

# **Texas Reliability Entity Event Analysis**

**Event:  
August 25-September 8, 2017 Hurricane Harvey  
Category 5 Event**

January 31, 2018

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## Introduction

The purpose of this report is to provide an independent assessment and analysis of Hurricane Harvey's impact on the bulk power system (BPS) to ensure a complete, coherent review and to document the event and restoration efforts. This report focuses on three main areas: (1) preparation, (2) operations during the event, and (3) restoration.

Hurricane Harvey made landfall near Rockport, Texas on Friday, August 25, 2017, at approximately 22:00 Central Daylight Time (CDT) as a Category 4 hurricane with winds of 130 mph. The leading edge of the storm began to inflict transmission and distribution system outages on the BPS as early as 16:00 that day. As the main body of the storm progressed over the Texas power system from August 25 through August 30, approximately 225 transmission assets were impacted. These included 345, 138, and 69 kV transmission lines and transformer banks. Transmission Operators reported that low-lying stations were flooded and became completely inoperable, and that high winds had damaged transmission and substation equipment. Generating facilities over a very wide footprint were either forced or tripped off-line, and some generators were rendered unavailable due to the loss of interconnecting transmission. Over the course of the event, a peak 10,992 MW of generation capacity was rendered unavailable, including 1,196 MW of Private Use Network (PUN) generation. The distribution system was also severely damaged. A peak of approximately 338,000 electric customer outages were reported across the impacted area. The total number of reported customer outages exceeded 1.67 million.

Wind turbines are commonly shut off at wind speeds of about 55 mph and higher to protect them from damage, and several turbines in ERCOT's coastal area were shut off while high winds from the storm passed. ERCOT's southern region saw increased levels of wind generation during the four days after landfall when wind speeds were relatively high but below 55 mph.

The recovery effort was initiated by the transmission, distribution, and generation asset owners when it was safe for crews to enter the impacted areas. The initial recovery consisted of inspections and asset assessments. The equipment owners' initial assessments were greatly hampered by flooding and the unavailability of roads. The priority, as communicated by the utilities, was to restore transmission assets to generating facilities needed for distribution load recovery. While there was sufficient generation capacity available to meet the load as restoration progressed, there were some cases where customer restoration was hindered by local area transmission outages. This includes instances in which substations were so severely damaged, they did not allow power to be delivered to the distribution system.

Most entities returned 95% or more of their customers to service between August 26, 2017, and September 2, 2017. Due to flooding in Houston, one of the hardest-hit areas, power restoration was not completed until September 8, 2017.

This report provides: (1) an overview of the event; (2) a description of regional preparation for hurricane events; (3) the sequence of events; (4) a review of system impacts and operations during this event; (5) a review of recovery from the storm; and (6) observations and recommendations for follow-up action.

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## I. Executive Summary and Event Overview

On August 25, 2017 at 22:00 CDT, Hurricane Harvey made landfall at Rockport, Texas. Harvey made landfall as a Category 4 hurricane. After making landfall at Rockport, Harvey moved slowly inland and became nearly stationary from August 26 through August 27. Harvey diminished to tropical storm strength at noon CDT on August 26. Harvey moved back into the Gulf of Mexico the morning of August 28, and then made one final landfall the afternoon of August 29 near Cameron, Louisiana – just east of the Texas border.

Major hurricane force winds inflicted significant damage across Aransas County. Nearly every structure in Port Aransas, Rockport, and Fulton was damaged. Significant structural damage due to the winds were reported at Port Lavaca, Copano Village, and Ingleside. The highest storm surge was recorded at the Aransas Wildlife Refuge, where a 12 foot surge was reported. Port Lavaca's storm surge topped 10 feet.

The extended duration of the hurricane caused widespread flooding in Southeast Texas from August 25 to August 29.

Most of the Houston metropolitan area recorded over 30 inches of rainfall in total. The maximum rainfall total was recorded at Cedar Bayou, where 51.88 inches fell. Harvey's rainfall totals made it the wettest tropical cyclone in the recorded history of the continental United States. Houston's total rainfall for the month of August was 39.11 inches, which was more than twice the previous record for the month.

Beaumont and Port Arthur also experienced extensive flooding, recording 47.35 inches of rain. At one point, the entire city of Port Arthur was submerged by flood waters.

Many rivers exceeded flood stage, including the Guadalupe, Colorado, Brazos, Buffalo Bayou, Brays Bayou, West Fork San Jacinto, Trinity River, and Village Creek. Most rivers peaked on Monday, August 28. In total, 50 Texas Counties were impacted by Harvey-related flooding.

Hurricane Harvey affected many entities along the Texas coast and inland. These areas included the large coastal population centers of Corpus Christi, Victoria, Houston, Galveston, and Beaumont/Port Arthur, and also farther inland as far as San Antonio and Austin. The coastal areas impacted include the transmission and distribution service territories of American Electric Power, South Texas Electric Cooperative, Texas-New Mexico Power, and CenterPoint Energy. Inland areas impacted include the transmission and distribution service territories of Bryan Texas Utilities, Austin Energy, CPS Energy, Lower Colorado River Authority, Brazos Electric, and Oncor.

### Harvey: By the Numbers

Rainfall: 51.88 inches maximum rainfall recorded in Cedar Bayou near Highlands, Texas  
Minimum surface pressure: 938 millibars at landfall, tying for 16<sup>th</sup> lowest pressure on record  
Multiple landfalls:

- Category 4 near Port Aransas, Texas
  - Tropical storm in Cameron, Louisiana
- Top wind gust measured: 132 mph near Port Aransas  
Lightning strikes: More than 42,000

Counties affected by flooding: 50

**Bulk Power System Damage**

Customers Affected: over 1.67 million  
 Transmission structures downed or damaged: over 850  
 Distribution poles downed or damaged: over 6,000  
 Transmission and distribution conductor replaced: over 700 miles  
 Substations damaged: over 85  
 Employees and contractors involved in the restoration: over 10,000

**Operational Impact**

Facility	Voltage Class	# Facilities Impacted
Transmission lines	345	7
Transmission lines	138	99
Transmission lines	69	119
Auto-transformers	345/138	3
Auto-transformers	138/69	1
Transmission substations	345, 138, 69	6 (bypassed due to flooding)
Load-serving substations	138, 69	204

**Comparison of Harvey to other Named Storms in Texas**

Storm	Year	Landfall	Category at Landfall	Customer Outages
Harvey	2017	Texas	4	1.7 million
Ike	2008	Texas	2	3.2 million
Rita	2005	Texas/Louisiana	3	2 million

**System Resiliency**

Bulk power system (BPS) resiliency during major storm events can be evaluated in two ways: (1) ability of the BPS to withstand damage during the storm event; and (2) ability of the BPS to quickly recover from the event.

Harvey’s impact on the BPS can be separated into two distinct areas. Major damage to the transmission system was caused primarily by hurricane-force winds and tornados in areas surrounding Victoria Port Aransas, Corpus Christi and areas south. Flooding was the major impact in the Houston and Galveston areas.

In the Corpus Christi, Port Aransas, and Victoria areas, hurricane force winds and tornados damaged over 800 transmission line structures. The vast majority of these were wood poles. High winds also damaged cooling towers at several power plants. Utilities worked with federal and state agencies to prioritize the restoration of critical transmission facilities, in particular, feeds to refineries and petro-chemical plants. Over 95% of the transmission lines and substations were returned to service by September 8.

In the Houston area, the unprecedented flooding created severe challenges. Substations and power plants experienced damaged equipment due to high flood waters. Several transmission line structure foundations were washed out. Substations had to be de-energized, re-configured, or bypassed due to flooding. A mobile substation was used in one location when the existing

substation was flooded. Areas were inaccessible for extended periods, delaying restoration activities. High water vehicles and boats were used to access some areas. All transmission lines and substations were returned to service by September 13.

### Summary

Hurricane Harvey was a devastating storm that caused extensive damage to the bulk power system, affecting over 225 transmission lines and transformer banks, over 10,000 MW of generation, and causing power outages to over 1.67 million customers. ERCOT and utilities exhibited outstanding coordination, working together to restore power to customers and protect the reliability of the grid.

Other observations and recommendations pertaining to the Hurricane Harvey event are:

1. **System Resiliency:** The vast majority of damaged transmission line structures were wood poles. Utilities should review design criteria and construction methods to “harden” transmission lines in hurricane zones in order to reduce or limit the damage caused by hurricane-force winds in accordance with P.U.C. SUBST. R. §25.94 and §25.95.
2. **Substation DC supply systems:** Monitoring and recovery was impacted by the loss of backup DC power supplies at multiple substations due to the loss of station service AC power sources. The loss of the DC supplies affected protection system equipment and Remote Terminal Units (RTUs) providing telemetry. Utilities used portable generators to power the charging of DC supply systems until station service could be re-established. Consideration should be given to installing multiple station service sources, or providing backup generators for station service to critical substations in hurricane zones.
3. **Telemetry and Inter-Control Center Communications Protocol (ICCP):** While loss of telemetry and ICCP connections did not cause significant impacts during Harvey, it did provide challenges to monitoring and control of the system. Two non-utility ICCP carrier services went out of service due to inadequate backup power supplies. Loss of ICCP and telemetry data created excessive mismatch errors for ERCOT’s State Estimator, creating situations where operators had to manually replace SCADA values.
4. **Fuel shortages:** Gasoline and diesel fuel availability was a significant challenge for utilities after Harvey made landfall. Harvey impacted several refineries in the Houston, Corpus Christi, and Victoria areas. Local gas stations were without power. Roads were inaccessible or blocked by debris. Utilities should give consideration to back-up fuel supplies for primary and back-up control centers, fuel reserve supplies at power plants (e.g., diesel fuel for machinery to move coal to resources), etc.
5. **Training:** Consideration should be given to providing enhanced training for System Operators based on lessons learned from Harvey. This should include, but is not limited to, training for loss of telemetry and ICCP during hurricane drills and black-start drills as well as training for response to loss of station DC supplies.

The event met the definition of a Department of Energy (DOE) OE-417 reportable event (loss of > 50,000 customers for 1 hour or more). The event was categorized as a Category 5 event under NERC’s Event Analysis Program.

Data in this report is based on responses to a joint Request for Information (RFI) authored by Texas Reliability Entity, Inc. (Texas RE) and the Electric Reliability Council of Texas (ERCOT) to request information from Registered Entities involved in the event.

## II. Preparation

### A. Weather Alerts

Predicting the storm path for Hurricane Harvey proved to be very difficult. Throughout much of the storm, the weather models used by ERCOT staff predicted varying outcomes as to the strength and path of the storm. For nearly the entirety of the storm, once it reached the Western Gulf of Mexico, the various weather models could not agree with the expected movement of the hurricane. The models were in agreement that the storm would stall out somewhere north of the Corpus Christi area for a day or so, before moving on.

Additionally, comparing the potential track areas from the National Hurricane Center, the tracks were not consistent. As of 10:00 on August 25, the prediction was that Harvey would move east towards Louisiana, but by 04:00 on August 26, the prediction had Harvey potentially moving further west, possibly over the Texas Hill Country. The 04:00 update on August 27 then changed the model back towards Louisiana, possibly moving off shore and rebuilding first. After the 04:00 update the storm future tracks began to be more consistent, moving the remnants of Harvey north and east; by then significant damage and flooding had already been recognized along the coastal region of Texas.

The utilities of the Texas RE Region all use various weather tools to monitor current and forecast weather. The most often used tools or services are NOAA and staff meteorologists. Other weather services in use are WeatherSentry, MDA, StormGeo, Weather.gov, Intellicast, Weather Underground, and The Weather Channel. Virtually all control centers also use local and national television and radio forecasts.

### B. Operator Training

ERCOT ISO's most recent Hurricane Drill was conducted June 21-22, 2016. Forty-five entities and 439 operators participated.

The drill simulated the path and intensity of the 1942 Matagorda Hurricane with winds reaching 115 mph during its peak. The hurricane weakened from a Category 3 to Category 1 before hitting landfall just after midnight on August 30, 1942 near Matagorda, TX. The drill also referenced the storm track of Tropical Storm Bill in 2015 where significant flooding had occurred in and around Houston, Galveston, Alice and San Antonio.

A summary of the operational participation is in the table below.

