PENS

Power Event Notification System

Houston, We Have A Problem

March 10, 2021

Gridmetrics™

1. Introduction

Recently, severely cold weather in Texas caused unprecedented strain on the electrical power system. In this whitepaper, we provide insights into this situation by accessing a large set of independent sensors that provide an observational view of the power grid based on a proprietary monitoring platform from Gridmetrics, Inc. While not an exhaustive analysis, this whitepaper provides a glimpse into the unique capabilities available from Gridmetrics.

The observations presented here are based on measurements from over 10,000 power sensors distributed across the low-voltage distribution grid in the Houston, TX area. These sensors provide a voltage reading (± ~1 volt) at a particular latitude and longitude at 5-minute intervals. For the purposes of this analysis, power sensors have been aggregated and mapped to the U.S. National Grid, (USNG) a standard 1 km x 1 km square.

This data is made available through Gridmetrics' new Power Event Notification System (PENS). Gridmetrics PENS provides an unprecedented level of near-real time situational awareness of the power grid. More information on Gridmetrics and the Power Event Notification System can be found at www.gridmetrics.io or by contacting PENS@gridmetrics.io.

Herein, both macro and subtle patterns can be seen as the widespread power outage and subsequent recovery unfold. The exact cause of an outage at any particular sensor cannot be inferred directly from the data—i.e., whether the outage was due to downed lines or due to operator-controlled power shutoffs (aka load shed)—but analyzing temporal and spatial behavior of voltages and power conditions reveals a new, independent lens to view and understand the severity and duration of outage events across the city and within particular neighborhoods. In addition, analyzing voltage trends prior to outage events, as well as residual voltage readings on de-energized lines during outage events, highlights an urgent need for better real-time situational awareness of the distribution grid to anticipate localized grid stresses and to manage utility worker and public safety.

2. Analysis

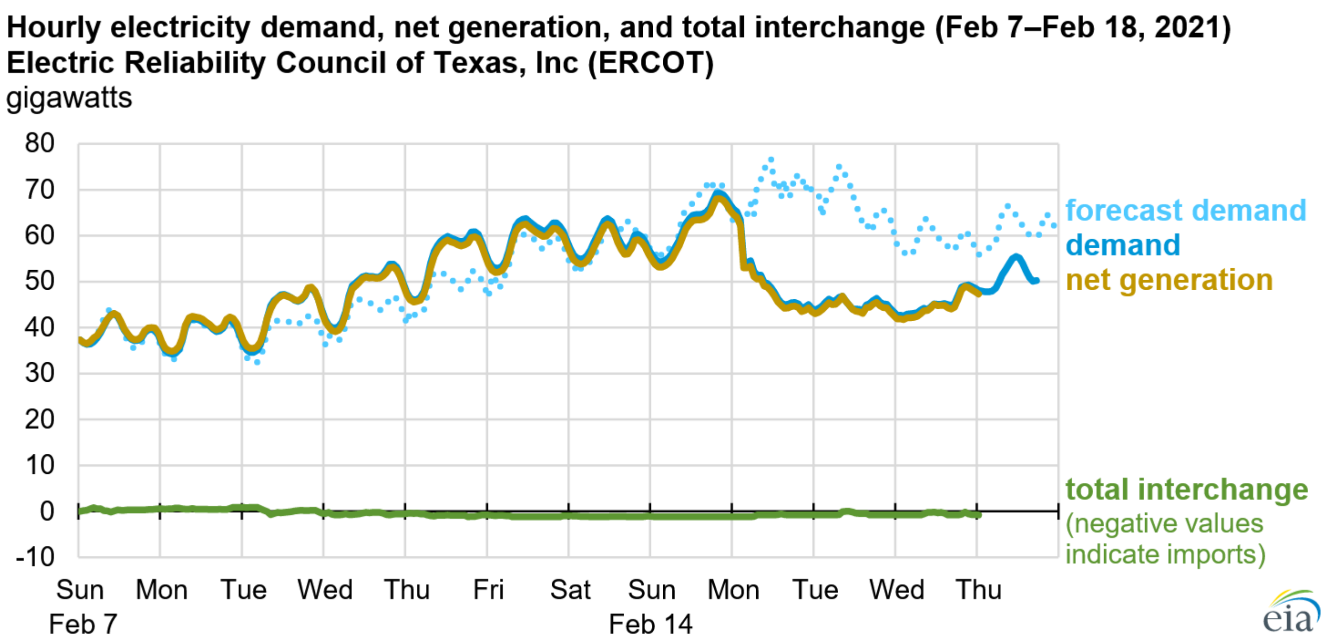
We focus our analysis in the Houston area consisting of approximately 10,000 sensor stations. In the analysis presented, we look at different signatures of the recent Houston power outage, how it unfolded, and how it recovered.

