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Improving the estimated cost of sustained power interruptions to electricity customers

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ABSTRACT

Electricity reliability and resiliency have become a topic of heightened interest in recent years in the United States. As utilities, regulators, and policymakers determine how to achieve optimal levels of electricity reliability while considering how best to prepare for future disruptions in power, the related issue of how much it costs when customers lose power remains a largely unanswered question. In 2006, Lawrence Berkeley National Laboratory developed an end-use based framework that estimates the cost of power interruptions in the U.S that has served as a foundational paper using the best available, yet far from perfect, information at that time. Since then, an abundance of work has been done to improve the quality and availability of information that now allow us to make a much more robust assessment of the cost of power interruptions to U.S. customers. In this work, we find that the total U.S. cost of sustained power interruptions is $44 billion per year (2015-$) –25% more than the $26 billion per year in 2002-$ (or $35 billion per year in 2015-$) estimated in our 2006 study.

1. Introduction

Since we completed our first paper on the total cost of power interruptions in 2006 [1], interest in electricity reliability and resiliency in the United States has increased dramatically. The White House issued a *National Electric Grid Security and Resilience Action Plan* that describes activities the country is taking at the federal level to strengthen the security and reliability of the power system [2,2a]. In 2017, the Department of Energy issued a *Staff Report to the Secretary on Electricity Markets and Reliability* that highlights the importance of future investments in the power grid to ensure a reliable and resilient grid. A report issued by the National Academy of Science titled *Enhancing the Resilience of the Nation's Electricity System* in 2017 presents a series of overarching and specific recommendations intended to increase the resilience of the U.S. power system from events that result in outages that last several days, weeks or even months [3]. Among them, large-scale blackouts as well as widespread and long-duration interruptions resulting from catastrophic weather events, have highlighted the question of what is required and how much it will cost to maintain or improve electricity reliability, bringing it to the forefront of discussions among utilities, their customers, state utility regulators, and policy makers.

Recent reports have highlighted severe weather as the leading cause of power outages in the United States [4,5]. With more frequent severe or catastrophic U.S. weather events such as Hurricane Harvey, Irma, or Maria occurring, many electricity customers are focused on the issue of electricity reliability. Some customers are willing to pay to prevent unwanted power interruptions, and others wonder why utilities are not more reliable. Purchases of diesel backup generators have increased, both in the residential and commercial/industrial sectors [6,7]. Utilities are spending more on vegetation management and storm hardening, including tree trimming and upgrades to poles and fixtures. One of the key causes of the 2003 blackout was insufficient tree trimming [8–10]. Some utilities are considering whether there is economic justification for undergrounding their distribution lines to reduce exposure to environmental hazards [11,12].

These recent changes coupled with the ability to significantly improve the representation and quality of the input components of our previous cost estimate gave us reason to revisit our work of more than a decade ago. In this study we wanted to determine whether any of these recent changes were impacting the economic cost of power interruptions in the United States.

This paper is structured as follows: Section 2 describes the improvements in data now available to support an updated estimate

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Acronyms

CAIDI	customer average interruption duration index
CDF	customer damage function
EIA	United States Energy Information Administration
IEEE	Institute of Electrical and Electronics Engineers
SAIDI	system average interruption duration index
SAIFI	system average interruption frequency index

of the national cost of power interruptions; Section 3 highlights studies conducted since our 2006 literature review; Section 4 reviews the framework that we developed in 2006 and the updated assumptions in the current study; Section 5 updates our 2006 base-case estimate of a $26 billion (2002-$) cost attributable to sustained power interruptions in the United States; Section 6 explores a set of sensitivity cases using a step-by-step method that updates one element of the estimate at a time, with a focus on sustained interruptions, including Monte Carlo uncertainty analysis; and Section 7 summarizes our findings including some concluding remarks.

