

## Overview of New Jersey Power Outages: Risks to the New Jersey Grid

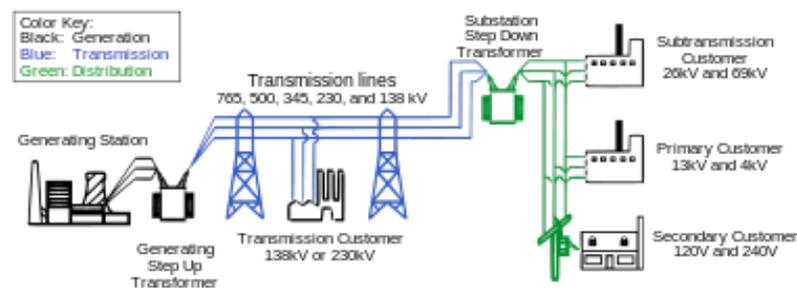
March 6, 2014

The Staff of the New Jersey Board of Public Utilities has asked the Center for Energy, Economic and Environmental Policy (CEEEP)<sup>1</sup> to assess the vulnerability of New Jersey to electric power outages. This assessment is a challenging and critical task. Power outages may be described by their frequency, duration and magnitude. They can have a range of initiating events such as severe weather, human causes (physical threats, cyber security, human error, and high electricity demand) and equipment failures<sup>2</sup>. This report provides an overview of the electric power system and reliability, identifies the types of initiating events that might lead to large-scale power outages, and presents a database of New Jersey weather related power outages that begins to categorize their frequency, magnitude, and duration.

There are real and significant threats to New Jersey and the nation's power systems including, but not limited to, severe weather. Historical records can provide information about the frequency, magnitude and duration of blackouts and other major power outages but do not account for emerging and increasing threats such as changing climate, physical attacks, and cybersecurity.

### I. Overview of Electric Power System and Reliability

The electric power system consists of four major components: generation, transmission, distribution, and electric load (customers). The *bulk power system* consists of generation and transmission. Distinguishing between the bulk power (sub) system and the distribution (sub) system is important because the causes and consequences of electric power outages depend on which part of the entire power system (bulk and distribution) is being affected. Figure 1 is a simplified diagram of the electric power system.



Reference: US Department of Energy.

<sup>1</sup> CEEEP is part of the Edward Bloustein School of Planning and Public Policy, Rutgers, The State University of New Jersey.

<sup>2</sup> See P. Hines, J. Apt, and S. Talukdar, "Trends in the History of Large Blackouts in the United States," IEEE Power and Energy Society General Meeting, 2008 and F. Felder, "Incorporating Resource Dynamics to Determine Generation Adequacy Levels in Restructured Bulk Power Systems," *KIEE International Transactions on Power Engineering*, Vol. 4-A, No. 2, June 2004, pp. 100-105.

### Figure 1: Simplified Diagram of the Electric Power System

New Jersey is part of the PJM Interconnection bulk power system. PJM operates and plans the bulk power system as well as administers wholesale electricity markets. See Figure 2 for a map of PJM.