2.1 Supply and Demand Mismatch

The figure below shows the extreme mismatch between supply and demand starting on February 15, 2021. The mismatch caused rolling outages that we can look at in some detail with the nearly ten thousand sensors in the Houston area that are sampled every five minutes.

FEBRUARY 19, 2021

Extreme winter weather is disrupting energy supply and demand, particularly in Texas



Source: U.S. Energy Information Administration, *Hourly Electric Grid Monitor* (ERCOT demand, net generation, and interchange)

Figure 1. Texas energy supply and forecasted demand showing extreme mismatch between forecasted demand and generation.

2.2 Fraction Outage in the Houston Area

Figure 2 below shows the fraction of outages by USNG cells during the period major outage period of 2/15/2021 - 2/17/2021. The red numbers correspond to areas of high outage fractions and the purple to areas of low outage fractions, where fraction refers to the portion of hours a sensor was offline. Perhaps not surprisingly, Galveston Island had one of the highest outage fractions, i.e., the longest outage durations. Note that similar colors tended to be clustered together. This indicates that the outages were broad-based over many USNG cells. It also shows there were wide disparities on the fraction of outage times observed.

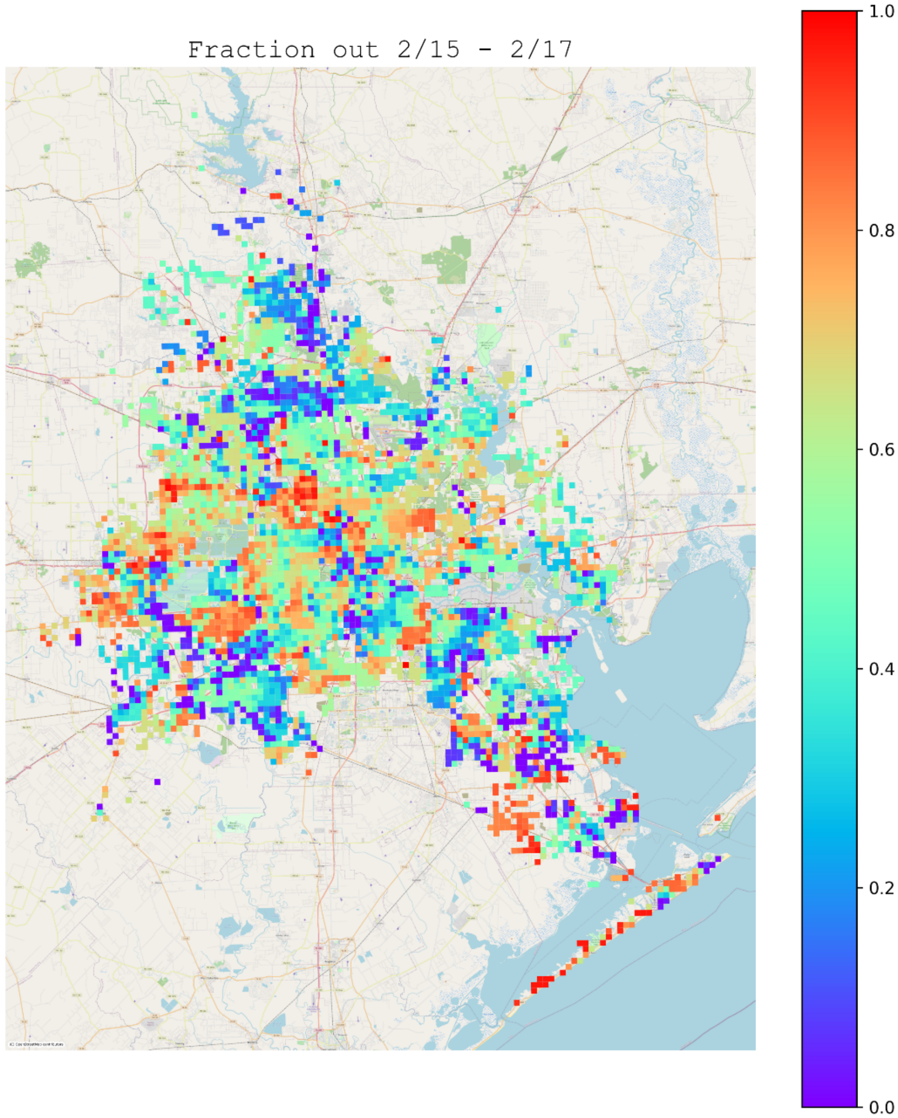


Figure 2. Fractional duration of outage hours by USNG in the Houston area during the major outage period.