2. Background

In 2006, Lawrence Berkeley National Laboratory (Berkeley Lab) developed an end-use-based framework for estimating the costs of power interruptions to U.S. electricity customers [1]. Our work found that the total cost of sustained power interruptions was $26 billion (2002-$).[1] This estimate considered all electricity customers in the residential, commercial, and industrial sectors across all U.S. census regions. Note that our 2006 study considered both sustained interruptions as well as momentary, or interruptions lasting less than 5 min. With a better understanding of the challenges utilities still face in their ability to adequately monitor momentary interruptions with the current technologies deployed, we have since determined that the estimated cost of momentary interruptions was too speculative to include in the current work. Our 2006 study acknowledged that there was significant uncertainty in the publicly available information at that time and showed that using better information could either lower our estimate by a factor of almost 4 or increase it by a factor of almost 2 when decreasing or increasing the average duration and frequency of power interruptions by one standard deviation, respectively.

In just the last decade, Berkeley Lab research has expanded the understanding and representation of reliability information in the United States. Expanding on pioneering efforts by the Institute of Electrical and Electronics Engineers (IEEE) Distribution Reliability Working Group and the National Association of Regulatory Utility Commissioners to develop a consistent approach for reporting reliability information, Berkeley Lab in 2008 examined current practices for collecting and reporting electricity reliability information in the United States [13].

When we prepared our first report on reliability trends in 2012, we studied the portion of reliability metrics reported using a voluntary standard, IEEE 1366 Standard, to define major events and determined that this information was difficult to find in the public domain [14]. IEEE 1366 Standard is a voluntary standard that articulates a consistent set of definitions and procedures for measuring and reporting distribution reliability information, including major events. Berkeley Lab has since worked with the United States Department of Energy and the Energy Information Administration (EIA) to include reporting of reliability metric information as part of EIA Form 861, with a separate section for entities that use the IEEE 1366 Standard. EIA Form 861 requires under Federal law that electric power industry entities annually report information on the status of generation, transmission, and distribution as a way of assessing the state of the U.S. electric power industry.

In 2015, the Department of Energy commissioned Nexant to update the customer damage functions (CDFs) that form the backbone of the online Interruption Cost Estimate calculation tool. This update entailed including additional utility customer surveys in the tool and improving the parsimony of the statistical regressions. Additionally, in 2015 Berkeley Lab commissioned a report to evaluate the current inventory of back-up generators that customers purchase to protect against the impacts of power interruptions. Berkeley Lab also issued a 2016 update of our 2012 assessment of electricity reliability trends. This update found that reliability is worsening, especially when major events are included, and that this worsening trend is likely a result of an increase in severe weather events [5].

We applied this extensive research on electricity reliability over the past decade to the current interruption-cost update. We are now able to use a more sophisticated approach for estimating the cost of power interruptions; that is, we can now account for the uncertainty of some of the input values using Monte Carlo simulation. Given the nature of the input parameters to our estimation framework, it makes sense to construct the results as a range of possible outcomes and their associated probabilities of occurrence. The outcomes reflect the most likely estimate based on the best available data, along with less likely and even extreme possible estimates that could result from various circumstances. Structuring the results in this way allows us to use a likely range of values instead of relying on a single value. Given the uncertainty in the input parameters, this presentation of results increases their usefulness for decision makers assessing electricity service reliability.

3. Recent studies

Since our 2006 report was released, some studies have focused on the issue of severe weather impacts. We discuss those studies briefly here and summarize their highlights in Table 1. Although none of these studies claim to comprehensively represent all types of interruptions or all electricity customers, they contribute to our understanding of outages and their costs are symbolic of the recent focus on the influence of severe weather on the cost of power interruptions.

A 2012 U.S. congressional report summarizes results from other studies and, based on this literature review, estimates that storm-related interruptions in the United States cost between $20 billion and $55 billion annually. That report draws from a Primen 2001 study [15] that we discussed in our 2006 report and extrapolates to derive a weather-focused estimate. The congressional report also cites our 2006 study and presents the base-case estimate for sustained interruptions ($26 billion), noting this estimate includes both weather and non-weather causes [16].

A 2013 White House report prepared by the President's Council of Economic Advisors and the United States Department of Energy also focuses on severe weather. The White House report states that power interruptions due to severe weather between 2003 and 2012 cost the U.S. economy an average of $18 billion to $33 billion annually. This study asserts that severe weather is the leading cause of power interruptions and that this pattern is likely to increase

[1] Sustained interruptions are interruptions of power lasting more than 5 min. We do not estimate a cost to customers from momentary interruptions, which are interruptions of power lasting 5 min or less.