Policy and Data Needs for Increased Grid Reliability and Energy Equity

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Abstract

Identifying, sharing, and analyzing the right types of data are key to ensuring reliability and resilience of the electric grid and improving long-term reliability assessments. This is especially important in light of increasing occurrences of extreme weather, the changing mix of power generation and demands on the grid, and the need to ensure reliability and resilience in rural and disadvantaged communities. Currently, data are not consistently reported at a sufficiently granular level to provide necessary information for models of weather-dependent resources and loads, or to identify where disparities in reliability or resilience may exist on a city or community level. This paper describes policies that can enable the collection and sharing of these data to help ensure equitable reliability for all.

1. Introduction

Our nation's electrical grid is experiencing significant changes and uncertainties: (1) increasing loads from projected growth in manufacturing, data centers, and electrification of homes, businesses, and vehicles; (2) a changing mix of centralized and distributed generation resources; (3) an increasing number of severe weather events; and (4) aging infrastructure. As a result, we need to identify ways to collect and share more data that will enable utilities, grid operators, and customers to model, monitor, and maintain reliability and resilience in the face of these growing changes and uncertainties. Outages currently cost the U.S. economy approximately $150 billion each year (Joint Economic Committee, 2024). Data to quantify where, when, and why these outages occur will enable more efficient and equitable solutions. Two forms of data are addressed in this paper: (1) energy-related weather data and (2) distribution-level reliability data.

Energy-related weather data includes solar irradiance, wind speed, temperatures, precipitation, and other weather data that can impact weather-dependent resources, such as solar photovoltaics, concentrated solar power, and wind turbines. Solar and wind power have become the fastest-growing generation resources on the U.S. grid. The U.S. Energy Information Administration (EIA) forecasts that solar and wind generation will grow 75% and 11%, respectively, from 2023 to 2025 (U.S. EIA, 2024). In 2023, renewable sources from solar, wind, hydro, biomass, and geothermal accounted for 22% of total generation in the U.S., surpassing nuclear generation for the first time in 2021 and coal generation for the first time in 2022. Increasing contributions from these weather-dependent, variable resources require more granular data to improve both real-time grid operations and longer-term reliability planning.

Distribution-level reliability data includes information regarding the duration and frequency of customer outages typically caused by severe weather or animals that cause faults or downed power lines. Eto et al. (2019) and Lawson (2022) found that more than 90% of outages on the grid were caused by the distribution system, as opposed to the bulk power system, which comprises power generation and transmission systems. In addition, increasing amounts of distributed (and sometimes bi-directional) energy resources and loads, such as solar panels, battery storage systems, and electric

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vehicles, are being added to the grid. While distribution-level reliability data is currently collected by the EIA, the frequency, duration, and recovery times of outages are currently averaged and reported at an entire utility level (U.S. EIA, 2023). Identifying ways to collect and share more granular distribution-level reliability data could help increase reliability, resilience, and energy equity on a city or community level.

2. Data Needs

2.1. Energy-Related Weather Data

2.1.1. Existing Weather Data and Use

Models of solar energy, wind energy, and other weather-dependent electric generation resources and loads require meteorological data such as solar irradiance, wind speed, and temperature. Utilities, public utility commissions, regional transmission organizations (RTOs), and independent system operators (ISOs) use these data in resource-adequacy models. These models aim to ensure that electric loads throughout the year can be met by a portfolio of generation resources (e.g., gas-fired turbines, wind turbines, solar farms) with consideration of expected electrical loads in future years.

However, many models and available data sets are based on historical weather data. Climate change and greater frequency of extreme weather events increases the uncertainty in these data and models. Improved modeling methods, such as probabilistic modeling, that can accommodate these uncertainties have been recommended by the North American Electric Reliability Commission (NERC, 2016), industry (EPRI, 2022), academia (Gao and Gorinevsky, 2020), and national labs (Ho et al., 2023).

Although various energy-related weather datasets exist that can be used in these models, they are disparate and decentralized. Also, the type of data, spatial and temporal frequency of the data, and amount of data available varies by source. Below is a sampling of existing energy-related weather databases:

- National Solar Radiation Database (NSRDB): The NSRDB is managed by the National Renewable Energy Laboratory. The NSRDB contains hourly and sub-hourly values of meteorological data for the United States and a subset of international locations, including solar radiation (global horizontal, direct normal, and diffuse horizontal irradiance).