The video below shows the time evolution of the power outages in the Houston area.

Figure 3. Fraction of voltage sensors working from the period of February 14-20, 2021.
(Click here if the video does not play: Houston Power Event Video)

2.3 Outages over Time

Figure 3 below shows the fraction of voltage sensors operationally online and okay (working properly) from the period of February 14-20, 2021. The horizontal axis is time, and the vertical axis is the fraction of sensors online. As can be clearly seen the period before February 15th essentially all the sensors were reporting nominal voltages (between 90 and 150 Volts). After that time, we see a sharp drop indicating that power was out followed by some periods of partial recovery before power was largely restored by February 19th. Generally, the power went off quickly but when it was restored it was also restored quickly, in less than half a day in both cases. Also of note are the short periods of partial recovery followed by further outages. These on-again off-again power cycles add more strain to the grid as well as HVAC systems and appliances.

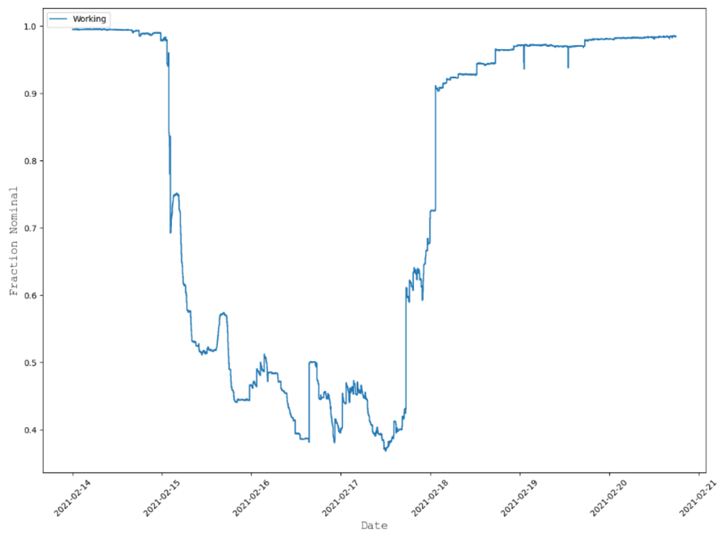


Figure 3. Fraction of total sensor population reporting online and okay as defined by a voltage criterion sampled every 5 minutes. Time is US Central Time.

2.4 Maximum Outages

In Figure 4 below we show the distribution of maximum outage time for each sensor. The horizontal axis is time, and the vertical axis is the number of sensors offline. Note that many of the sensors never went offline. Also, note the small peak around 24 hours and 36 hours. The peak at 120 hours is maximum time limit for this study and means that those sensors were still not operating through February 19th.

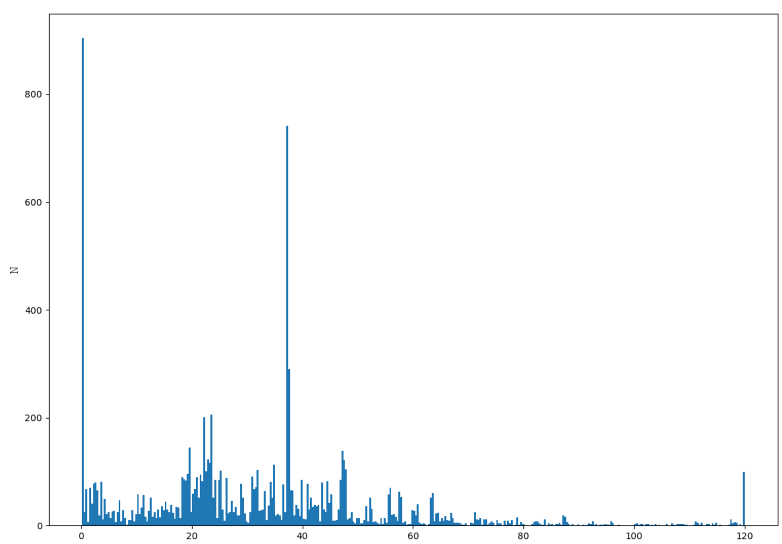


Figure 4. Maximum outage time distribution by sensor.