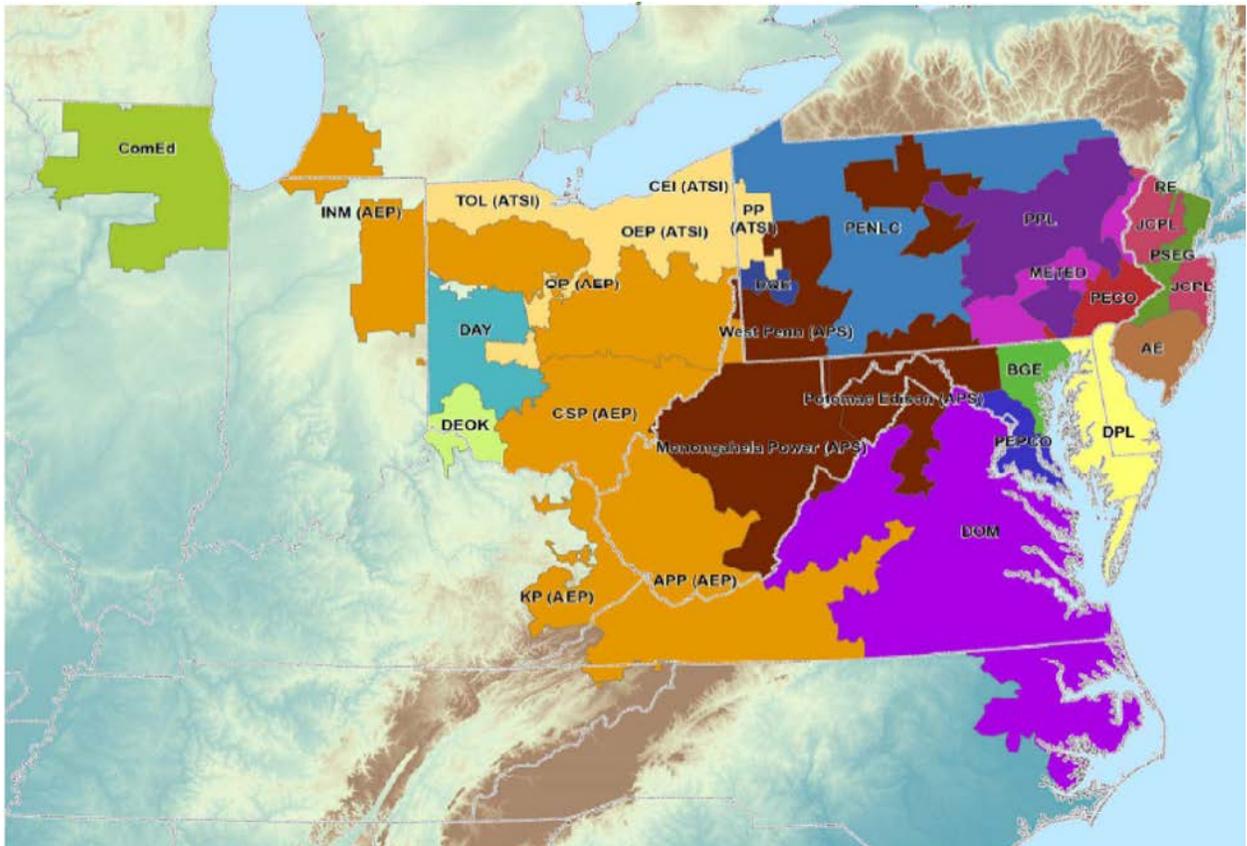


Figure 2: Map of the PJM Bulk Power System

The North American Electric Reliability Corporation (NERC) is the non-profit entity whose mandate is to ensure the reliability of the bulk power system. NERC defines “a reliable bulk power system as one that is able to meet the electricity needs of end-use customers even when unexpected equipment failures or other factors reduce the amount of available electricity<sup>3</sup>.” At the bulk power level, reliability is divided into two components: adequacy and security<sup>4</sup>.

<sup>3</sup> NERC, Frequently Asked Questions, November 2012, available at [http://www.nerc.com/AboutNERC/Documents/FAQs\\_DEC12.pdf](http://www.nerc.com/AboutNERC/Documents/FAQs_DEC12.pdf)

<sup>4</sup> See F. Felder, “‘An Island of Technicality in a Sea of Discretion’: A Critique of Existing Electric Power Systems Reliability Analysis and Policy”, *The Electricity Journal*, Volume 14, Number 3, April 2001, pp. 21-31 for a critique of reliability policy.

As per NERC *adequacy* refers to whether the bulk power system has enough generation and transmission to meet electricity demand. The adequacy standard in the United States is that the bulk power system should be planned so that the probability of demand exceeding supply should not exceed one time every ten years. This adequacy standard translates into an installed reserve margin of having more generation that can be delivered to the distribution systems than peak demand. That reserve margin is approximately 15% for PJM.

This one-in-ten-year-adequacy is a planning standard; operational measures are also in place to avoid (if possible) and to limit (if necessary) the amount of electrical load that is disconnected when demand exceeds supply. If load is disconnected in this situation, it is done so in a controlled and planned manner in order to prevent a large-scale blackout. Sometimes this situation is referred to as *rolling blackouts*.