- Wind Data Hub: The Wind Data Hub is managed by the Pacific Northwest National Laboratory and provides modeled and observational wind data from remote sensing systems and in-situ measurements of meteorological variables.

- Open Energy Data Initiative (OEDI): The OEDI is managed by the U.S. Department of Energy (DOE) and provides datasets uploaded from researchers working for DOE programs, offices, and national laboratories. It provides

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access to data resulting from specific projects across the broad spectrum of energy programs and projects funded by DOE.

- U.S. Energy Atlas: The U.S. Energy Atlas is managed by the DOE Energy Information Administration and provides data and interactive maps of energy infrastructure and resources in the United States.

- NCAR Data for Climate and Weather Research: The National Science Foundation (NSF) National Center for Atmospheric Research (NCAR) manages the Research Data Archive, which contains a collection of meteorological and oceanographic data, as well as model outputs from NCAR's Computational and Information Systems Lab.

- NASA's LANCE and FIRMS Databases: The National Aeronautics and Space Administration (NASA) manages the LANCE and FIRMS databases. The Land, Atmosphere Near real-time Capability for Earth observations (LANCE) website provides near real-time data and satellite imagery for monitoring natural and human-made phenomena. The Fire Information for Resource Management System (FIRMS) provides near real-time fire data from satellites that can be used to analyze potential impacts on solar irradiance and solar-energy resources.

2.1.2. Weather Data Needs

To improve models of weather-dependent resources and loads, the energy-related weather data should span long periods (~30 years), be sampled frequently (at least every hour) and contiguously, include a wide range of available meteorological data, span numerous regions (preferably in a gridded fashion) across the United States, and enable modeling of future impacts of climate change and extreme weather on weather-dependent energy resources and loads (ESIG, 2023). Very few current datasets meet these criteria. In addition, DOE should serve as a centralized clearinghouse for these data. A central portal that provides access to vetted and secure data specifically for resource-adequacy modeling and long-term electric-reliability planning would greatly benefit the modeling community.

2.2. Distribution-Level Reliability Data

2.2.1. Existing Reliability Data and Use

The IEEE 1366 Standards provide distribution-system reliability metrics that are widely used and reported by utilities (IEEE, 2022). Some examples of these reliability metrics include the following:

- **Customer Average Interruption Duration Index (CAIDI)**: A metric that indicates the average time required to restore service to a customer after a sustained interruption lasting more than five minutes

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- **System Average Interruption Frequency Index (SAIFI)**: A metric that indicates how often the average customer experiences a sustained interruption lasting more than five minutes over a predefined period of time

Although these distribution reliability metrics are required to be reported by larger utilities via EIA form 861, the data are averaged over the entire utility, which can span large regions. This makes it difficult to identify trends in reliability or resilience at the city or community level.

2.2.2. Reliability Data Needs

The California Public Utilities Commission Energy Division presented an overview of electric system reliability and several recommendations (Enis, 2021). They stated that more granular reliability data "can show where recurring issues are happening and areas where the greatest improvement is needed" and also "how widely the metrics vary over entire service territories."[1] The CPUC recommends future improvements that include increased data granularity and "determining possible equity impacts of unreliable service." They also recommend improvements to the "usability of data presented in annual reports."

Fig. 1 shows a plot of two reliability metrics, CAIDI and SAIFI, reported by the Public Service Company of New Mexico, from 2013 to 2022. CAIDI and SAIFI represent the average duration and number of customer outages per year. The average number of outages has been fairly consistent at approximately one sustained interruption (lasting more than five minutes) per year. However, the duration of the average customer outage appears to be trending upward since 2017. Fig. 2 shows the spatial variability in CAIDI and SAIFI reported in 2022 from four service providers in New Mexico. These service providers include three investor-owned utilities (Public Service Company of New Mexico, Southwestern Public Service Company, and El Paso Electric Company) and the Western Area Power Administration (WAPA), which provides federal hydropower to various state and federal agencies, municipalities, Native American tribes, and rural electrical cooperatives. The "heat maps" of CAIDI and SAIFI shown in Fig. 2 illustrate the potential spatial variability of reliability metrics across New Mexico. However, because these reliability data are reported as average values over an entire utility, it is difficult to identify if disparities exist and where improvements are needed at a city or community level.

