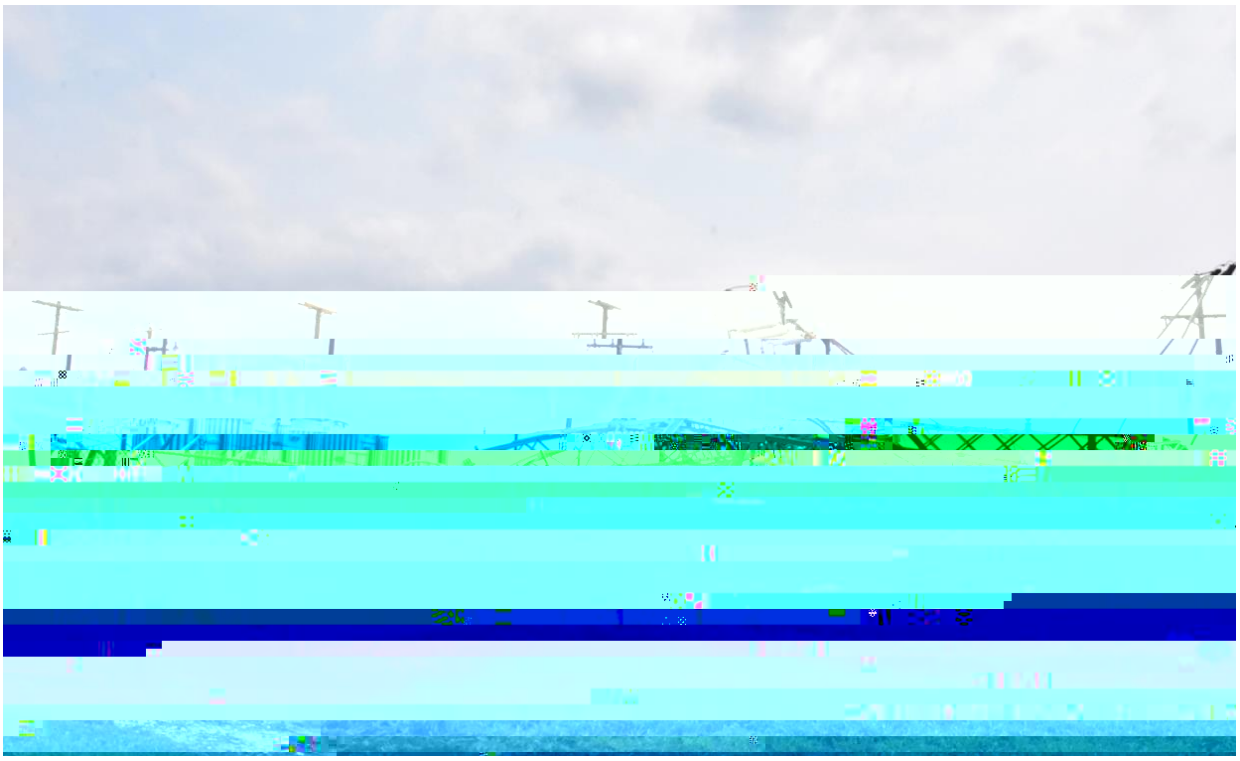
Establishment of contacts with state and local emergency management coordinators and key stakeholders was key in maintaining continuity and prioritization of the recovery effort.

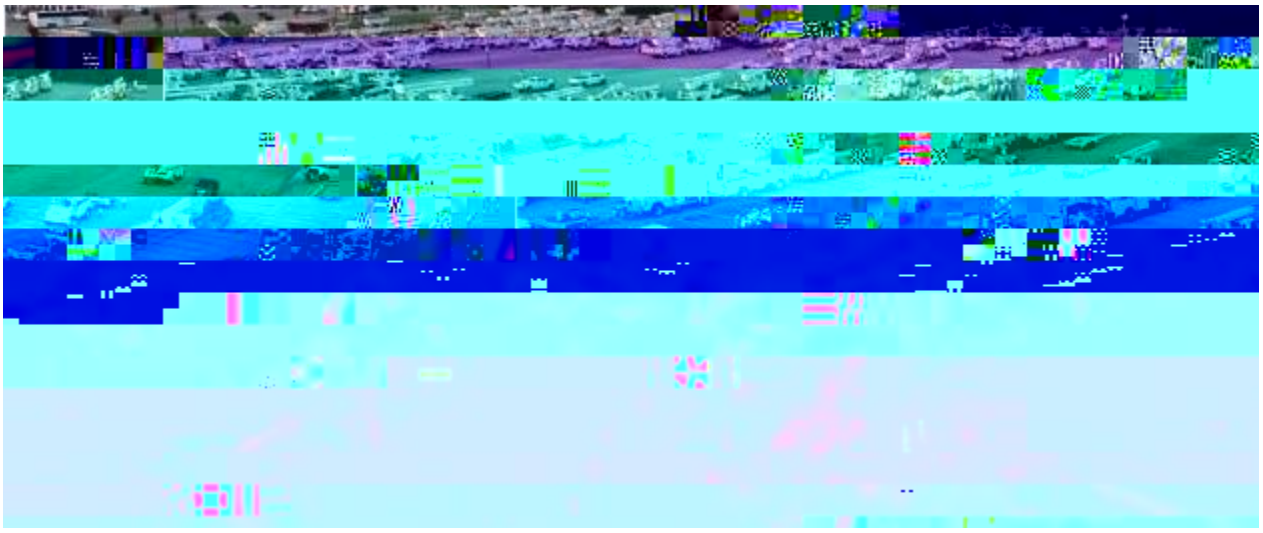
The use of advanced meters and intelligent grid devices was effective to pinpoint outages, operate equipment remotely, and increase efficiency.