*Security* refers to the ability of the bulk power system to continue to operate and serve electrical load even when the bulk power system experiences unexpected disturbances such as major equipment failure including those caused by man-made physical or cyber-attacks<sup>5</sup>. The bulk power system is operated at a minimum so that if any single component fails, there is no interruption of load. Sometimes, multiple component failures occur within a short period of time and large-scale blackouts result. In these situations, the disconnection of load is not planned and controlled. Instead, there are cascading outages of transmission and generation equipment resulting in what would be colloquially called a blackout. A recent bulk power-system blackout that affected New Jersey (and elsewhere) occurred on August 14, 2003.

Generally, bulk power system initiated blackouts are rare but large; distribution related interruptions are more frequent but generally affect many fewer customers than bulk power-system blackouts. The one exception is severe weather initiated events, for example hurricanes, Nor'easters and ice storms, which have disrupted electricity service for millions of customers for many days or even several weeks. Reliability policies and metrics at the distribution level differ from those at the bulk power level. Whereas the Federal government through the Federal Energy Regulatory Commission (FERC) mandates reliability rules and policies based upon NERC's standards, individual states via their public utility commissions write regulations, monitor performance, and conduct distribution reliability rules and enforcement.

Unfortunately, there is not one comprehensive database that records both at the bulk and distribution levels the cause or causes of an outage, its duration, and magnitude. Instead, as discussed in Section II, it is necessary to try to integrate various databases to arrive at incomplete and uncertain estimates of the frequency, magnitude and duration of electric customer outages.

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<sup>5</sup> NERC, Frequently Asked Questions, November 2012.

## II. Weather Initiated Power Outages in New Jersey

### A. Historical Weather Related Power Outages

The link between severe weather and electric power outages is undeniable. The Executive Office of the President found the following:

Severe weather is the number one cause of power outages in the United States and costs the economy billions of dollars a year in lost output and wages, spoiled inventory, delayed production, inconvenience and damage to grid infrastructure. Moreover, the aging nature of the grid – much of which was constructed over a period of more than one hundred years – has made Americans more susceptible to outages caused by severe weather. Between 2003 and 2012, roughly 679 power outages, each affecting at least 50,000 customers, occurred due to weather events.”<sup>6</sup>

This section presents the effort to catalog weather events in New Jersey and collect the number of customer power outages associated with each event.<sup>7</sup> This effort was limited by having a relatively brief history of recorded weather, absence of a cohesive source for reported weather events, and inconsistent reporting of associated power outages.

A 2012 national level report, *Weather-Related Power Outages and Electric System Resiliency*, prepared by Richard J. Campbell for the Congressional Research Service provided guidance for the beginning steps of this analysis<sup>8</sup>. Another important reference was a 2009 study, *Trends in the History of Large Blackouts in the United States*, which proved to be instrumental in the way we approached analyzing the collected data<sup>9</sup>.

Historical weather data (date of storm, highest recorded wind gusts/sustained wind speeds, amount of precipitation, number of customer power outages, and span of outage until power restoration) was collected using the National Oceanic and Atmospheric Administration’s (NOAA) National Climatic Data Center webpage, the Bayshore Regional Storm Events webpage, and the NOAA Miami Regional Library *Monthly Weather Review*. The NOAA’s “Storm Events Database<sup>10</sup>” provides detailed information for up to year 1996. The Bayshore Regional Watershed Council web resource of “notable NJ storms” was used to complement the

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<sup>6</sup> Executive Office of the President, *Economic Benefits of Increasing Electric Grid Resilience to Weather Outages*, August 2013, p. 4 referencing the Department of Energy, “U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather,” July 2013.

<sup>7</sup> Accompanying this report is a presentation that provides more detailed information on the relationship between historical weather events and power outages in New Jersey.

<sup>8</sup> Richard J. Campbell, *Weather-Related Power Outages and Electric System Resiliency*, Congressional Research Service, 1-15, August 28 2012, <http://www.fas.org/sgp/crs/misc/R42696.pdf>.