[1] Oak Ridge National Laboratory manages the Outage Data Initiative Nationwide (ODIN) website, which provided real-time outage information provided on a voluntary basis by utilities across the United States. However, temporal and spatial trends in reliability are not tracked to inform where improvements are needed.

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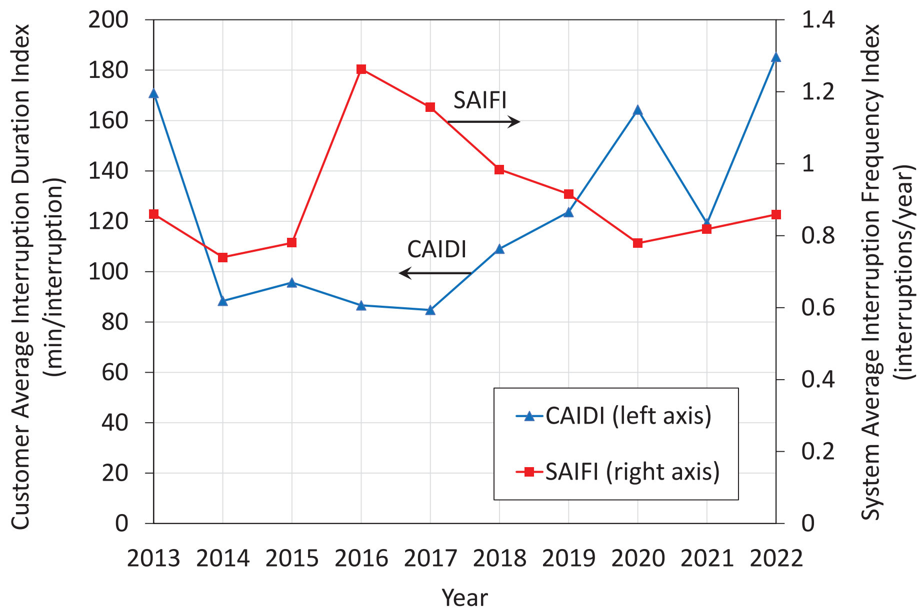

Fig. 1. Plot of CAIDI and SAIFI reliability metrics reported by the Public Service Company of New Mexico from 2013 to 2022 (from data reported to U.S. EIA, 2023)

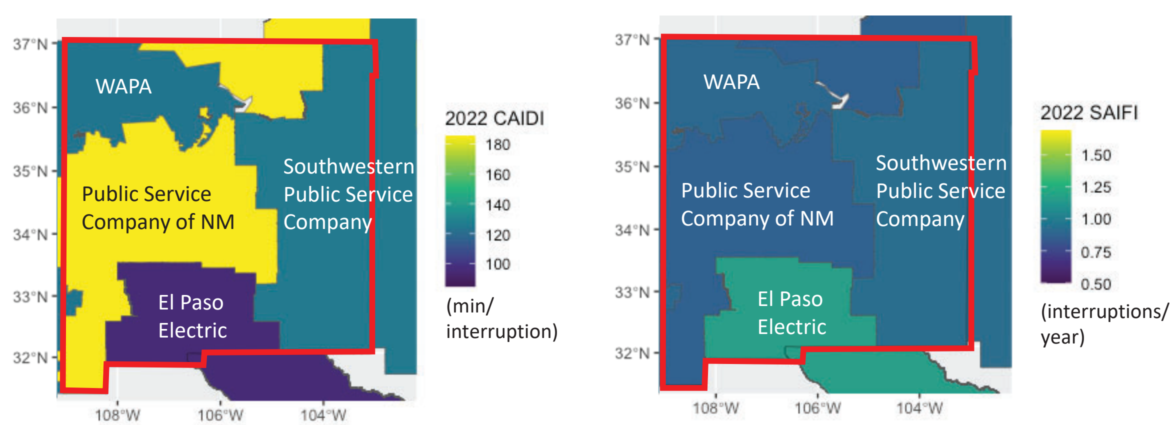

Fig. 2. Approximate regions depicting 2022 CAIDI and SAIFI reliability metrics reported in New Mexico (Note: WAPA provides electricity to several electric cooperatives in NM). (from data reported to U.S. EIA, 2023)

3. Other Policy Needs

In addition to the need for more granular weather and distribution-level reliability data, improvements are also needed to expand and improve our transmission infrastructure and to increase accountability for grid reliability.