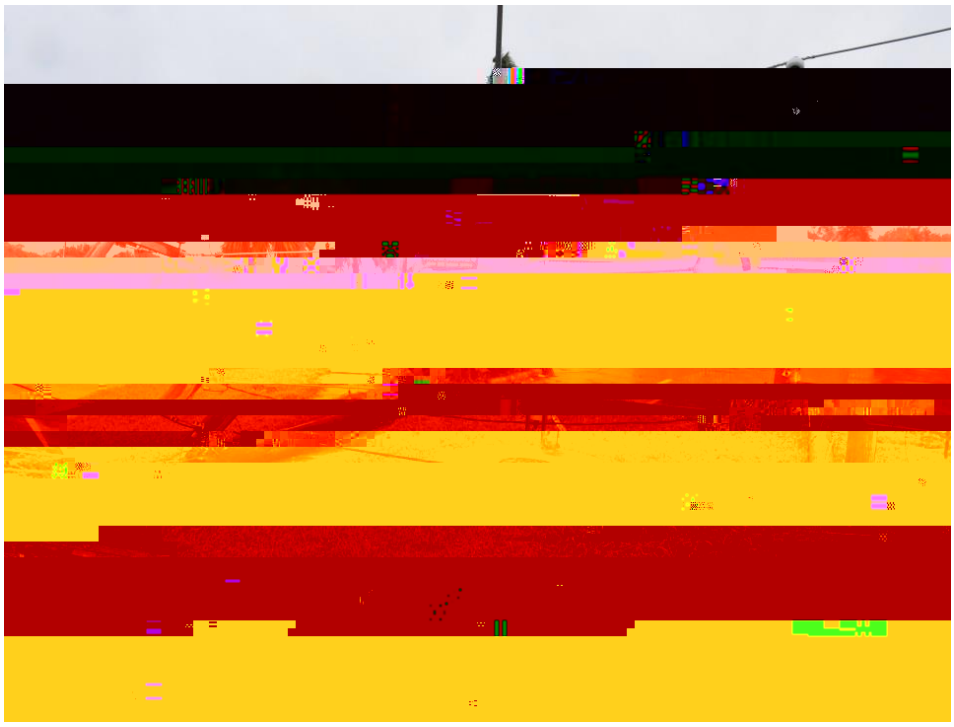
The use of Facebook, Twitter, Power Alert Service, and text messages was effective in keeping customers informed.

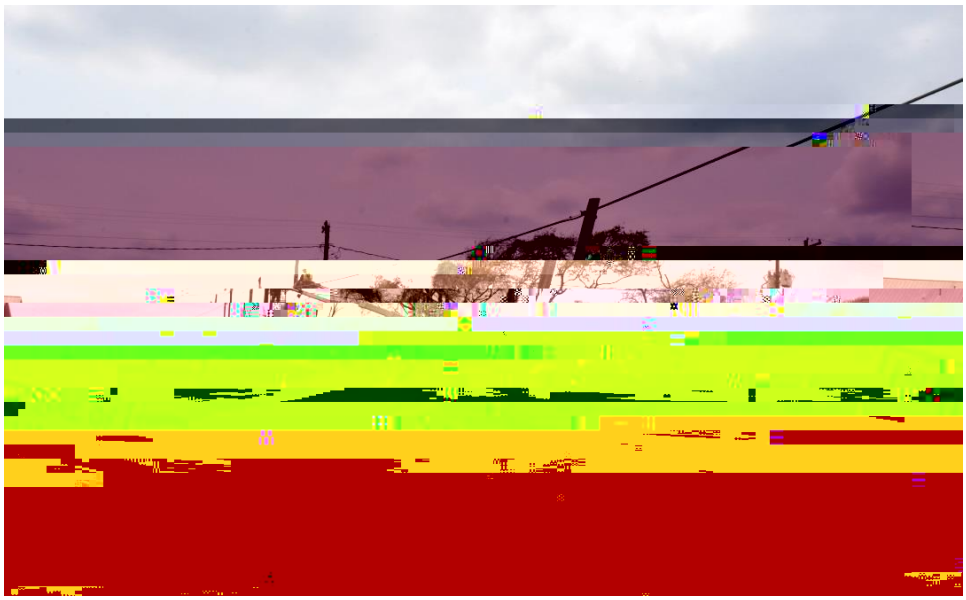
The use of aerial drones was effective to assess damage, evaluate work conditions, and enable real-time situational awareness. Infrared capabilities helped identify equipment that needed further inspection.

Pausing wind turbines prior to experiencing high wind cut-out speeds helped avoid individual turbine faults, stop yawing, and allow the turbines to continuously pitch into the wind as long as possible.









NERC would like to express its appreciation to the many people who provided information and technical support for this report. Any questions about the contents of this report including corrections, improvements, and any suggestions please contact NERC.EventAnalysis@nerc.net