<sup>9</sup> P. Hines and S. Talukdar. *Trends in the History of Large Blackouts in the United States*. Energy Policy v. 37, pp. 5249-5259, 2009, [http://www.uvm.edu/~phines/publications/2008/Hines\\_2008\\_blackouts.pdf](http://www.uvm.edu/~phines/publications/2008/Hines_2008_blackouts.pdf).

<sup>10</sup> National Oceanic and Atmospheric Administration Storm Events Database.

<http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=34%2CNEW+JERSEY>

NOAA resource for years 1985 through 1996<sup>11</sup>. The NOAA Miami Regional Library’s *Monthly Weather Review* was used to complement these other sources. There is very scarce information available for years prior to 1985. Availability of public data increased after 1985, the year that the devastating storm Hurricane Gloria occurred.

This comprehensive dataset was then narrowed down and outages were grouped into three categories using the following definitions:

1. All of the outages reported are sustained outages.
2. Events collected were 1,000 or more outages per a weather event.
3. “Major” events are defined as 100,000 or more outages per a weather event.

Richard Campbell characterizes sustained outages as “sustained duration outages lasting longer than five minutes (and extending to hours or days)”<sup>12</sup>. The compiled storm events history database was coded by the type of storm event reported – storms were either classified by NOAA, or details provided through other electronic sources gave a narrative perspective of each storm which generally included indicators such as wind speeds, precipitation type, as well as other factors. From the coded data, events were totaled, along with the total number of customers that were reported to have lost power for that event type.

Overall, one hundred and forty three (143) events composed our database ranging from 1985 to June 2013. Table 1 summarizes collected data for these events.

**Table 1: Summary of weather events resulting in power outages (1985 – 2013)**

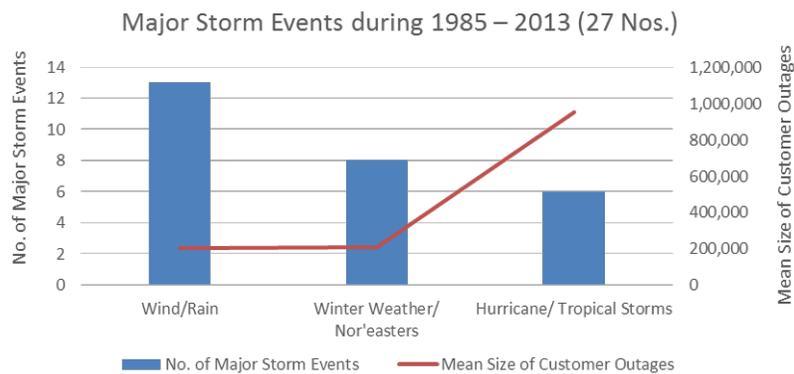
	<b># of Total Events</b>	<b># of Cumulative Affected Customers’ Meters</b>	<b>% of reported events</b>	<b>Mean size of customer meter outages</b>
<b>Wind/Rain</b>	96	4,430,900	67.1	46,155
<b>Winter Weather/Nor’easters</b>	22	2,018,200	15.4	91,736
<b>Ice Storm</b>	5	95,500	3.5	19,100
<b>Tornado</b>	2	121,000	1.4	60,500
<b>Lightning</b>	9	175,800	6.3	19,533
<b>Hurricane/Tropical Storm</b>	9	5,768,500	6.3	640,944
<b>Totals</b>	<b>143</b>	<b>12,609,900</b>		

*Note: The electric power industry defines outages by meter and not by the number of people affected.*

<sup>11</sup> The group that put together this resource is a volunteer advocacy organization dedicated to the restoration and conservation of Raritan & Sandy Hook Bays.

<sup>12</sup> Richard J. Campbell, *Weather-Related Power Outages and Electric System Resiliency*, p. 30.