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Regarding transmission expansion and improvements to alleviate the growing congestion and interconnection queues on the U.S. grid, three barriers are often cited: (1) planning, (2) paying, and (3) permitting (Gramlich, 2019).

Planning for new transmission lines and upgrades needs to focus on longer-term requirements (>10 – 15 years) with consideration of increasing weather impacts on generation resources and loads on the grid. Interregional transmission planning also needs to be coordinated among multiple states, as required by Federal Energy Regulatory Commission (FERC) Order No. 1000 (FERC, 2011), to help alleviate local power shortages. Two Congressional Research Service (CRS) reports provide a summary of issues, federal policies and legislation aimed at addressing shortcomings in transmission planning and siting (Lawson, 2023; Lawson, 2024).

Paying for large transmission infrastructure and improvements, or cost allocation, can be contentious if customers need to pay for projects that do not directly benefit them. FERC Order No. 1000 establishes cost allocation that follows the "cost causation" principle of electricity ratemaking, which requires that beneficiaries of a grid asset pay for the costs (FERC, 2011). This requires a determination of who benefits from a transmission line or upgrades and what the share of costs should be to each beneficiary. A FERC Notice of Proposed Rulemaking also addressed cost allocation for transmission infrastructure (FERC, 2022). Federal policies and legislation that address transmission cost allocation have been summarized by CRS (Lawson, 2024).

Permitting for large, interstate transmission requires approvals from multiple states and local governments along the path of the transmission line. This process can be long and arduous, and recommendations to streamline the process and provide federal authorities for projects serving the national interest have been proposed by Congress (Lawson, 2024).

In addition to planning, paying, and permitting for transmission improvements, there is a need to ensure that innovations that can improve capacity and efficiencies on the grid are incentivized for adoption. These grid-enhancing technologies include dynamic line ratings, advanced transmission conductors, power flow controls, and topology optimization (U.S. DOE, 2022). Other innovations at various stages of deployment that can increase the reliability and resilience of the grid include distributed energy resources and storage systems (including electric vehicles), artificial intelligence for grid operations and planning, and virtual power plants. Policies that appropriately monetize and incentivize these technologies and their integration on the grid will also help to increase electric reliability and resilience for both bulk-power and distribution systems.

Finally, policies to enhance accountability for grid reliability are needed, especially in deregulated markets. Angwin (2020) notes that there is a general lack of accountability for grid reliability in deregulated markets run by RTOs and ISOs due to the diversified nature of electricity generation, transmission, and distribution in those markets. "Pay for performance" or performance-based regulation have been implemented in a number of states to improve utility performance by changing the way they make money. However,

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national standards for ensuring accountability and payments based on grid reliability are lacking. Some challenges include the following:

- Different electricity requirements and resources that will necessitate location-specific features of performance-based regulations

Diversity of owners and operators of electricity generation, transmission, and distribution systems, especially in RTO areas, and the different authorities of regulated and deregulated markets

Providing accountability in this multifaceted and diverse ecosystem, both at the federal and state levels, can pose significant challenges. However, general approaches for performance-based regulation and ratemaking based on best practices are needed to provide accountability for grid reliability and resilience.

4. Conclusions

The U.S. electric grid is facing challenges with increased frequency of extreme weather, uncertainty associated with weather-dependent resources and loads, and aging infrastructure. These factors can impact the reliability and resilience of the grid. This paper has identified and recommended the following needs to address these challenges:

- A centralized repository or portal for weather data required for models of weather-dependent electric generation resources and loads
- More granular distribution-level electric reliability data that can be used to identify where improvements are needed at the city or community level
- Policies that enable or incentivize necessary transmission expansions, upgrades, and other innovative technologies that improve reliability, resilience, and efficiency of the grid
- Policies that ensure accountability of grid reliability and resilience through performance-based regulation and ratemaking

Conflict of Interest

No financial conflicts of interest.

The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the Senate or Committee offices to which the authors belong.

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