Photo by Dennis Schroeder, NREL 62227

Explained: Reliability of the Current Power Grid

Maintaining reliability of the bulk power system, which supplies and transmits electricity, is a critical priority of electric grid planners, operators, and regulators. Based on the standards set by power system reliability entities, the U.S. grid has been and continues to be very reliable. Over the past decade, the large majority of customer interruptions are due to outages of local distribution systems from events such as equipment failures or severe weather rather than shortages of electricity supply on the bulk power system. While there have been a few notable incidents in recent years of bulk power system outages due to loss of supply tied to extreme weather events, these still represent a small minority of total interruptions experienced by consumers across the country.

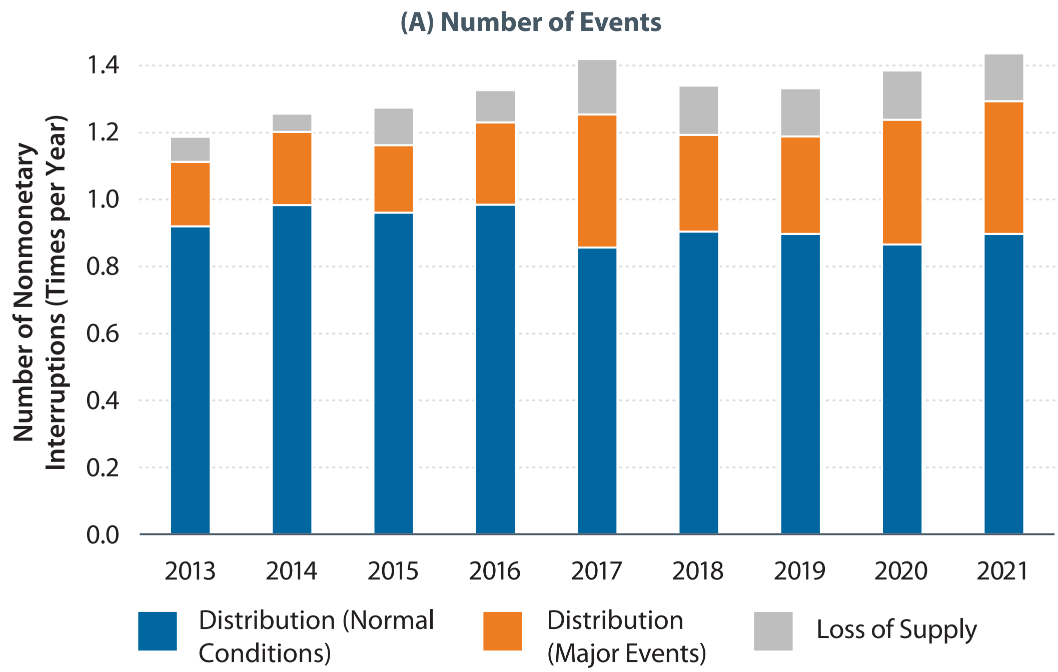
Overall Reliability Trends

Between 2013 and 2021 (the latest year for which data are available), the average U.S. customer experienced about 1.3 electric interruptions (or outages) per year (Figure 1, top), which lasted about 5 hours per year (Figure 1, bottom).[1] More than 90% of these interruptions were due to outages on the distribution system, which is the set of lower-voltage wires and systems that deliver electricity to homes and business. These outages are largely due to falling trees, fires, wildlife, and traffic accidents that result in downed wires and other damage either under "normal" conditions (shown in blue) or during "major events" such as severe storms (orange). The remainder of outages, which are shown in gray in the figure, are associated with a loss of electric supply, meaning failures of the bulk power system (including generation and transmission systems).[2]

The length of outages an average customer experiences varies significantly from year to year, from a total of about 3 hours in 2015 to 8 hours in 2017. Variation in yearly outage length is driven largely by extreme events, often due to longer restoration times after hurricanes and other events that occur over wide areas.

[1] Only "nonmomentary" outages are considered in these numbers. See U.S. Energy Information Administration (EIA), *Electric Power Annual 2021* (November 2022), https://www.eia.gov/electricity/annual/pdf/epa.pdf.

[2] Loss of supply could include failure of other equipment or processes.