Total Number of participants in the drill	439
Total Number of ERCOT operators in the drill	11
Total Number of NERC-Certified operators in the drill	136
Total Number of NERC-Certified ERCOT operators in the drill	11
Number of hours towards ERCOT/NERC reliability testing	1655
Entities Participating	TO/TDSP: 19 QSE: 26



The Hurricane Drill provided a realistic training basis for many of the emergency actions that ERCOT and other Transmission Operators were required to take between August 25 and September 8, 2017. Operators were provided remote access to the ERCOT simulator, which included access to the Macomber Map.

### *C. Communications Prior to the Event*

The table below is a summary of the key communications between ERCOT, Qualified Scheduling Entities (QSEs), and Transmission Operators (TOPs) prior to the event.

- August 23, 2017 at 08:00: ERCOT Outage Coordination and System Operations advised the TOPs to restore any transmission equipment on planned maintenance, and to withdraw any new planned transmission outages in the South Texas area.
- August 23, 2017 at 10:30: ERCOT System Operations issued an Operating Condition Notice (OCN) for Tropical Storm Harvey to all QSEs and TOPs with instructions to evaluate fuel supplies and to review outages and emergency procedures.
- August 24, 2017 at 07:50: ERCOT System Operations issued an Advisory for Tropical Storm Harvey to all QSEs and TOPs repeating previous instructions and providing additional instructions regarding communications.
- August 24, 2017 at 11:00: ERCOT System Operations issued a Watch for Hurricane Harvey to all QSEs and TOPs with additional instructions to prepare for anticipated system conditions and keep ERCOT notified of actual and anticipated resource conditions.
- August 24, 2017 at 16:00: ERCOT had a phone call with gas pipeline companies serving the coast and Lower Rio Grande Valley (RGV) generation facilities to determine potential impacts on gas supply to those facilities. The gas companies indicated the potential for gas curtailments due to compressor stations and gas processing facilities being shut down due to the evacuations. One gas pipeline carrier reported it was blending raw gas to avoid curtailments and allow continued gas delivery to generators in the Valley.
- August 25, 2017 at 17:00: ERCOT System Operations issued an Emergency Notice for Hurricane Harvey to all QSEs and TOPs with additional instructions to prepare for anticipated system conditions and keep ERCOT notified of actual and anticipated resource conditions.

QSEs instructed to:

- Be prepared to reduce Generator output due to anticipated load loss and respond to voltage support issues as requested,
- Keep Current Operating Plans (COPs) and High Sustainable Limits (HSLs) current.

TOPs instructed to:

- Be prepared to lose load and expect high voltage conditions
- Keep ERCOT informed of any issues.

### *D. Control Center Staffing*

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-site support to the control room over the weekend from Operations Support, EMMS Production Support, Facilities, and Advanced Network Applications (ANA). One Transmission Operator evacuated its backup control center since it was in the storm impact area in Corpus Christi. Another Transmission



Operator moved its operations to its backup control center. All other Transmission Operators operated out of their primary control centers and did not provide staffing at the alternate control center locations.

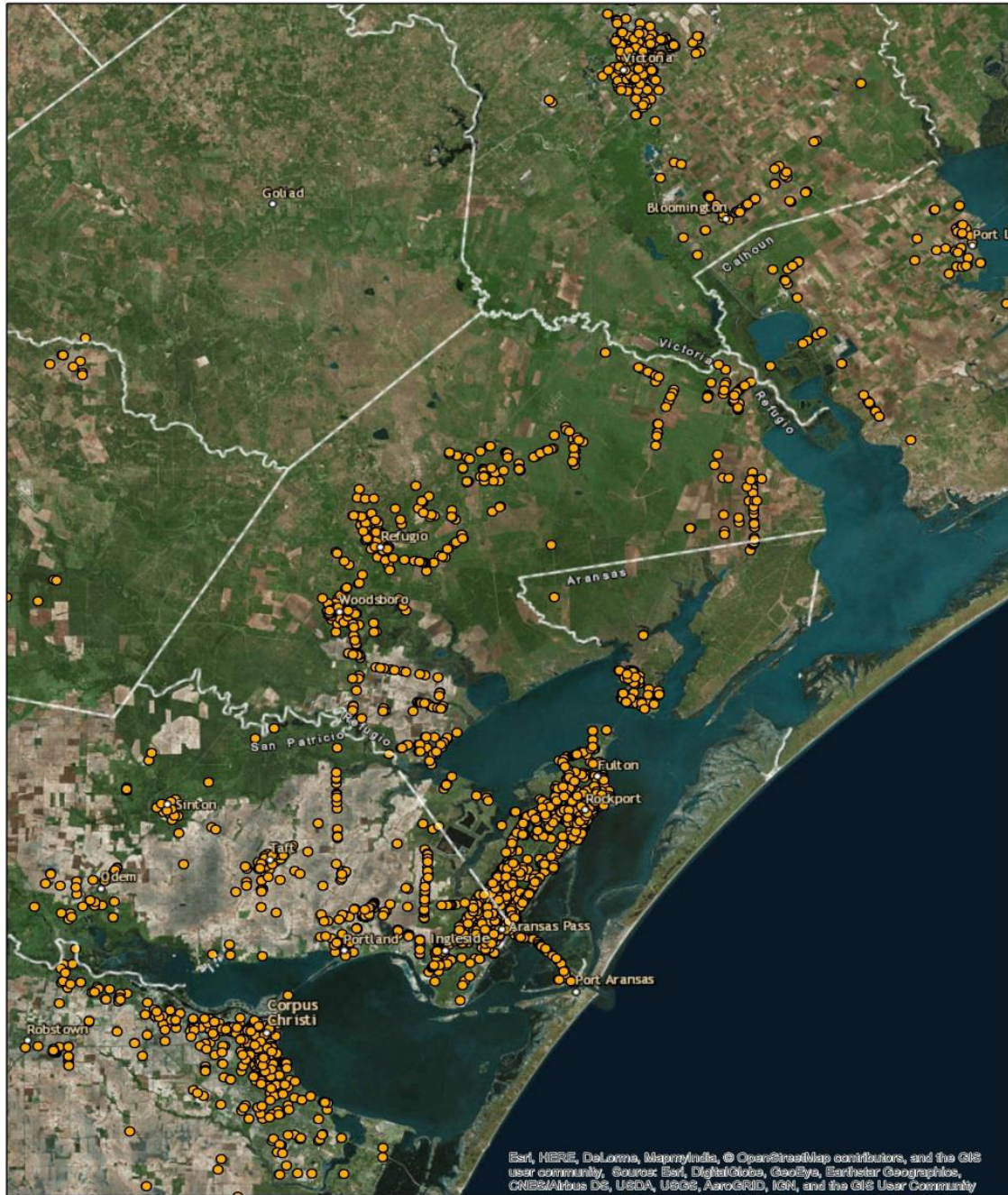
### *E. Preparation Summary*

Entities across the impacted area made the following special preparations:

- Existing storm preparation plans were activated
- Loose equipment and materials in substations were inspected, secured, or removed
- Retention ponds, basins, and sumps were pumped down to minimum levels
- Additional pumps and generators were secured
- Fuel storage tanks were topped off
- Labor, equipment, and materials were staged to allow for a quicker start at restoration
- Critical mobile equipment was moved to the mainland to protect against damage
- Service vendors and contractors were contacted
- Additional transmission line and vegetation management resources were scheduled
- All available transmission and generation outages was returned to service
- Satellite and alternate communications paths were tested

While the above were for the most part effective, additional challenges were noted. At several power plant facilities, employees were held in a “lockdown” status for extended periods. Food and medical supply shortages became an issue for sites that were held in “lockdown” for four to five days.







345kV Transmission Structure Damage



69kV Substation Damage



## Flooded substations



Misoperations of protection systems were reported on 13 transmission lines. These misoperations did not have any significant impact to the magnitude or duration of outages or restoration.

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## *B. Generation Impact*

A peak of 10,992 MW of generation capacity became unavailable as a result of the storm. The lost generation coupled with the reduced amount of load due to the continued rain and lower temperatures allowed for load and reserves to be met with sufficient remaining capacity. There were no Disturbance Control Standard (DCS) criteria events related to the storm.

Generation facilities in the hurricane impact area suffered the following damage:

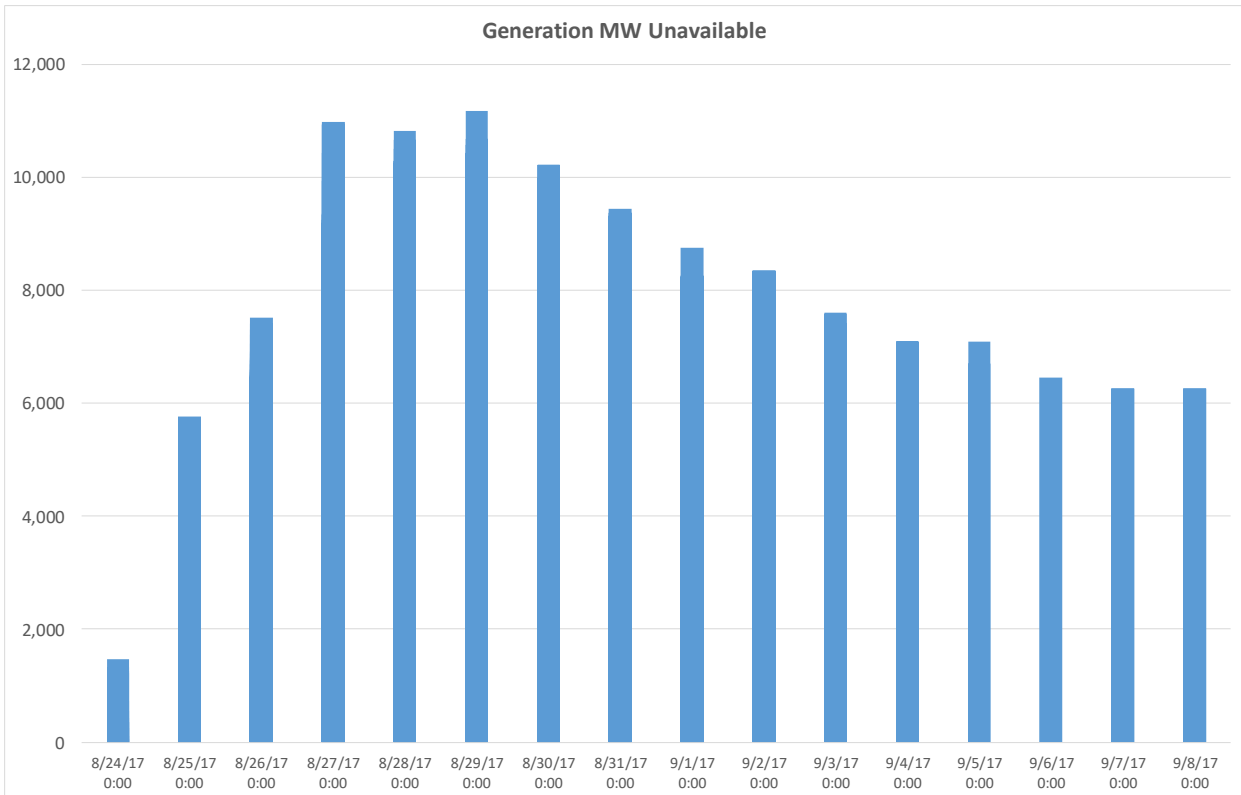
- Flooding or water intrusion into administration buildings, storage facilities, and waste water treatment facilities
- Wind damage to building siding, windows, and roofs
- Wind damage to cooling tower housings and fans
- Flooding of substations
- Damage to substation equipment from wind-blown debris
- Water damage to protective relays, batteries, controls, motors and motor controls, and pumps
- Water intrusion into instrumentation enclosures

ERCOT did not instruct any generation to go off-line during the event; however, some entities chose to shut down and or evacuate in preparation of anticipated storm impact. There was a total of 3,043 MW of generation that shutdown between August 24 and August 25 in anticipation of the storm.

Additionally, 5,679 MW of generation capacity was de-rated between August 25 and August 29 due to fuel issues such as wet coal, low gas pressure, and high wind. A generation entity reported that one of its natural gas suppliers shut down during storm, but that the entity was able to receive gas from an alternate supplier. Pressure drops in natural gas supply lines resulted in temporary de-rates of units at three other sites. Wet coal issues resulted in de-rates at four sites. Two coal units switched to natural gas to maintain generation capability, although at a reduced capacity, due to wet coal.