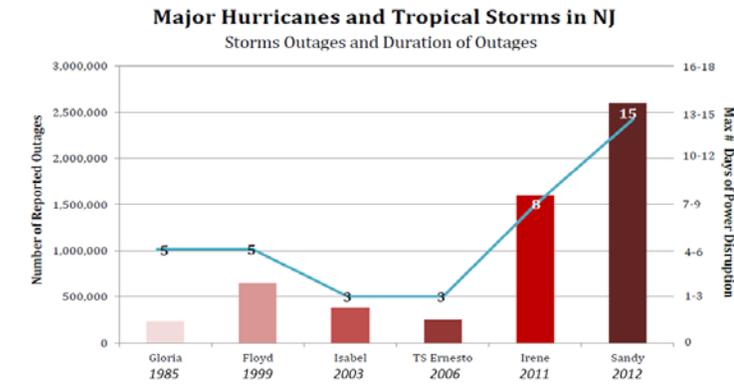
Of the total 143 events in the database, 27 different coded events were classified as “major”. By classifying these outages according to the magnitude of customers that lost power, the types of storms that most affected electrical distribution and when they occurred could be identified. Despite accounting for only a relatively small percentage of the types of weather-related events that have caused power outages in the state since 1985, hurricanes and tropical storms show a considerable number of mean customer outages (as seen in Figure 3).



**Figure 3: Classification of Major Storms in NJ and the mean size of outages (1985 – 2013)**

Although the number of reported hurricanes and tropical storms major events is less as compared to that for wind/rain related major events (6 and 13 respectively during 1985 to 2013), the mean size of customer outages in case of hurricane and tropical storms is much higher than that observed for wind/rain related major events (953,083 and 201,679 respectively).

Using data retrieved from the Bayshore Regional Watershed Council online resource entitled “List of New Jersey's Most Notable Storms” coupled with other sources, a total of 36 hurricanes and tropical storms have been identified since 1985 that affected New Jersey in various capacities – as remnants of the storm to high levels of precipitation and winds. This translates to an average of 1.3 hurricanes or tropical storms per year over that span of time. While some of these 36 hurricanes/tropical storms reported minor electricity distribution impact, including little to no major power loss to customers, the database included 9 total with reported power outages at 1000 or more, and classified 6 as “major” with over 100,000 outages (many of the 6 exceeding this number). The below chart presents these 6 major events and their corresponding number of reported outages and the maximum days of power disruption observed.



**Figure 4: Reported major hurricanes/ tropical storms in NJ (1985 – 2013)**

Thus, “major” hurricanes/tropical storms average at .21 per year over the 28-year span of 1985-2013, or averaging about one “major” hurricane every five years. These storms were: Hurricane Gloria, Hurricane Floyd, Hurricane Isabel, remnants of Tropical Storm Ernesto and a large high pressure system over eastern Canada, Hurricane Irene, and Hurricane Sandy. These 6 major storms accounted for an estimated total of 5,717,800 reported outages over the course of 1985-2013, averaging to 952,966 per storm. For these 6 “major” hurricanes/tropical storms, the duration for sustained outages was recorded from various sources, including press reports. Data on the duration of outages was less consistent than the number of reported outages, for all storms, which made it difficult to make any concrete assessment.

Overall, the database creation was ultimately limited by the amount of readily available historical data for NJ weather events. While the NOAA reporting database proved crucial, its time frame was much smaller than desired. In complementing this resource with other archived data, the span of the database was increased back to 1985 for a total of 28 years to the present. The database does provide a perspective of a general frequency of events, with “major” hurricane/tropical storms averaging at one per five years, according to our data. The true merits of compiling the data, however, may be found in that the raw data shows the power and effect of hurricanes and tropical storms on electrical infrastructure in New Jersey. The sheer number of outages for these coded storms was far beyond that of others (wind/rain, ice, winter weather, etc.), even if only for the past few decades.