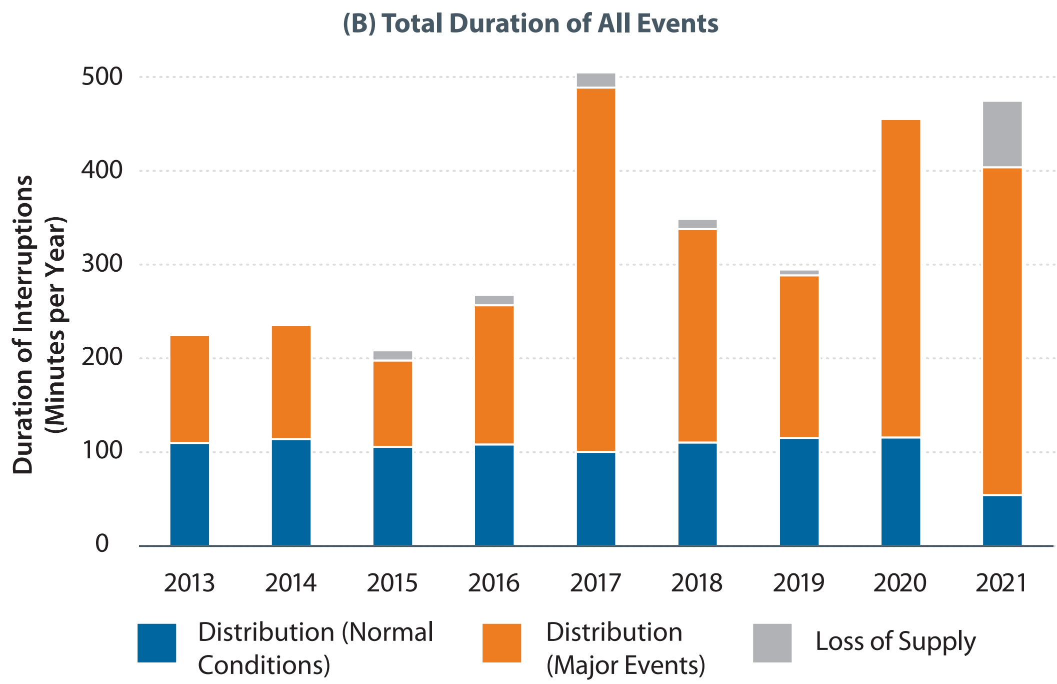


Figure 1. From 2013 through 2021, average number of interruptions (A) and total duration of interruptions (B) has occurred largely due to distribution system issues[3]

Distribution network reliability is largely driven by local conditions, including weather and vegetation near overhead power lines. Figure 2 shows regional variation in outage duration values, including consistently more outages in heavily forested places like Maine and in coastal states like South Carolina and Louisiana in years with severe weather or hurricanes.

[3] The definitions of "normal conditions" and "major events" are not uniform and are often established by individual utilities. For additional discussion, see "Table 11.1. Reliability Metrics of U.S. Distribution System" in EIA's *Electric Power Annual 2021* (November 2022), https://www.eia.gov/electricity/annual/pdf/epa.pdf and https://www.eia.gov/electricity/annual/html/epa_11_01.

Causes of Outages on the Bulk Power System

Interruptions due to lack of supply (failures of generation or transmission on the bulk power system) typically causes less than 5% of the total duration of all outage events.[4] This means the average U.S. customer has only experienced about 15 minutes of outages per year due to supply limitations of the bulk power system.

Figure 3 summarizes the total hours of the year in which grid operators anywhere in the United States had to shed load (creating local blackouts) due to a lack of supply. These cases are primarily driven by extreme weather events.[5]

In particular, extreme weather can greatly increase demand and at the same time cause power plant failures that are driven by extreme heat, freezing, wind, flooding, or other weather-related conditions.[6,7] A recent notable incident was the February 2021 cold winter event, which led to significant load shedding with serious societal and economic consequences. Extreme weather is projected to occur with even greater frequency in the future.[8]