2.5 Rolling Blackouts

Figure 5 below shows power history, as measured via voltage, for eight different USNG cells. The horizontal axis is time, the vertical axis is observed voltage, and colors denote different sensor locations. As we can see, the rolling outages are different for different geographical areas. In USNG cells with multiple sensors, only one sensor was used as being representative of that cell.

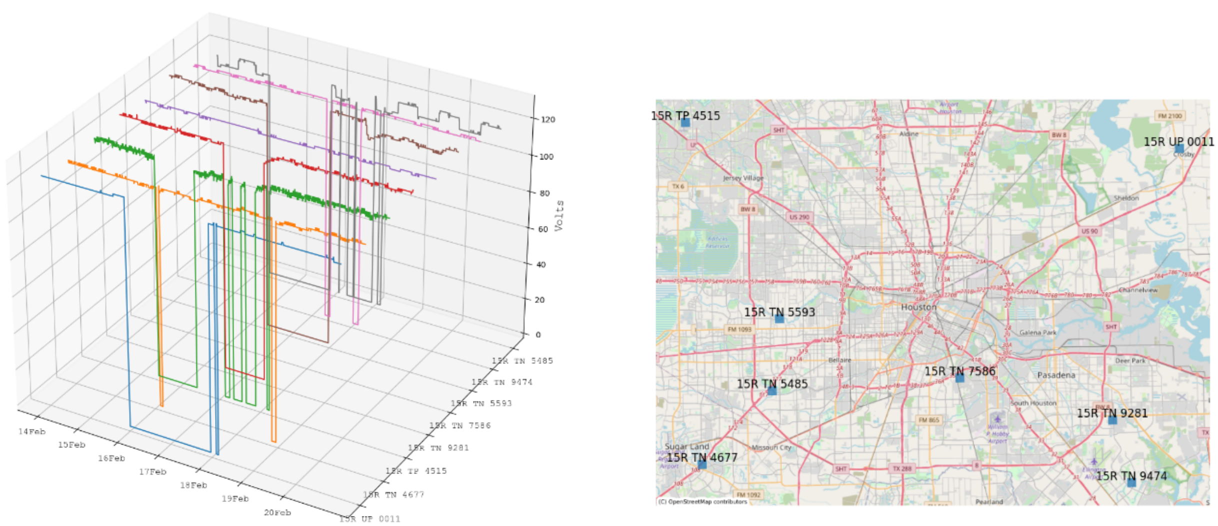


Figure 5. Examples of different blackout periods from eight different USNG cells (left) and their location (right).

2.6 Outage Duration

Figure 6 below shows the distribution of outage times using logarithmic-logarithmic scales. The horizontal axis is time, and the vertical axis is the number of events. The time resolution between measurements was nominally five minutes, but due to occasional delays, the actual time could be longer by up to a minute or so. Thus, in this figure, to be conservative, consecutive measurements were defined as those occurring within 10 minutes. As we would expect, the number of minutes between nominal measurements was much wider during the outages (defined as voltage less than 90V) than under normal circumstances. Under normal circumstances, there will always be a relatively small fraction of sensors that report out of tolerance values, either due to very local conditions or something to do with the sensor device itself. The fact that the event lasted approximately three days and there are very few outages of that duration show the effect of rotating outages.

Before the blackout, the average outage was 16 minutes compared to 10.8 hours during the rolling blackouts. Though there seem to be more events during the blackout, this is due to their being very few outages before the blackouts.

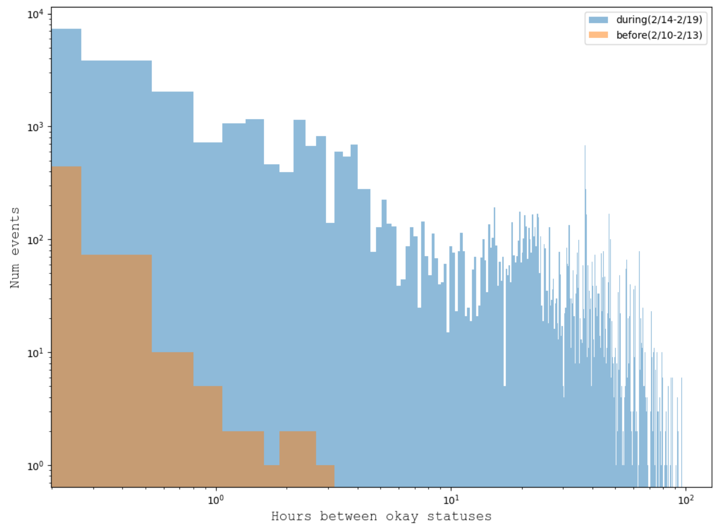


Figure 6. Time between outages (<10 minutes removed), by sensor.