### Pictures of wet coal issues





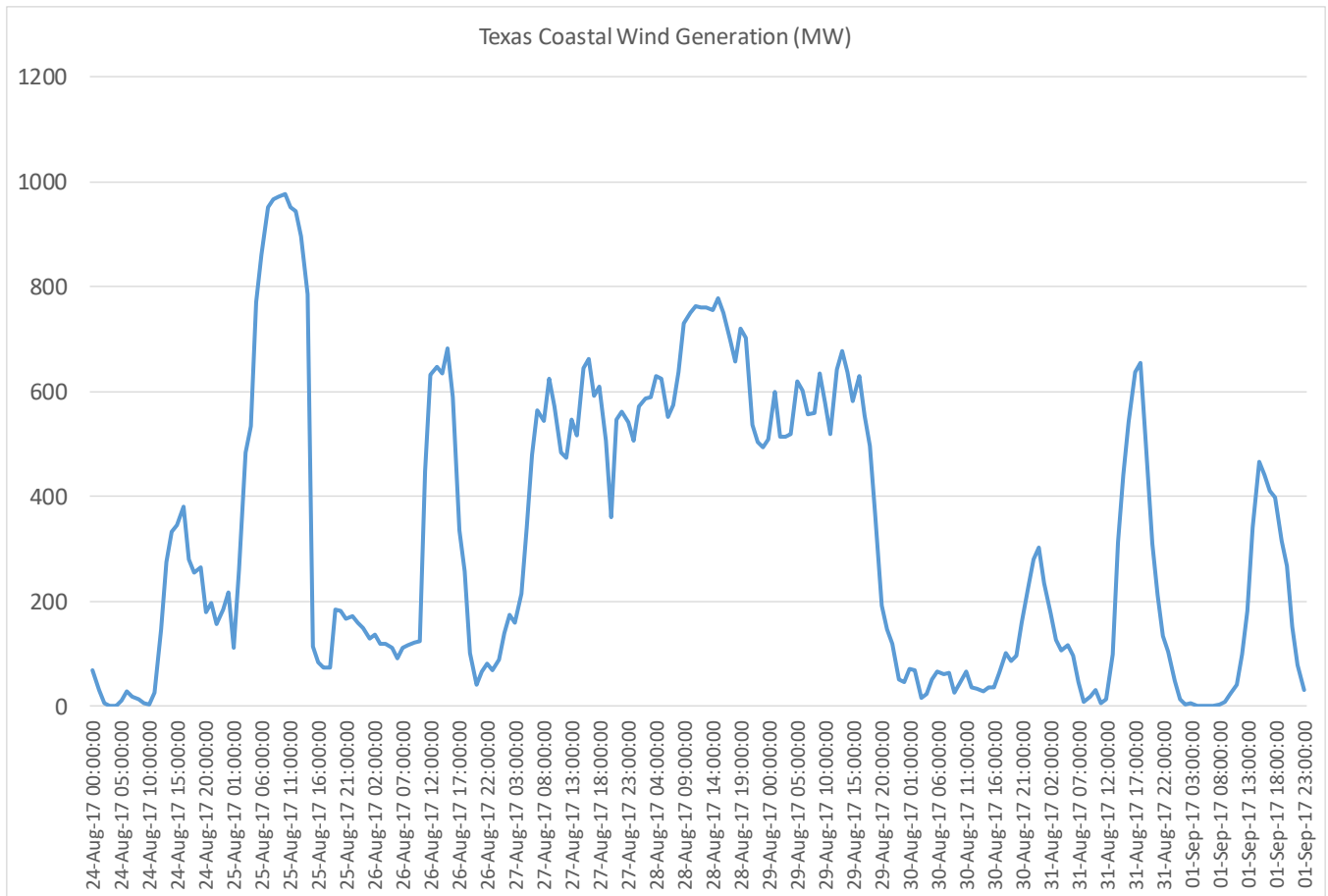


Outage Cause	Number of Units Impacted	Total MW Impact
Wind, Flooding	40	9,594
Evacuated, Site Shutdown prior to storm	34	3,043
Fuel	27	6,514

Nuclear units continued to operate throughout the storm. No storm damage from wind or rain was reported, with the highest sustained winds measuring 40 mph. One plant sequestered a storm crew on site for emergency response, if needed, including representatives from the Nuclear Regulatory Commission (NRC). One plant did experience the loss of one 345-kV transmission exit from the site. Offsite power was maintained.

Wind Generation

Only minor damage was reported, but some wind units were taken off-line due to the high winds, resulting in 1,168 MW of unavailable wind capacity. One facility located near Corpus Christi, Texas was off-line for six days. Other wind facilities were returned between August 26 and August 27.



Storm Damage and Operational Issues

On August 26, the loss of a 138kV 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.

ERCOT instructed one generator in the Rio Grande Valley to come on-line due to loss of a 345-kV line between the Valley and the Corpus Christi area, in consideration of the likelihood of additional transmission outages in the area. An additional generator was also instructed to stay on-line to provide generation to the local area in support of load restoration efforts in the Victoria area.

Several generation operation issues were identified during the storm. These included:

- Unavailability of three Black Start units as a result of the transmission system outages.
- Increased potential for Loss of Off-site Power (LOOP) 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 provider's facilities, loss or reduction of pressure in gas supply lines.
- Impact to chemical deliveries due to flooded or impassable roadways.

### *C. Voice Communications*

There were no abnormal challenges associated with loss of voice communications. ERCOT used alternate communications (cell phones, satellite phones, UHF radios, etc.) when the primary communication channels were impacted between ERCOT and Registered Entities. Radio tower and cell coverage was affected in the Aransas Pass, Rockport, and Fulton areas. This was managed by installing a portable radio system and a satellite VPN router to allow communications with field personnel.

### *D. Telemetry and ICCP*

Multiple entities experienced issues with loss of telemetry and ICCP data during the hurricane. These issues were caused by:

- Extended Remote Terminal Unit (RTU) outages at substations due to loss of battery backup power that was caused by extended station service outages.
- RTU outages due to lightning-induced surges causing circuit board failure.
- Loss of ICCP links by external carriers. External carrier sites did not have sufficient backup power sources.

To overcome these issues, utilities used multiple solutions such as the following:

- Temporary cellular communications.
- Portable generators for temporary station service for re-charging substation batteries.
- Monitoring substations from the remote ends of transmission circuits terminating at the substation.

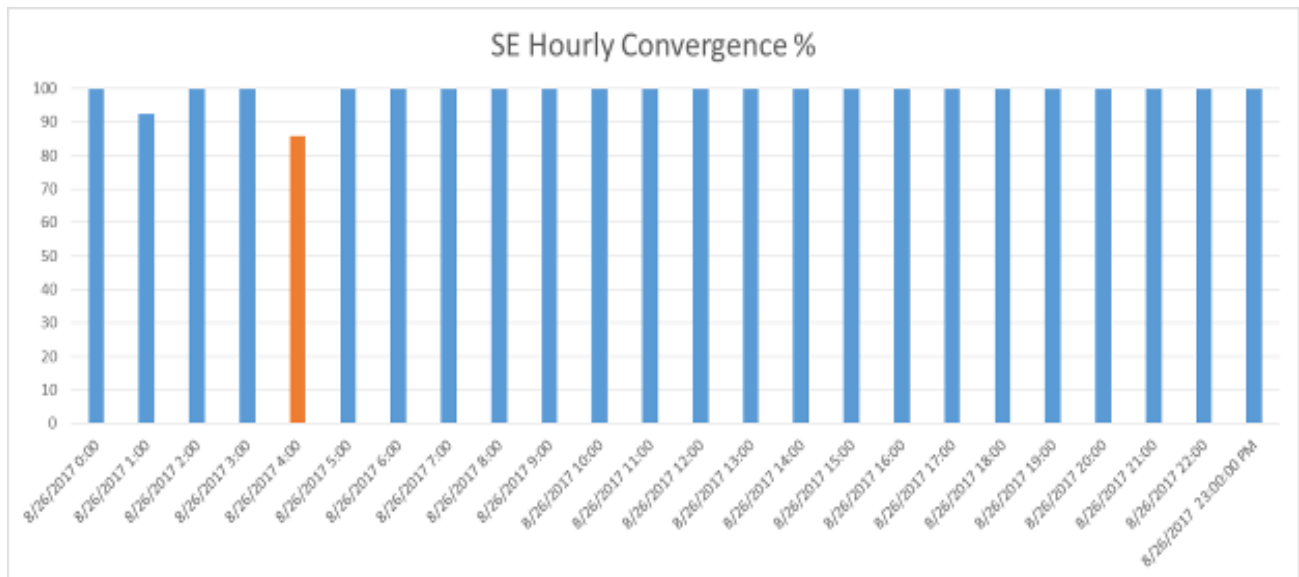
- Manually entering or replacing telemetry values.

### E. Operations Analysis Tools

In general, the ERCOT real-time 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. State Estimator (SE) was able to continue to solve during the loss of telemetry. On-site engineering support monitored the areas affected and watched for issues based on surrounding telemetry that remained available. SE solved with 100% convergence from 16:00 to 12:00 on August 25. The only time frames of note were on August 26 at 01:00 and 04:00 where SE solved with excessive mismatch around 01:00, which contributed to a 92.31% SE convergence for that hour due to growing telemetry failures.

For hour ending 04:00, the convergence performance reduced to approximately 85%. At this time, the ICCP link for one Transmission Operator went down. Discrepancies between out of service elements, telemetered MW generation, transmission flows and switching device status, caused the State Estimator to yield a 'solved with Excessive Mismatch Solution' status. ERCOT Engineering Support personnel were able to use the State Estimator Statistical (SESTAT) application to quickly identify MW/MVAR mismatches and topology coherency issues in order to validate the system status with QSEs and TOPs. 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 State Estimator Convergence.

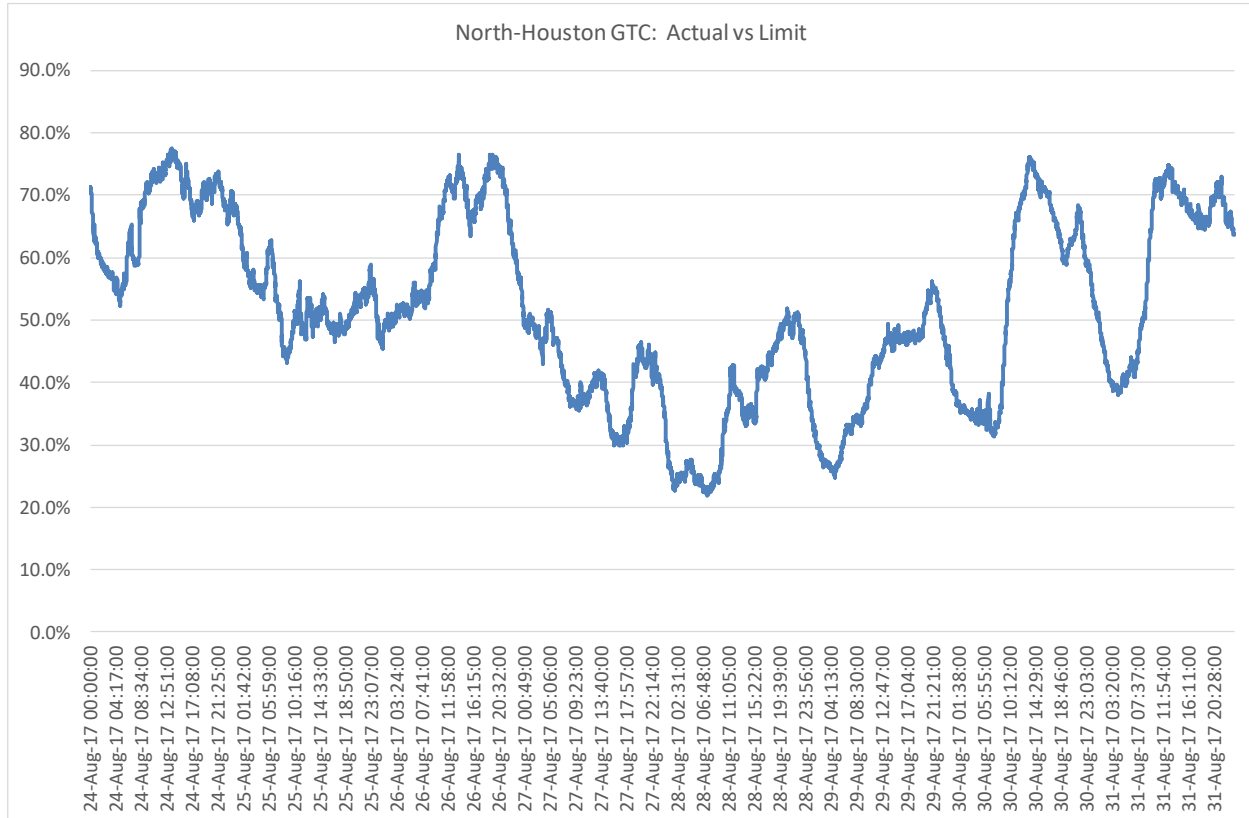
Another Transmission Operator had intermittent ICCP issues on August 26 and August 27 which did not cause any issues due to smaller footprint and actions taken to quickly identify and manage MW/MVAR mismatches and topology coherency issues.