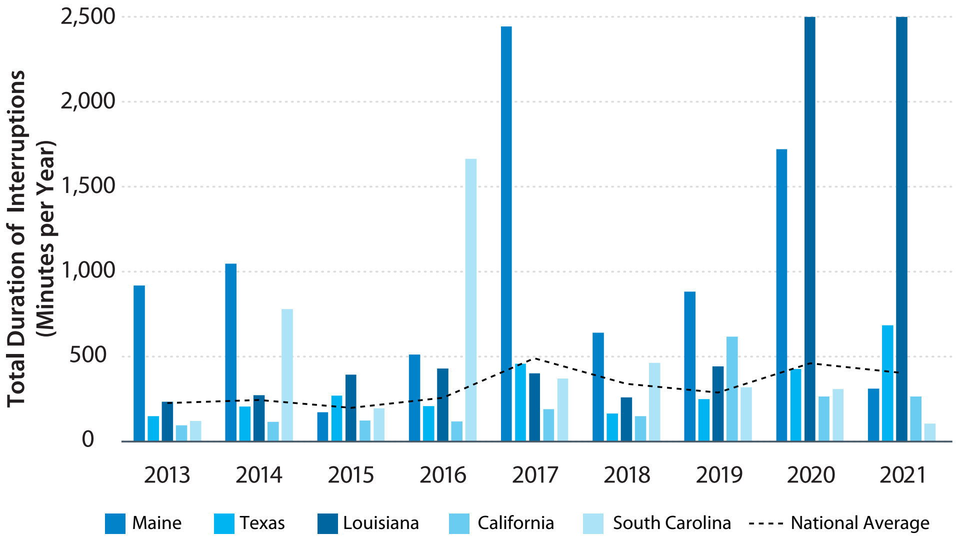


Figure 2. Example of regional interruption duration from 2013 to 2021 showing significant variation driven largely by local conditions and impact of severe storms

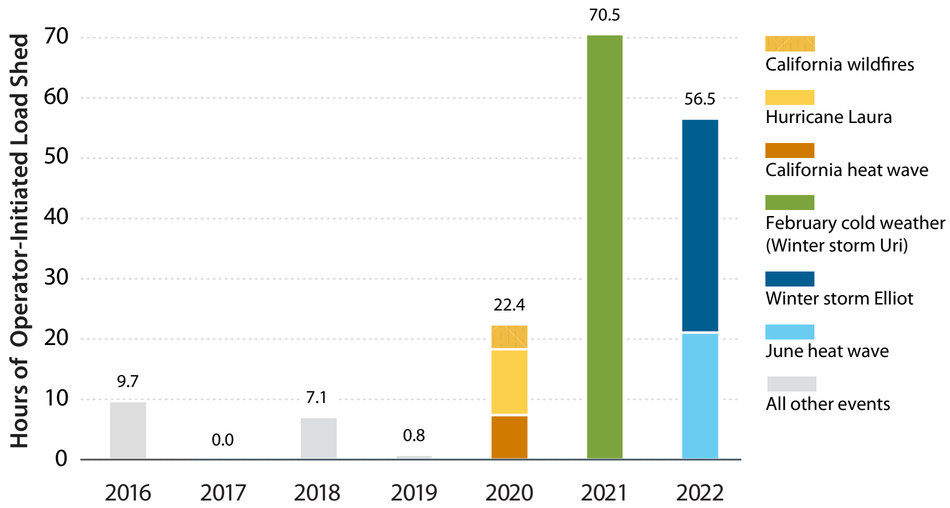


Figure 3. Reliability of the power system has been high, with loss of supply-related interruptions driven mostly by extreme weather events

Learn about causes of the recent major blackouts and what is being done in response by visiting www.nrel.gov/docs/fy24osti/87308. Learn about maintaining a reliable future grid with lots of wind and solar by visiting www.nrel.gov/docs/fy24osti/87298.

Want to learn even more? Take a deeper dive into grid reliability by visiting www.nrel.gov/docs/fy24osti/85880.

4 Eto, Joseph H., Kristina H. LaCommare, Heidemarie C. Caswell, and David Till. 2019. "Distribution System Versus Bulk Power System: Identifying the Source of Electric Service Interruptions in the US." *IET Generation, Transmission & Distribution* 13 (5): 717–723. https://doi.org/10.1049/iet-gtd.2018.6452.

5 NERC (North American Electric Reliability Corporation) 2023. *2023 State of Reliability Technical Assessment: Technical Assessment of 2022 Bulk Power System Performance*, https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2023_Technical_Assessment.pdf.

6 ESIG (Energy Systems Integration Group) 2021. *Redefining Resource Adequacy for Modern Power Systems.* Reston, VA: ESIG. https://www.esig.energy/resource-adequacy-for-modern-power-systems/.

7 Murphy, Sinnott, Luke Lavin, and Jay Apt. 2020. "Resource Adequacy Implications of Temperature-Dependent Electric Generator Availability." *Applied Energy* 262: 114424. https://doi.org/10.1016/j.apenergy.2019.114424.

8 (FERC) Federal Energy Regulatory Commission. "FERC Acts to Boost Grid Reliability Against Extreme Weather Conditions," June 16, 2022. https://elibrary.ferc.gov/eLibrary/filedownload?fileid=57afc1e8-d159-c747-97e1-816e84600000.

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