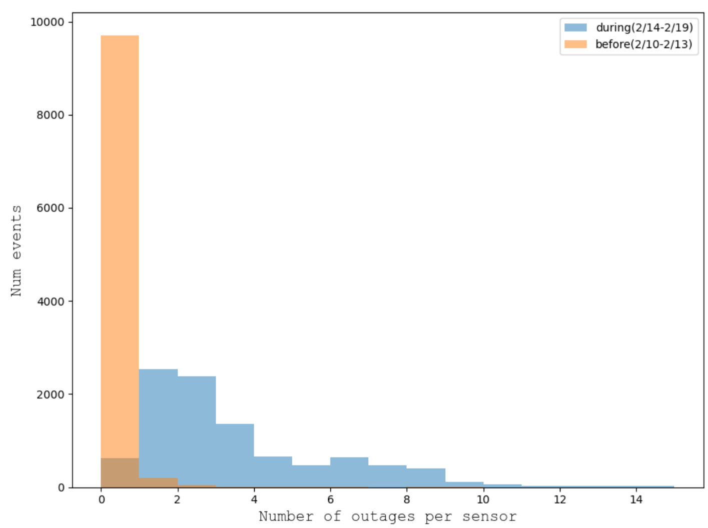


Figure 7. Number of outages over all sensors.

Figure 7 above shows the number of outages over all the sensors before (orange) and during (blue) the event. Before the outage there were an average of 0.05 outages per sensor and during the event there were an average of 3.4 outages per sensor.

2.7 Fraction of Time Power Out

In Figure 8 below we show the fraction of time the power was okay per USNG. The horizontal axis is fraction of time, and the vertical axis is fraction of sensors. Note that some USNG cells did not have any outages (the 1.0 bin), while almost as many cells were out about half of the time during the 4-day period 2/15-2/18, inclusive.