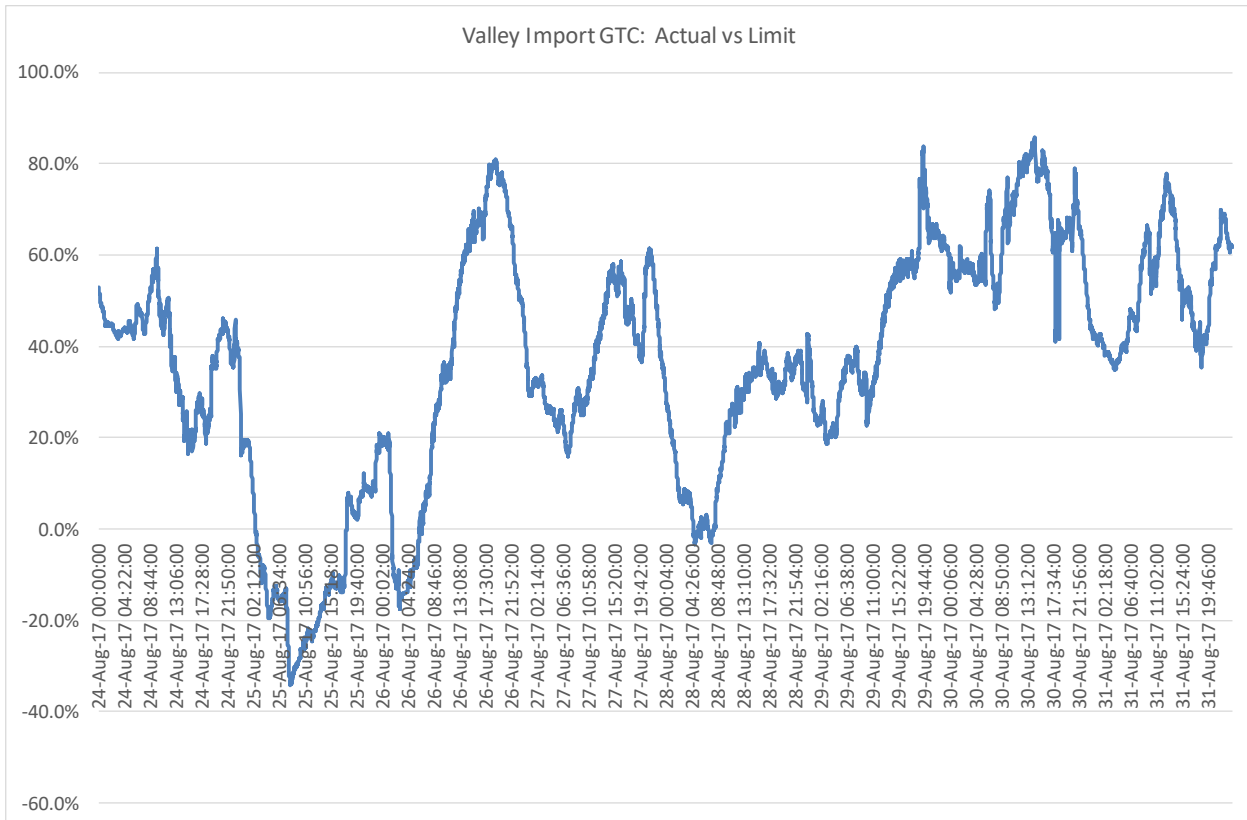


The Real Time Contingency Application (RTCA) and Voltage Security Assessment Tool (VSAT) successfully ran for all State Estimator valid solutions during the event.

### F. Transmission Constraints

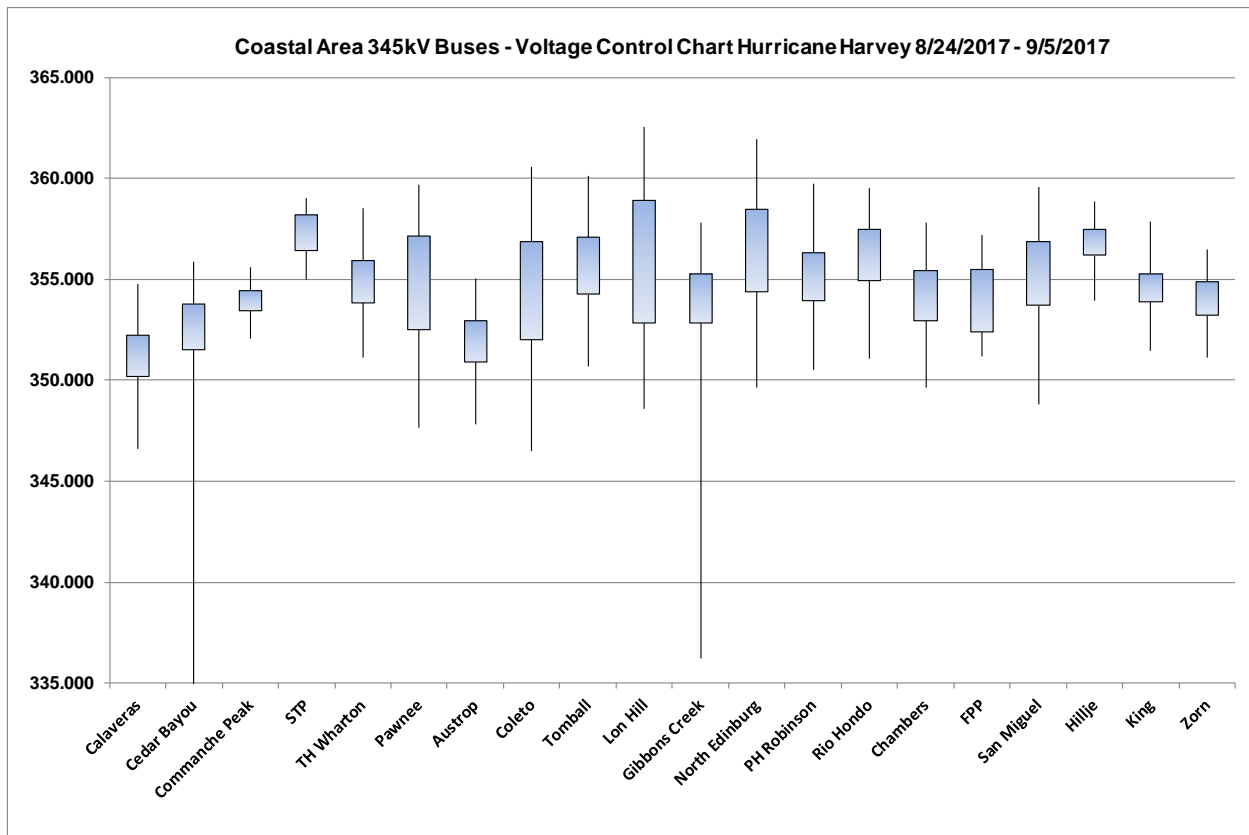
No issues were noted regarding the ability to operate within the Generic Transmission Limits (GTL) for the North-Houston interface, Valley Import Limit, or Zorillo-Ajo interface.





ERCOT did not experience challenges associated with BPS transmission thermal issues outside of typical real-time and post-contingency issues. Constraints were activated per normal operating procedures for Security Constrained Economic Dispatch (SCED) to re-dispatch generation as needed to mitigate post-contingency thermal overloads. Operational switching and Temporary Outage Action Plans (TOAPs) were also used to mitigate many post-contingency thermal overloads.

ERCOT did not experience challenges associated with high or low system voltage issues outside of typical real-time and post-contingency issues. For the voltage issues that did manifest due to multiple outages, TOAPs were developed, or impacted ERCOT Transmission Operators were instructed to take actions to mitigate the voltage issues.



Three voltage contingency issues were noted:

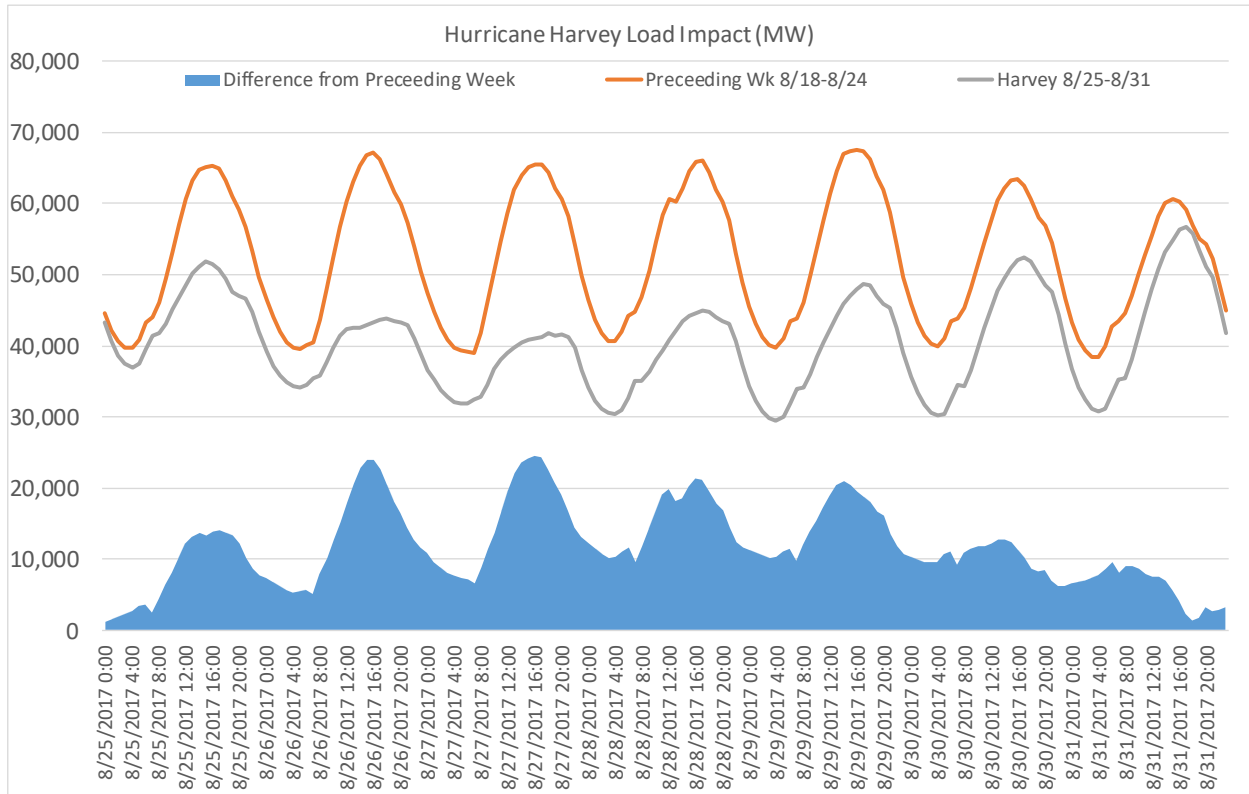
- 1) 8/26/2017 at 01:07: Basecase high voltage violations were noted on the 138kV lines near the coast due to the loss of a 345kV circuit. Opening the radial 138kV lines resolved the issue.
- 2) 8/26/2017 at 17:58: ERCOT instructed Transmission Operators in the Rio Grande Valley to coordinate with generators and nearby TOPs to increase voltages by placing capacitors in-service and to turn off reactors near weak busses without exceeding high voltage System Operating Limits (SOLs).
- 3) 8/29/2017 at 19:18: Multiple 345kV contingencies showed overloads and possible voltage collapse of the 69kV system south of San Antonio. Operating Instructions were issued at 19:31 to perform transmission switching which alleviated all post-contingency overloads greater than 120%. A TOAP was developed to mitigate the remaining overloads.