## **B. Future Severe Weather Initiated Power Outages**

The frequency and intensity of future severe weather events may be different than historical<sup>13</sup>. The U.S. Department of Energy<sup>14</sup> concludes the following with respect to the electric power system relevant to New Jersey:

1. “Thermoelectric power generation facilities are at risk from decreasing water availability and increasing ambient air and water temperatures, which reduce the efficiency of cooling, increase the likelihood of exceeding water thermal intakes or effluent limits that protect local ecology, and increase the risk of partial or full shutdowns of generation facilities”;
2. “Energy infrastructure located along the coast is at risk from sea level rise, increasing intensity of storms, and higher storm surge and flooding, potentially disrupting oil and gas production, refining and distribution, as well as electricity generation and distribution”;
3. “Electricity transmission and distribution systems carry less current and operate less efficiently when ambient air temperatures are higher, and they may face increasing risks of physical damage from more intense and frequent storm events or wildfires”;
4. “Increasing temperatures will likely increase electricity demand for cooling and decrease fuel oil and natural gas demand for heating.”

The report notes that some effects are projected to vary by region and that compounding factors may create additional challenges not only within and across energy sector but for other sectors as well (p. I and p. 5).

### **III. Man-Made Initiated Power Outages**

There are many categories of man-made initiating events that may lead to blackouts. These categories are (with the percentages of that each cause led to a blackout in the United States between 1984 and 2006): intentional attack (1.6%), supply shortages (5.3%), equipment failure (29.7%), operator error (10.1%), voltage reductions (7.7%), and volunteer reductions (5.9%).<sup>15</sup>

Some categories of these events are relatively new and emerging threats to power systems such as terrorism, physical attacks and cyber security threats and are more difficult to anticipate and

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<sup>13</sup> See U.S. Department of Energy, *U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather*, July 2013 and Chandramowli and F. Felder, “Impact of Climate Change on Electricity Systems - A Review of Models and Forecasts,” *Sustainable Energy Technologies and Assessments*, Vol. 5, March 2014, pp. 62-74 for a discussion of how climate change may affect the electric power system.

<sup>14</sup> U.S. Department of Energy, 2013, p. i.

<sup>15</sup> Hines et al (2008).

address than traditional threats to the electric grid such as extreme weather.<sup>16</sup> For instance, a report by the Idaho National Laboratory concluded:

Cybersecurity for energy delivery systems has emerged as one of the Nation's most serious grid modernization and infrastructure protection issues. Cyber adversaries are becoming increasingly targeted, sophisticated, and better financed.<sup>17</sup>

A report by the Bipartisan Policy Center stated:

Protecting the nation's electricity grid from cyber attacks is a critical national security issue. Evidence collected by the U.S. Department of Homeland Security (DHS) suggests that cyber attacks on key energy infrastructure – and on the electricity system in particular – are increasing, both in frequency and sophistication. These trends are alarming because the potential consequences of a successful large-scale cyber attack – Or combined cyber and physical attack – on the electric power sector are difficult to overstate.<sup>18</sup>

A recent report by congressional staff concluded:

The last few years have seen the threat of a crippling cyber-attack against the U.S. electric grid increase significantly. Secretary of Defense Leon Panetta identified a 'cyber-attack perpetrated by nation states or extremist groups' as capable of being 'as destructive as the terrorist attack on 9/11.' A five-year old National Academy of Sciences report declassified and released in November 2012 found that physical damage by terrorist to large transformers could disrupt power to large regions of the country and could take months to repair, and that 'such an attack could be carried out by knowledgeable attackers with little risk of detection or interdiction.'<sup>19</sup>

#### **IV. Conclusion**

There are real and significant threats to New Jersey and the nation's power systems. Historical records can provide important information about the frequency, magnitude and duration of blackouts and other major power outages but do not account for emerging and increasing threats such as changing climate, physical attacks, and cybersecurity.

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<sup>16</sup> Bipartisan Policy Centers, "Cybersecurity and the North American Electric Grid: New Policy Approaches to Address an Evolving Threat," February 2014, p. 9.

<sup>17</sup> Idaho National Laboratory, *Vulnerability Analysis of Energy Delivery Control Systems*, September 2011, p. iii.

<sup>18</sup> Bipartisan Policy Centers, "Cybersecurity and the North American Electric Grid: New Policy Approaches to Address an Evolving Threat," February 2014, p. 9.

<sup>19</sup> Staff of Congressmen Edward J. Markey and Henry A. Waxman, *Electric Grid Vulnerability: Industry Responses Reveal Security Gaps*, May 21, 2013, p. 2.

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