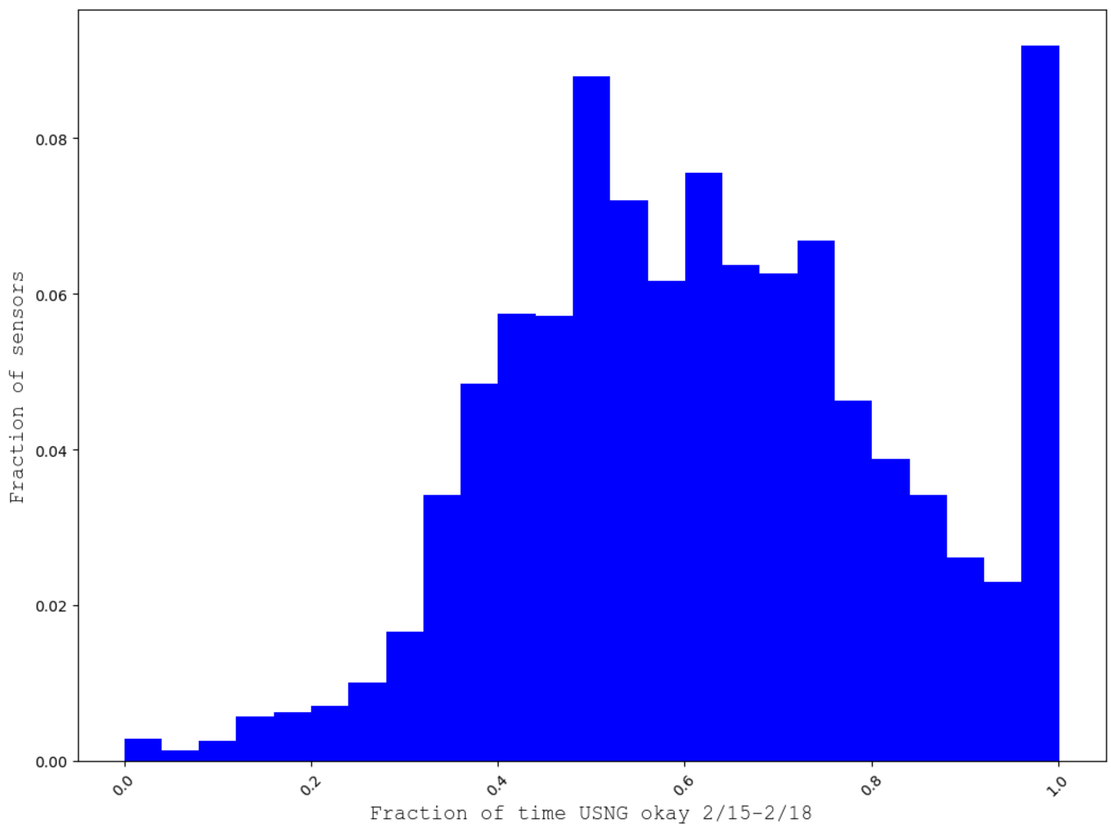


Figure 8. Fraction of time power okay by USNG from 2/15-2/18, inclusive.

2.8 Economic Impact

We now look at the economic impact of the outages by zip code and adjusted-gross-income (AGI) mostly based on IRS data from 2019. As seen in Table 1, the outages were divided across all income levels in proportion to their representation in the population, showing that this outage was very widespread and spared almost no one. This data was for Feb. 15 through Feb. 18, inclusive. A total of 4% of the sensors had no outages. Based on the economic demographics overlay of all the areas, we observed that the power outage behaved similarly across all the AGI demographics.

Table 1. Effect of Outages on Different AGIs

AGI	Fraction of population	Fraction of maximum outages	Fraction of all outages	Fraction of outages in 95th percentile outages	Fraction with no outages
<$25,000	.339	.344	.346	.357	.316
$25,000-$49,999	.226	.226	.226	.233	.213
$50,000-$74,999	.132	.131	.130	.128	.133
$75,000-$99,999	.082	.080	.080	.075	.086
$100,000-$199,999	.147	.143	.142	.153	.160
>$200,000	.078	.077	.076	.073	.093

Figure 2.9 below shows the distribution of areas with no outages and those in the 95th percentile of total outage time. There is some tendency for there to be clusters of no outages and very high outages.

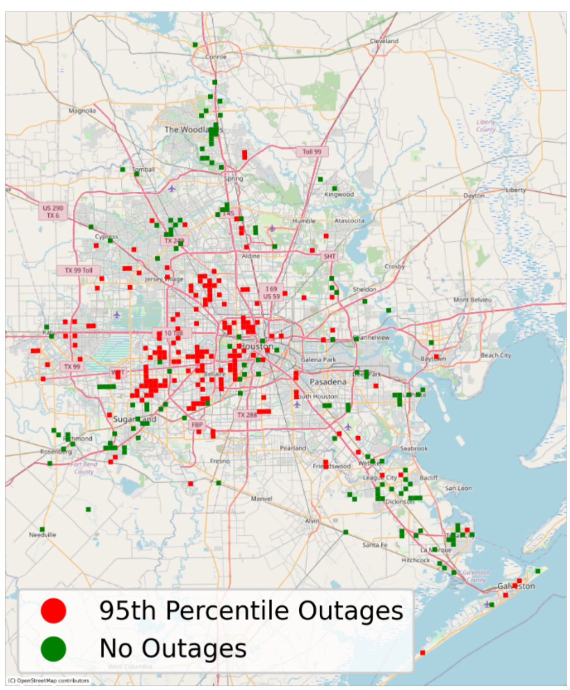


Figure 2.9. Locations of the areas with no outages and those in the 95th percentile of total outage time.

3. Discussion

The data presented show how widespread the blackout was and how quickly it took place and also how quickly power was restored once the restoration began. Some areas were barely affected while others were heavily affected illustrating the large divergence of outage durations. Heavily affected regions show which areas are most in need of upgrading for extreme weather events like the one experienced in mid-February in Texas.

4. Conclusion

Gridmetrics' PENS greatly increases the spatial and temporal reporting of outage data. Heretofore, large area outage data has typically been available based on utility-specific county-level reporting. As a result of PENS, the spatiotemporal resolution of outage reporting is dramatically increased, which presents many opportunities for exploring advantages and implementing improvements in grid outage reporting.