### *G. Generation/Load Balance, Frequency Control, and Ancillary Services*

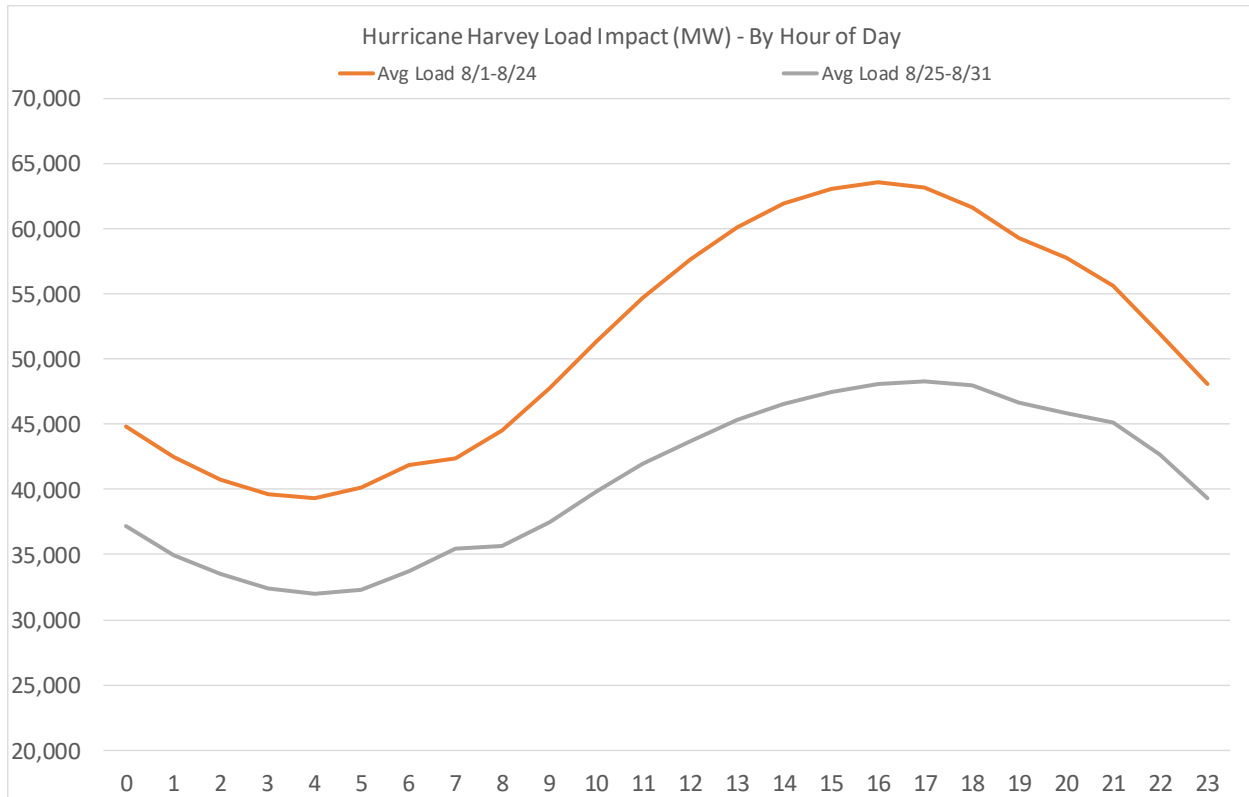
Demand during the storm period was approximately 15,000-20,000 MW lower than typical August load. This was attributed to the cloudy and cooler temperatures as well as the number of customer outages experienced in the storm impact areas.

ERCOT experienced challenges with its short-term load forecasting due to load loss during the hurricane. ERCOT used manual intervention on the Mid-term Load Forecast (MTLF) in order to have the forecast be more in line with actual loads during the hurricane. This was necessary as

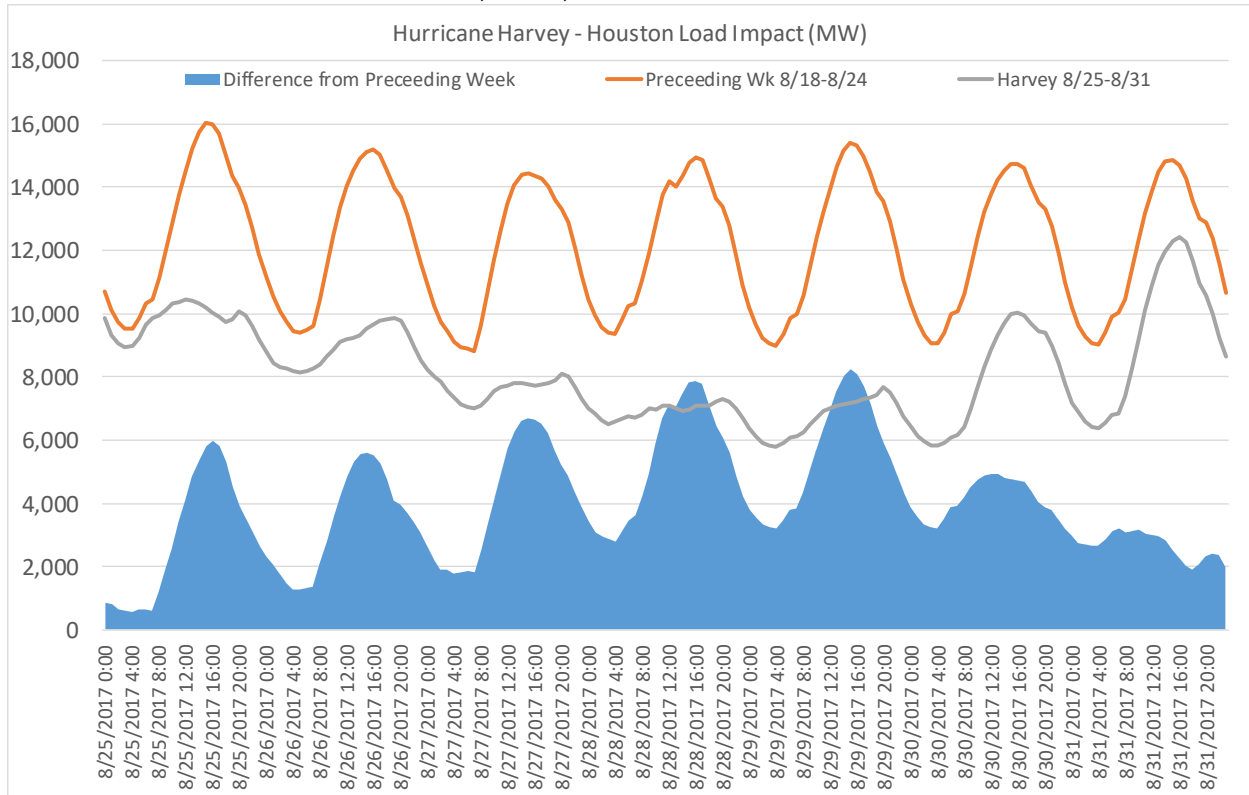
the existing models were forecasting based on historical load levels that did not reflect the amount of outages that were present during the storm. For the Short-Term Load Forecast (STLF), ERCOT enabled purely autoregressive models (meaning the forecasts are based on lagged actual load values). This allowed for the STLF to rapidly adjust to the actual 5-minute loads during the storm.



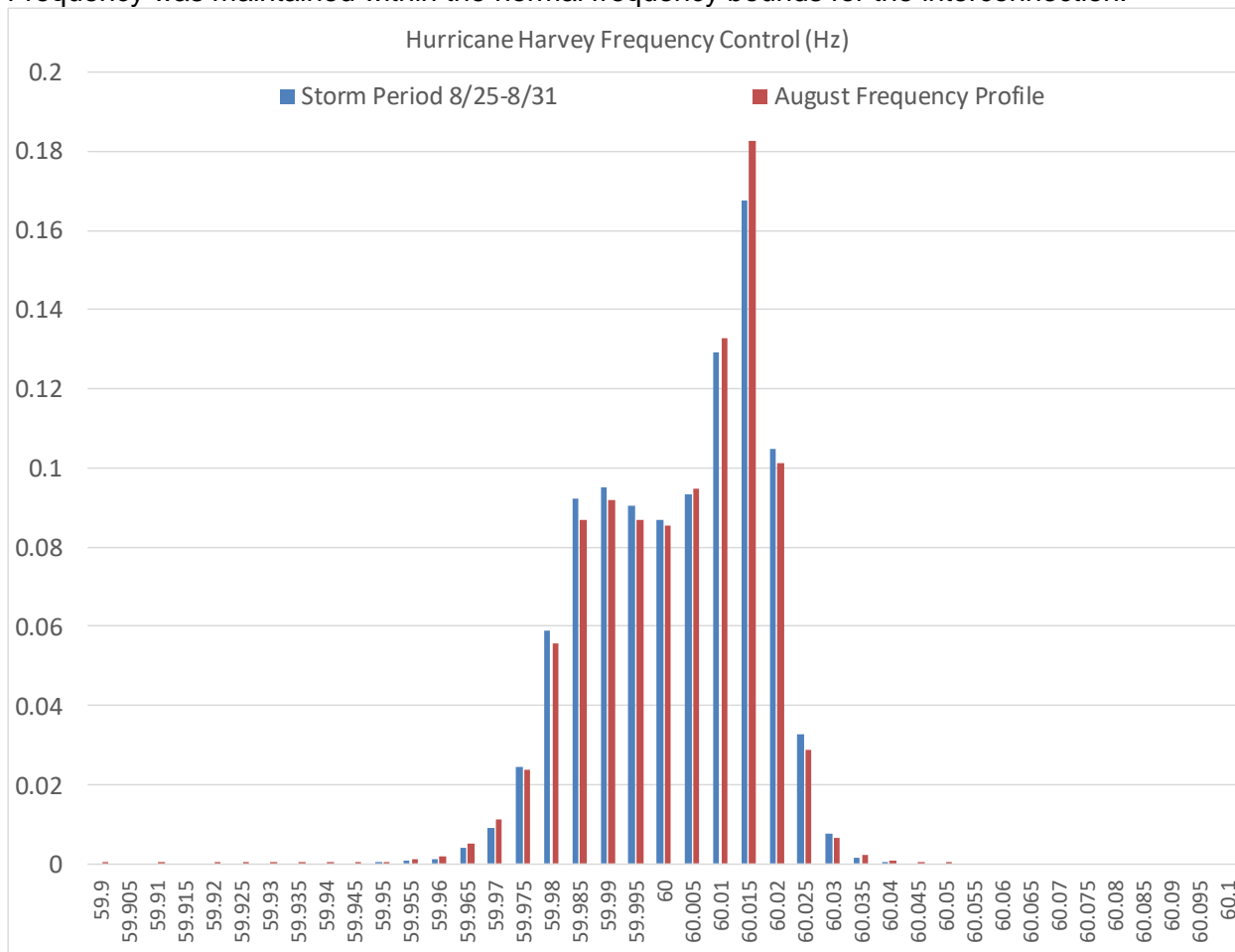




Demand in the Houston area was 5,000-8,000 MW lower than normal.



Frequency was maintained within the normal frequency bounds for the interconnection.



### Reliability Unit Commitments (RUC)

To position the system for balancing generation and load in consideration of the likelihood of additional transmission outages in the area, ERCOT instructed two Reliability Unit Commitments related to Hurricane Harvey. A forced outage of one 345kV line prompted ERCOT to issue a Reliability Unit Commitment for additional generation in the Rio Grande Valley. ERCOT later committed a generator to remain online to provide generation to the local area in support of expected load restoration efforts.

### Responsive Reserves, Regulation, and Non-Spin

ERCOT did not increase generation reserves or additional ancillary services in preparation for or during Hurricane Harvey. ERCOT did not have to transfer ancillary services to resources outside of the anticipated storm impact area. There were no Non-Spin Generation or Responsive Reserve deployments during the storm.

