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CROPS Determines the Best Measures

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As we decide how to best make our power systems more resilient to catastrophes, one key question we should be asking is not just how much it will cost, but also who should pay for it?

The assumption that state utility customers alone should pay to enable us to recover more quickly from disasters may have made sense in the past. After all, electricity customers are the beneficiaries of a resilient system, so shouldn't they pay for any necessary improvements, as determined by regulators?

Yes and no, since times have changed. Electricity is fundamental to our economy and livelihoods, and becoming more so, as we move towards electric vehicles, renewables, the storage of power, and overall electrification.

Without secure electricity supplies, our factories may not run, our shopping malls may shut down, our gas pipelines may not operate, our transportation systems can become inoperable and our water systems may cease to function. Perhaps worst of all, our mobile devices can go kerflooey.

Most of the jobs we hold are not viable without secure power, and there would likely be a breakdown in civil society if power is unavailable for an extended period. There would be severe military consequences as well.

Avoiding these societal consequences is surely in the interest of more than just local power customers, so other regional, state and federal entities should share responsibility and costs for ensuring a secure power supply.

Given the size of the U.S. economy and our consumption of power, on a macro level, each kilowatt-hour of electricity is worth almost four dollars to our economy.[1] Average retail rates are about eleven cents, so this is about thirty-five times what we pay. Some customers and regions value electricity much more than others.

Because the value of electric power (VOEP) is so high, there should be some non-local funding of resiliency measures, to pay part of what we can call the insurance premium for a secure supply of power to protect the viability of our economy.

The national highway infrastructure was central to the U.S. economy and our defense in the 1950s and merited federal and state funding then. State and federal taxes through the years have funded its upkeep. By the same token, bolstering and maintaining the electricity infrastructure of today merits state and federal support as well.

At a national level, FERC has recognized the vital role of resilience by opening a stand-alone proceeding on the subject (AD18-7-000), and a number of regions, states and utilities are assessing how to incorporate resilience in their planning and rates. At a regional level, PJM formed the Security and Resilience Advisory Committee in March 2017. These are good efforts, to be sure; we just need to do more, given what's at stake.

We continue to receive reminders of the increasing risks to our power grid and economic well-being. The severe wildfires in California in 2017, perhaps set off by downed power lines; the "bomb cyclone" this past winter; the reported attempts to hack our power networks by foreign agents; and the ongoing lack of full power restoration in Puerto Rico point out our ongoing vulnerabilities. Managers of utilities and regional power grids must now plan to protect against a wider range of more serious threats than ever before.

How should we determine the optimal level of resilience measures without breaking the bank? What's needed is for each jurisdiction to undertake a four-step process to categorize and cost out the threats to resilience, identify the potential solutions, determine their societal costs and benefits to rank-order the actions, and decide which entities should pay for such remedies.

Let me provide a concrete example. As a consultant, I worked on a project in Guam in 2003-2004, and our assignment was to recommend to FEMA whether to approve funds for the Guam Power Authority to put selected transmission lines underground - at considerable cost - when rebuilding after a nasty typhoon.

Instead of the traditional analysis, limited to the power network, we took a forward-looking, VOEP perspective. To do so, we first assessed the future likelihood of major storms, the likelihood that power would be knocked out again, for how long, and which specific customers would be affected.

In some key areas, Guamanians were without power for extended periods, so the economic impact was high, particularly since some of the candidates for undergrounding served major shopping malls, hospitals, tourist areas and military bases. We then determined what the economic "hit" would be to Guam in reduced GNP if power were cut off in the future, for days or weeks, along each of the transmission lines, as determined by our analysis of storm frequency and severity.

This calculation led to a monetary benefit from undergrounding for Guam that was much higher than without using the VOEP. Our team recommended burying a number of lines, primarily due to incorporating the societal economic impact of electric power.

Here on the mainland U.S., with threats to resilience rising, we should proactively, not retroactively, conduct this type of analysis to properly determine which resilience efforts to fund, and decide who should pay for them.

How should we do so? Overall, I call the application of these ideas the Comprehensive Resilience and Operating Planning System (CROPS), and I envision a four-step process, repeated every two to three years, as shown in Figure One.

See Figure One.

Step One - A Detailed Threat Taxonomy

As the first part of CROPS, utilities should collaborate with regulators (state and federal), as well as regional entities (ISOs, RTOs) to develop a comprehensive list of the severe but irregular events that could befall the power system and affect its supply to a meaningful number of customers. This is the easy part, and could include two types of disasters:

Human interference: Transformer and substation attacks, cyber intrusion on a major scale, lack of tree trimming, deliberate downing of key transmission lines, forced or accidental disruption of key fuel, fuel storage, or water supplies to power plants, electro-magnetic pulses.

Natural disasters: Major forest fires, severe hurricanes and tornadoes, significant floods, prolonged droughts and heat waves, excessive cold snaps, snow or ice storms, sea-level rise, geo-magnetic disturbances.