ERCOT executed a Supplemental Ancillary Service Market (SASM) for operating day August 28<sup>th</sup> to replace an anticipated Responsive Reserve Service (RRS) shortfall for HE05-HE14 due to the loss of one generator that tripped due to low pressure from wet fuel.

## IV. Recovery

### A. Transmission System Recovery

Damage assessments were hampered in some areas due to flooding and other areas due to limited or impeded access caused by heavy debris on the roads. The slow forward speed of the storm also affected the ability to perform aerial patrols of transmission lines. Damage assessments were started in the areas that were accessible and the weather allowed; while the other areas were delayed one to two days while hazards were cleared, weather abated, and the flooding subsided.

The challenges included:

- Road hazards
- Loss of station service AC power to the DC supply systems at the stations
- Wind damage to substation control buildings roofs and window. One substation control house failed.
- Water damage to relay systems due to flooding or damaged control buildings
- Transmission line tower foundations washed out due to flooding
- Restoration personnel unable to use bucket trucks until wind speed reduced to safe levels
- Flooding, mosquitos, as well as wind and mud created special challenges for work crews.





Additional challenges included the need to secure food, lodging, and fuel for the work crews. As is the case for many large events, management faced challenges in effectively utilizing resources needed to safely restore or maintain power.

Gasoline and diesel fuel availability was a significant challenge for utilities after Harvey made landfall. Harvey impacted several refineries in the Houston, Corpus Christi, and Victoria areas. Deliveries to gas stations were hindered by debris and flooded roadways. Local gas stations were without power.

Specialized equipment and technology, such as drones, ATVs, pictometry, and helicopters were utilized during the assessment and restoration efforts.

Unmanned aerial drones were used to perform damage assessments on inaccessible transmission and distribution lines and evaluate work conditions. Infrared capabilities helped identify equipment that needed further inspection.





Amphibious vehicles and airboats were used to access flooded areas.





Helicopters were used to bring material to flooded area.



In the Corpus Christi, Port Aransas, and Victoria areas, hurricane force winds and tornados damaged over 800 transmission line structures. The vast majority of these were wood poles. High winds also damaged cooling towers at several power plants. Utilities worked with federal and state agencies to prioritize the restoration of critical transmission facilities, in particular, feeds to refineries and petro-chemical plants. ERCOT System Operations and representatives of Transmission Owners and state government held conference calls on priority loads such as hydrogen gas facilities near the Gregory/Portland and Victoria areas and also the refineries in the Corpus Christi area. Over 95% of the transmission lines and substations were returned to service by September 8.

In the Houston area, the unprecedented flooding created severe challenges. Substations and power plants experienced damaged equipment due to high flood waters. Several transmission line structure foundations were washed out. Substations had to be de-energized, re-configured, or bypassed. A mobile substation was used in one location when the existing substation was flooded. Areas were inaccessible for extended periods, delaying restoration activities. High water vehicles and boats were used to access some areas. Over 95% of the transmission lines and substations were returned to service by September 13.



## Mobile substation



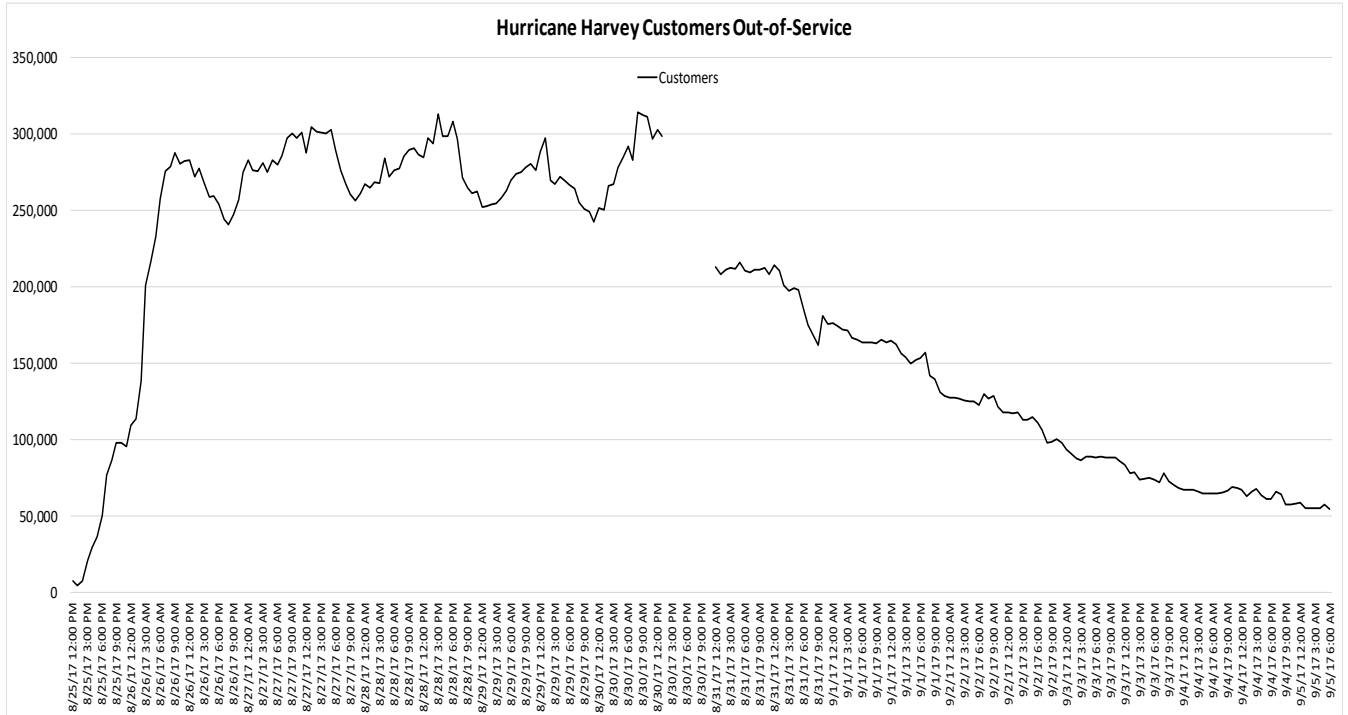
The hurricane presented unique opportunities for utilities to reconfigure transmission facilities in order to restore customer and maintain the integrity of the bulk power system. Two examples of this are described below. These reconfigurations also presented ERCOT with challenges for quickly updating network models, contingency analysis within State Estimator, and operator displays.

- On August 26, two Transmission Operators coordinated with ERCOT ISO regarding reconfiguration of a substation due to imminent flooding. The reconfiguration modified the two tie lines and created new end points in the adjacent TOP area remote substations. The reconfiguration was left in place until flood waters receded. After flood waters receded, the substations were restored to their original configurations on September 13.
- On August 28, an industrial facility contacted it's TOP about concerns with flooding and the need to de-energize the facility-owned substation. In order to de-energize the substation, the TOP sent crews to the two substations adjacent to the facility to switch out the circuit and open line switches. On September 7, the TOP reconfigured and energized the circuit, bypassing and removing the feeds into the industrial facility, thus establishing a new circuit. On September 13, a tap into the industrial facility was energized to enable the facility to make permanent repairs to its substation.

### *B. Load Restoration*



A peak of approximately 338,000 electric customer outages were reported across the impacted area, and the total number of reported customer outages exceeded 1.67 million. All customer outages were restored by September 8. Note that there is a gap in the customer outage data on August 30 between 14:00 and 24:00 due to loss of data from one entity website.



**Examples of Distribution Damage**











### *C. On-going Post-Storm Issues*

The following transmission and generation facilities suffered extensive damage due to the storm and remain out of service unless otherwise noted below. None of these outages are expected to cause reliability issues with the operations of the system.

- One generation facility suffered extensive damage to its cooling tower fan deck from high winds. Units were returned to service on November 15.
- One generation facility suffered site-wide flooding damage. Expected return to service is the end of May 2018.
- One generation facility suffered extensive flooding of its control room. Expected return to service is the end of January 2018.
- One 345/138-kV autotransformer failed. Expected return to service is the end of March 2018.
- One 345-kV line suffered heavy damage with approximately 25 miles of structures and conductor knocked down. Expected return to service is the end of May 2018.
- One 138-kV line suffered heavy damage with over 90 structures knocked down. Expected return to service is the end of December 2017.

### *D. Best Practices and Lessons Learned*

Following this event, the following good industry practices were identified by ERCOT:

- The Forced Outage Detector (FOD) application was instrumental in helping operators and support engineers identify undocumented outages which were not entered in the outage scheduler during the hurricane.
- Grid Applications Support Operations Engineers were able to use the State Estimator Statistical (SESTAT) application to quickly identify MW/MVAR mismatches and topology

issues from which validation of the system status for QSEs and Transmission Service Providers (TSPs) could be done.

- Having on-site Engineering Support from the Advanced Network Analysis and Operations Support departments ensured quick evaluations of issues with ERCOT applications.
- Issuance of regularly recurring updates in a pre-determined format to ERCOT management throughout the event helped ensure efficient communications.
- To aid in the development of the Next Day Study, which is performed to meet NERC Requirements, Operations Support Engineering staff created an Excel spreadsheet that pulls EMS study results and then evaluates potential options to mitigate base case and post-contingency overloads. This tool was leveraged for Pre-Event System Assessments scenarios to identify potential mitigation measures for the constraints observed. This significantly reduced the amount of time needed to complete these assessments, and should be used as an example of innovative actions and a great success.

The following areas for improvement and lessons learned were identified by ERCOT:

- Communications “Fact Sheet” is Beneficial for Dissemination of Information: Early on during the event it was determined that updates needed to be provided to ERCOT Management and Corporate Communications staff at regular intervals, for issues such as trending customer outages, transmission outages, and generation outages or derates, as well as any other important information. The established process for providing such regular reports during a Black Start event was modified to meet this need, but manual efforts were needed to catalog, organize, and report as conditions changed. ERCOT needs to formalize the process developed during Harvey for what information to collect and disseminate, as well as define the interval for updating and issuing updated reports.
- Chief System Operator communication channel: During these extreme weather events there should be a communication channel and or conference bridge set up for Chief System Operators to facilitate communication for strategic and informative discussions, in addition to the normal communications that occur between system operators. Currently these discussions occur in series and from point to point.
- Wide area overview with weather overlay: ERCOT should accelerate the planned development of a geospatially correct, wide area view of the ERCOT Transmission System with weather overlay to allow for System Operators to monitor radar, wind, lightning, severe weather watches/warning, etc., as it crosses the ERCOT Transmission System.
- Ad hoc real-time transient stability analysis: ERCOT should accelerate the planned development of tools and processes to allow for ad hoc real-time transient stability analysis for issues (local or inter area) that could evolve during a significant weather event.
- N-1-1 Automated Contingency Analysis Capability: ERCOT should accelerate development of planned tools and processes to perform automated N-1-1 steady state contingency analysis to identify critical outages that would require atypical action to restore the ability to be N-1 secure following the outage.
- Hurricane sensitivity as an input to Black Start unit selection process: ERCOT should consider factoring in sensitivity to hurricanes as an input to the Black Start selection process.
- Event Analysis Reporting tool: ERCOT should continue to pursue the Event Analysis reporting tool project and try to incorporate analysis from this report as part of its requirements. Ideally, any real-time reporting built for real-time communication of event information would be aligned with the Event Analysis reporting tool.

The following good industry practices were identified by individual entities:



- Increased collaborative efforts with other Texas utilities, ERCOT, and Regional Mutual Assistance Groups. 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.
- Establishment of contacts with the central FEMA Coordinator.
- Use of advanced meters and intelligent grid devices to pinpoint outages, remotely operate equipment, and increase efficiency.
- Use of Facebook, Twitter, and Power Alert Service to keep customers informed.
- Use of aerial drones to assess damage and evaluate work conditions. 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.
- Use of detailed pictures of transmission structures to facilitate a rapid design response allowing materials to be marshalled and a high level scope developed to mobilize construction resources.

The following areas for improvement and lessons learned were identified by individual entities:

- Fuel availability challenges after Harvey made landfall:
  - a. Evaluate back-up fuel supplies for primary and back-up control centers.
  - b. Evaluate coal yard fuel reserve supplies (diesel fuel for machinery to move coal to resources).
  - c. Implement diesel fuel conservation measures by limiting the number of start and stops of mills.
  - d. Consider developing a PUCT-supported power plant priority process for fuel availability/deliverability.
  - e. Raise re-order points for fuel at the beginning of hurricane season.
- Business continuity plan should be implemented seven days before the storm to allow employees ample time to take care of family matters before any travel that may be necessary.
- Ensure that plentiful wide-tracked equipment is engaged and available for the first day of restoration. Tracked diggers and buckets will speed the restoration process considerably over conventional transmission line equipment. Normal terrain equipment can be used but each crew requires D6 or larger wide-tracked dozers to clear paths and pull the equipment in through the thoroughly soaked farm and pastureland.
- Generation plant cooling towers: add tie down points for cooling tower fan blades.
- Transportation issues due to road closures posed a significant challenge to not only utility crews during the restoration process, but also to suppliers and external restoration resources. Significant flooding, including road closures, should be included into future planning exercises and mitigation during future events.

## V. Conclusions

Hurricane Harvey was a devastating storm that caused extensive damage to the bulk power system in ERCOT, affecting over 225 transmission lines and transformer banks, over 10,000

MW of generation, and causing power outages to over 1.67 million customers. ERCOT and utilities exhibited outstanding coordination, working together to restore power to customers and protect the reliability of the grid.



## Appendix 1

### National Weather Service Hurricane Harvey Recap

Hurricane Harvey began as a tropical wave that emerged from the African coast in early August. The disturbance finally formed into Tropical Storm Harvey east of the Lesser Antilles on August 17. Those islands experienced locally heavy rain and gusty winds as Harvey passed through. A couple of days later, Harvey weakened to a tropical wave due to dry air and unfavorable winds in the eastern Caribbean, and the National Hurricane Center ceased advisories on August 19.



The remnants of Harvey continued to push northwest for several days and eventually crossed Mexico's Yucatan Peninsula. Once its remnants moved back over water in the southwest Gulf of Mexico, Harvey quickly reformed into a tropical depression on August 23. In just 56 hours, Harvey grew from a regenerated tropical depression over the Gulf of Mexico into a Category 4 hurricane as it made landfall near the Texas Gulf Coast late on August 25. Harvey's center of circulation stalled over south Texas on August 26 and then meandered slowly east into the Gulf of Mexico before making a final landfall near Cameron, Louisiana, on August 30. Still a named storm 117 hours after landfall, Harvey was the longest a Texas landfalling hurricane remained a named storm after landfall on record. It was the slow movement from August 26 to August 30 that led to the catastrophic flooding that was observed in southeast Texas.

Harvey made landfall on the evening of August 25 near Rockport, a town of less than 10,000 people and about 30 miles up the Texas coast from Corpus Christi. Maximum sustained winds

in Harvey's eyewall were 130 mph at that time, making it a Category 4. With a diameter of approximately 280 miles, the effects of Harvey were felt from Brownsville, Texas to Lake Charles, Louisiana.

Harvey was the nation's first major (Category 3 or stronger) hurricane landfall since Hurricane Wilma struck South Florida in October 2005, an almost 12-year run. Harvey was the strongest storm to make a landfall in this area, known as the Texas Coastal Bend, since Hurricane Carla in September 1961.

Harvey's minimum surface pressure of 938 millibars at landfall tied it for the 16<sup>th</sup> lowest pressure U.S. landfall on record, according to NOAA/AOML. It was also the strongest hurricane landfall, by pressure, in the U.S. since Rita in 2005.



#### Top Wind Gust Reports

- Port Aransas: 132 mph, sustained to 110 mph
- Near Copano Village: 125 mph
- Near Lamar: 110 mph
- Rockport: 108 mph
- Near Taft: 90 mph
- Near Magnolia Beach: 79 mph
- Palacios: 69 mph
- Corpus Christi Int'l Airport: 63 mph
- Austin Bergstrom Int'l Airport: 52 mph

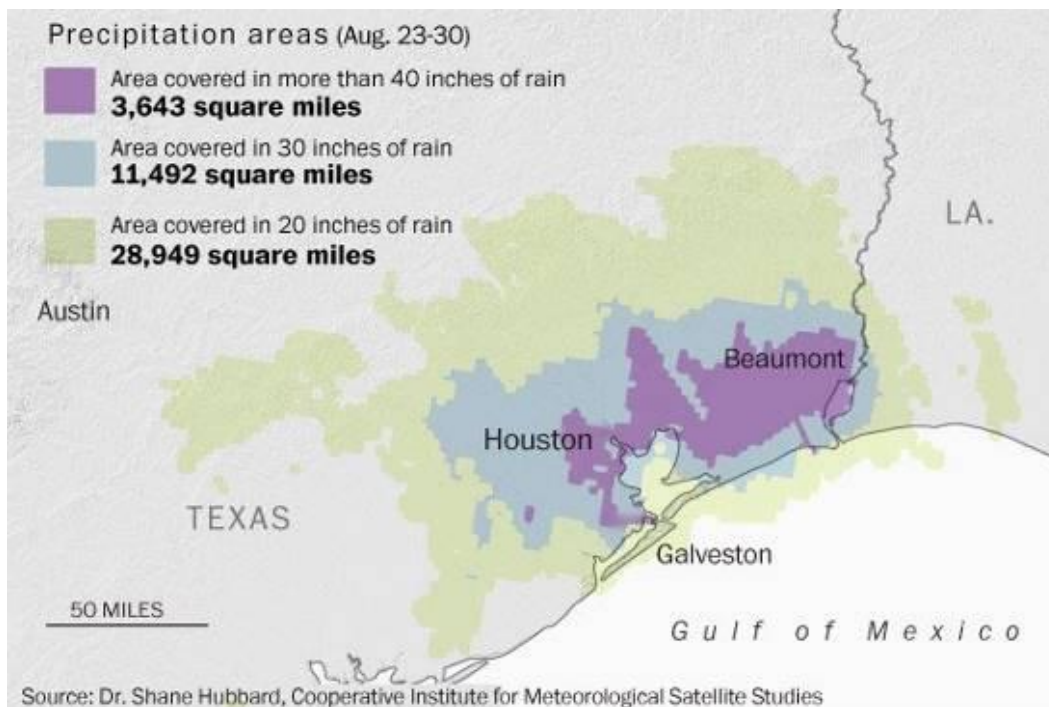
Harvey's extreme slow movement from August 26 to August 30 resulted in catastrophic flooding. Numerous flash flood emergencies were issued for the Houston and Beaumont, Texas,

metropolitan areas, and for Bastrop County and nearby communities. The area coverage of locations picking up at least 20 inches of rain was greater than the state of West Virginia, while the 40-inch-plus zone was larger than Delaware.

The top rainfall total was a preliminary 51.88 inches near Highlands, Texas, at the Cedar Bayou rain gauge.

#### Top Rainfall Reports

- 51.88 inches on Cedar Bayou near Highlands, Texas
- 49.40 inches on Clear Creek at Interstate 45 near League City, Texas
- 49.32 inches on Mary's Creek near Friendswood
- 49.23 inches near Dayton
- 49.20 inches on Mary's Creek at Winding Road
- 47.35 inches in Beaumont/Port Arthur, Texas
- 45.74 inches near Pasadena
- 44.91 inches near South Houston
- 43.38 inches at the NWS forecast office in Houston (League City)
- 37.01 inches at Houston Hobby Airport
- 31.26 inches at Houston Bush Intercontinental Airport
- 22.84 inches in Galveston
- 21.88 inches in Smithville
- 19.64 inches in College Station
- 15.60 inches near Victoria
- 15.41 inches near Lake Charles, Louisiana
- 12.33 inches near Hackberry, Louisiana

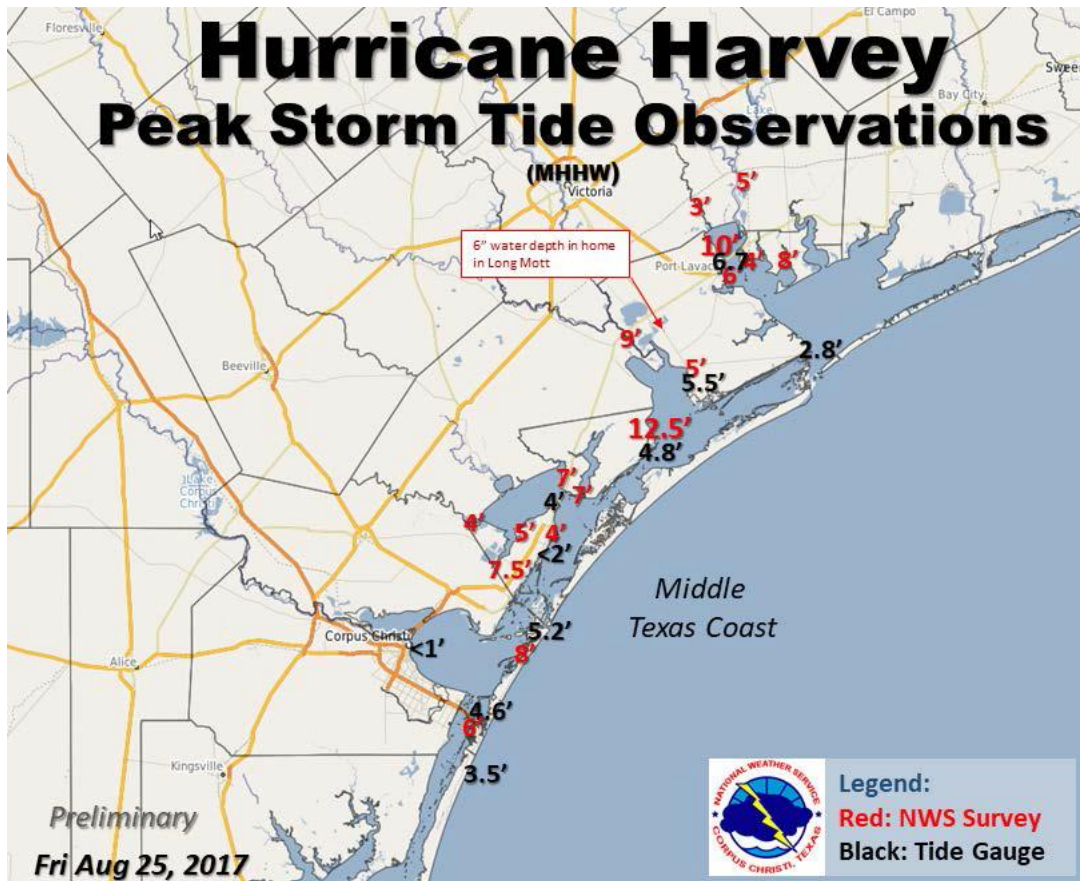


Houston's Bush Intercontinental Airport exceeded its record-wettest calendar day Sunday August 27 by over five inches, picking up 16.07 inches of rain, just under the five-day total of



16.48 inches from Tropical Storm Allison in 2001. Houston's Hobby Airport also exceeded a two-day rainfall record by almost eight inches, picking up 23.06 inches of rain August 26 to August 27. The average rainfall within the Harris County Emergency Management network exceeded that of Tropical Storm Allison (2001) in almost half of the time (two to three days versus five days). The Harris County Flood Control District (HCFCD) estimated one trillion gallons of water was dumped on the county alone in four days. The HCFCD estimated 70 percent of Harris County was flooded by at least 1.5 feet of water, with an estimated 136,000 flooded structures in the county alone, as of August 31.

Thousands of water rescues occurred in the Houston metro area as many homes and businesses were swamped by floodwaters. Jack Brooks Regional Airport near Port Arthur, Texas, picked up 26.03 inches of rain on August 29 alone, more than doubling the previous calendar-day rainfall record in Beaumont-Port Arthur set over 94 years ago. Its storm total from August 26 to August 30 was 47.35 inches of rain, almost 25 inches greater than its previous record four-day rain record set in September 1980.



Serious flooding also occurred southwest of Houston along the Brazos, Colorado and Guadalupe Rivers. In total, 19 National Weather Service river gauges had observed record flooding as of August 31. Harvey has also spawned numerous brief tornadoes in southeast Texas, Louisiana, Alabama, Mississippi, Tennessee and North Carolina. Harvey is one of the most prolific tornado producers for a tropical cyclone.



## Appendix 2

### Summary of Communications and Coordination

#### Communications between ERCOT and Transmission/Distribution Entities

08/23/2017 08:00: Senior Manager, System Operations contacted the Transmission Control Center Managers at BPUB, AEP, STEC, CenterPoint, and TNMP. Discussed the potential storm impacts and requested that all outages that can be restored be put back into service prior to any impacts of the potential Hurricane.

08/23/2017 10:30: ERCOT issued Operating Condition Notice (OCN) for future Tropical Storm Harvey.

QSEs instructed to:

- Review fuel supplies and notify ERCOT of any known or anticipated fuel restrictions.
- Review Planned Resource outages and consider delaying maintenance.
- Review emergency operating procedures and notify ERCOT of any changes or conditions that could affect System Reliability.

TOPs instructed to:

- Review planned and existing transmission outages to be canceled and/or restored.
- Review emergency operating procedures, evacuation plans, and the possible need to staff backup facilities.

08/24/2017 07:50: ERCOT issued Advisory for Tropical Storm Harvey in the Gulf of Mexico.

QSEs instructed to:

- Review fuel supplies and notify ERCOT of any known or anticipated fuel restrictions.
- Review Planned Resource outages and consider delaying maintenance.
- Review emergency operating procedures and notify ERCOT of any changes or conditions that could affect System Reliability.
- Instruct Plant Operators to prepare for projected severe weather conditions and review procedures for operating in the lead due to possible high voltage concerns.
- Notify ERCOT if relocating personnel to backup control centers.

TOPs instructed to:

- Review planned and existing transmission outages to be canceled and/or restored.
- Review emergency operating procedures, evacuation plans, and the possible need to staff backup facilities.
- Test communication with other TOPs and QSEs prior to the hurricane making landfall.

08/24/2017 09:00: WeatherSentry started providing live daily Harvey briefings.

08/24/2017 10:30: ERCOT Senior Manager, System Operations was in contact with the MISO Reliability Coordinator. Verified long distance numbers and discussed Block Load Transfers (BLT), if needed. BLTs were not needed during the events.

08/24/2017 11:00: ERCOT issued Watch due to Hurricane Harvey in Gulf of Mexico

QSEs instructed to:

- Notify all Resources of conditions.

- Review fuel supplies and notify ERCOT of any known or anticipated fuel restrictions.
- Review emergency operating procedures and notify ERCOT of any changes or conditions that could affect System Reliability.
- Make available any Resources that can be returned to service and keep COPs and HSLs updated.

TOPs instructed to:

- Be prepared to lose load and expect high voltage conditions.
- Keep ERCOT informed of transmission outages.

08/24/2017 13:00: ERCOT System Operations, Operations Support, Outage Coordination, Operation Analysis and Advanced Network Applications met to discuss Hurricane Harvey.

08/24/2017 14:00: ERCOT Disaster Management Team (DMT) held a conference call.

08/24/2017 16:00: ERCOT System Operations, Operations Support and Outage Coordination held a Harvey Electric/Gas conference call with Enterprise Products.

08/24/2017 16:30: ERCOT System Operations and Corporate Communications held a conference call.

08/25/2017 08:30: ERCOT System Operations and Corporate Communications held a conference call.

08/25/2017 09:00: WeatherSentry provided a live Harvey Briefing.

08/25/2017 11:00: ERCOT Disaster Management Team (DMT) held a conference call.

08/25/2017 13:30: ERCOT System Operations provided a preparation overview on the ERCOT Region on the NERC BPSA Government Agency conference call.

08/25/2017 16:00: ERCOT Disaster Management Team (DMT) held a conference call.

08/25/2017 17:00: Emergency Notice issued for Hurricane Harvey

QSEs instructed to:

- Be prepared to reduce Generator output due to anticipated load loss and respond to voltage support issues as requested.
- Keep COPs and HSLs current.

TOPs instructed to:

- Be prepared to lose load and expect high voltage conditions
- Keep ERCOT informed of any issues

08/25/2017 20:45: Transmission Watch for the Eagle Pass DC Tie due to reliability issues which may result in the curtailment of DC Tie exports to Mexico's National Center for Energy Control (CENACE).

08/26/2017 08:30: ERCOT System Operations and Corporate Communications held a conference call.

08/26/2017 08:59: Transmission Watch for the Eagle Pass DC Tie cancelled.

08/26/2017 09:00: WeatherSentry provided a live Harvey Briefing.

08/26/2017 10:00: ERCOT Disaster Management Team (DMT) held a conference call.

08/26/2017 13:30: ERCOT System Operations provided an update on the ERCOT Region on the NERC Bulk Power System Awareness (BPSA) Government Agency conference call.

08/26/2017 15:00: ERCOT System Operations and Corporate Communications held a conference call.

08/26/2017 16:00: ERCOT Disaster Management Team (DMT) held a conference call.

08/26/2017 17:58: Rio Grande Valley TOPs instructed to coordinate with connected generators and nearby TOPs to increase voltages by:

- Placing capacitor banks in-service,
- Turning off reactors near weak busses without exceeding high voltage SOLs.

08/26/2017 21:09: CenterPoint begins switching actions at the West Columbia station to bypass the 138 kV and 69 kV busses due to flooding in the station.

08/27/2017 08:30: ERCOT System Operations and Corporate Communications held a conference call.

08/27/2017 09:00: WeatherSentry provided a live Harvey Briefing.

08/27/2017 10:00: ERCOT Disaster Management Team (DMT) held a conference call.

08/27/2017 13:30: ERCOT System Operations provided an update on the ERCOT Region on the NERC BPSA Government Agency conference call.

08/27/2017 15:00: ERCOT System Operations and Corporate Communications held a conference call.

08/27/2017 16:00: ERCOT Disaster Management Team (DMT) held a conference call.

08/28/2017 02:12: Notification that ERCOT will be executing a Supplementary Ancillary Service Market (SASM) at 02:37 for Operating Day 08/28/2017 to replace RRS for HE05-HE14.

08/28/2017 08:30: ERCOT System Operations and Corporate Communications held a conference call.

08/28/2017 09:00: WeatherSentry provided a live Harvey Briefing.

08/28/2017 10:18: Weekly hotline call to TOPs and QSEs performed:

- National Terrorism Advisory System (NTAS) Advisory Level Bulletin discussed.
- ERCOT Emergency Notice for Hurricane Harvey still in effect.

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08/28/2017 14:36: CenterPoint begins switching actions at the Greens Bayou station to bypass the 345 kV bus and one 138 kV bus due to flooding in the station.

08/29/2017 09:00: ERCOT System Operations and the Governor's office held a conference call on priority loads such as hydrogen gas facilities near the Gregory/Portland and Victoria areas. Senior Manager, System Operations contacted the Transmission Control Center Manager at AEP and discussed the priority. AEP prioritized and restored transmission to the area.

08/29/2017 09:00: WeatherSentry provided a live Harvey Briefing.

08/30/2017 09:30: MISO inquired about the availability of the Crosby-Dayton BLT. CenterPoint notified ERCOT that they could send up to 100 MW if needed. No BLT at Crosby-Dayton was ever initiated.

08/30/2017 12:00: ERCOT cancelled Emergency Notice issued for Hurricane Harvey.

08/30/2017 12:00: ERCOT issued OCN for unplanned transmission outages that may impact reliability.

08/30/2017 14:00: Governor's office notified ERCOT System Operations about Flint Hills Resources (Koch) in the Corpus Christi area is in startup. Senior Manager, System Operations contacted the Transmission Control Center Manager at AEP and discussed. Transmission was already established and it was not an issue.

08/31/2017 20:00: CenterPoint begins switching actions at the Greens Bayou station to remove station bypass conditions due to flood waters receding from the substation.

09/04/2017 08:17: Weekly Hotline test call to TOPs and QSEs performed:

- ERCOT OCN for Hurricane Harvey still in effect.

09/05/2017 11:09: ERCOT cancelled OCN for unplanned transmission outages that may impact reliability.

09/13/2017 13:17: CenterPoint begins switching actions at the West Columbia station to remove station bypass conditions due to flood waters receding from the substation.

#### Regional Hot-Line Calls

08/23/2017 10:30: ERCOT issued OCN for future Tropical Storm Harvey

QSEs instructed to:

- Review fuel supplies and notify ERCOT of any known or anticipated fuel restrictions,
- Review Planned Resource outages and consider delaying maintenance,
- Review emergency operating procedures and notify ERCOT of any changes or conditions that could affect System Reliability.

TOPs instructed to:

- Review planned and existing transmission outages to be canceled and/or restored
- Review emergency operating procedures, evacuation plans, and the possible need to staff backup facilities.

08/24/2017 07:50:ERCOT issued Advisory for Tropical Storm Harvey in the Gulf of Mexico,



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QSEs instructed to:

- Review fuel supplies and notify ERCOT of any known or anticipated fuel restrictions,
- Review Planned Resource outages and consider delaying maintenance,
- Review emergency operating procedures and notify ERCOT of any changes or conditions that could affect System Reliability.
- Instruct Plant Operators to prepare for projected severe weather conditions and review procedures for operating in the lead due to possible high voltage concerns
- Notify ERCOT if relocating personnel to backup control centers,

TOPs instructed to:

- Review planned and existing transmission outages to be canceled and/or restored.
- Review emergency operating procedures, evacuation plans, and the possible need to staff backup facilities.
- Test communication with other TOPs and QSEs prior to the hurricane making landfall.

08/24/2017 11:00: ERCOT issued Watch due to Hurricane Harvey in Gulf of Mexico.

QSEs instructed to:

- Notify all Resources of conditions.
- Review fuel supplies and notify ERCOT of any known or anticipated fuel restrictions,
- Review emergency operating procedures and notify ERCOT of any changes or conditions that could affect System Reliability.
- Make available any Resources that can be returned to service and keep COPs and HSLs updated,

TOPs instructed to:

- Be prepared to lose load and expect high voltage conditions,
- Keep ERCOT informed of transmission outages.

08/25/2017 17:00: ERCOT issued Emergency Notice for Hurricane Harvey

QSEs instructed to:

- Be prepared to reduce Generator output due to anticipated load loss and respond to voltage support issues as requested,
- Keep COPs and HSLs current.

TOPs instructed to:

- Be prepared to lose load and expect high voltage conditions
- Keep ERCOT informed of any issues

08/25/2017 20:45: ERCOT issued Transmission Watch for the Eagle Pass DC Tie due to reliability issues which may result in the curtailment of DC Tie exports to CENACE.

08/26/2017 08:59: ERCOT cancelled Transmission Watch for the Eagle Pass DC Tie.

08/26/2017 1758: ERCOT instructed Rio Grande Valley TOPs to coordinate with connected generators and nearby TOPs to increase voltages by:

- Placing capacitor banks in-service.
- Turning off reactors near weak busses without exceeding high voltage SOLs.

08/28/2017 02:12: Notification that ERCOT will be executing a SASM at 02:37 for Operating Day 08/28/2017 to replace RRS for HE05-HE14.

08/28/2017 10:18: Weekly hotline call to TOPs and QSEs performed;

- NTAS Advisory Level Bulletin discussed,
- ERCOT Emergency Notice for Hurricane Harvey still in effect.

08/30/2017 12:00: ERCOT cancelled Emergency Notice for Hurricane Harvey.

08/30/2017 12:00: ERCOT issued OCN for unplanned transmission outages that may impact reliability.

09/04/2017 08:17: Weekly Hotline test call to TOPs and QSEs performed:

- ERCOT OCN for Hurricane Harvey still in effect.

09/05/2017 11:09: ERCOT cancelled OCN for unplanned transmission outages that may impact reliability.

#### Coordination with State and Federal Emergency Operations and Regulatory Agencies

08/25/2017 13:30: ERCOT System Operations provided a preparation overview of the ERCOT Region on the NERC Bulk Power System Awareness (BPSA) Government Agency conference call. ERCOT System Operations provided data to Texas RE and attended the NERC BPSA Government Agency conference calls on 08/26/17 and 08/27/17 at 13:30.

On 08/27/2017 16:56: ERCOT Legal provided an affidavit to the Railroad Commission of Texas (state oil and gas regulator) supporting potential finding of human need for continued gas supply to electric generating facilities.