Due to climate change, a number of natural disasters are becoming more frequent and severe than ever. The Fourth National Climate Assessment published by the U.S. Global Change Research Program in late 2017 is just one such document focused on what's occurred and what's expected in some of these areas.

Step Two - Impact Assessment

The second part of the Compre-hensive Resilience and Operating Planning System, one which is much harder, is to determine how much of an impact one or a combination of these events could have on the supply of power and on economic activity in the affected service territory or region.

To answer this question, resilience planners need to identify the potential frequency and severity of such events, and while it sounds negative, to focus on worst cases. Importantly, in a disaster, what specific facilities could be lost, for how long, affecting how many megawatt-hours, and what measures would you take to restore power to the vast majority of customers?

For example, which power facilities in your region could be damaged by a Category Four or Five hurricane? Which power plants are the most critical to system restoration, and which ones would need "black start" capabilities in a major outage? What if your region/utility simultaneously lost several major transmission lines or transformers due to an attack?

Which gas pipelines or storage facilities would impair the ability to deliver power if they were unable to deliver fuel due to an intense storm or sabotage? What if a major dam failed, or cooling water was unavailable due to drought? What if the utility lost control for a week to its system control room?

Homeowners suffer in disasters, of course, but the highest economic impacts are often due to the loss of facilities such as industrial plants, data farms, and transport systems. Remember the impact of the outage at the Atlanta airport in December 2017. To be counted, the loss of power needs to be extended, and cover a meaningful geography. Neighborhood outages don't count for this exercise!

Step Three - Benefit-Cost Analysis

The next step in CROPS involves evaluating the economic and societal cost of such outages, taking both uninsured expenses and the value of electric power into account. The lack of power for a week or more could displace economic activity associated with the billions of kilowatt-hours determined in Step Two.

In this analysis, we find that the loss of power to industry is generally the most costly to society. If an industrial facility produces a hundred fifty million dollars' worth of output in a week using five million kilowatt-hours of power, then that lost output is worth thirty dollars per kilowatt-hour, and a two-week outage should be valued at three hundred million dollars. This does not even count the significant potential loss of employee wages or damage to equipment.

Residential losses have traditionally been valued at just a few dollars per kilowatt-hour. But current VOEP research is scanty and bears updating, given how dependent we've become on our devices. Commercial losses (shopping malls, restaurants) generally fall between the other two.

Using such an approach, it was estimated that the eighteen-hour U.S. Northeast outage of August 2003 that affected over fifty million people cost the economy ten billion dollars. That would have paid for a lot of tree trimming to avoid that outage in the first place!

The analysis of options to avoid outages and ensure a secure power supply needs to take multiple measures and tradeoffs into account. One could reduce the impact of losing several major power plants during peak conditions by building more gas peakers, by installing energy storage, or by mitigating peak loads through demand management - or all three.

What's the best combination? While vital, it's not easy to determine, and to choose, we need metrics to evaluate what we are trying to achieve. Should we try to eliminate the impact of a certain type of catastrophe entirely, or lessen its impact by some large percentage to find the right balance?

We need to take technology advancement into account too. A recent study by GTM research indicates that within ten years, the falling cost of storage could displace the need for about one third of the gas peakers that might otherwise be needed.

We further need to decide whether the investments for resilience would be designed to entirely prevent or simply mitigate outages. How hard should a hardened system be? Grappling with these questions will be challenging the first time but will get easier with each CROPS iteration.

Step Four - Resilience Planning and Funding Analysis

The final step in the Comprehensive Resilience and Operating Planning System is to determine what measures and what funding sources make sense to mitigate against the disasters that could affect customers' power supplies, using a rigorous cost-benefit analysis.

This resilience planning needs to bring together the prior assessments, taking all vulnerabilities and potential solutions into account. As PJM stated in its March 9, 2018 filing with FERC, "Resilience efforts will require changes to transmission and infrastructure planning, operations and market rules, as well as to the recovery and restoration process."

This step in the process needs to rank order the measures and expenditures one could take today, compared to the value of electricity that they would save later if one of the potential disasters struck. Naturally, this analysis will give rise to debates over the likelihood, severity and impacts of a catastrophe, and the debate will be political as well as regulatory.

Some measures may be "no regrets", and others controversial. Some may require coordination with other entities such as gas pipelines, and greater understanding of their contingency plans. However, these conversations are what our modern economy and our citizens require.

Otherwise, we may regularly be faced with responding to disasters that knock out electric power after-the-fact, at a much higher cost than it would cost to make the system more resilient from the start.

For each resilience measure, there are several candidates for funding, which can vary depending on the geography and the severity of the resilience event they are designed to deal with:

Existing utility customers. The usual funders, as approved by state regulators.

All taxpayers in a state. Perhaps utilizing a bond measure to fund state-wide resilience. Examples could include funding to reduce the impact of wildfires in California, or to pay for better levees in Louisiana.

Regional electricity customers. If the disaster could affect regional power flows, funding could be managed through a non-bypassable transmission charge at the ISO or RTO level, with state or FERC buy-in.

Federal budgets. If a disaster such as a major storm or cyber-attack might affect enough customers. It might be decided that FEMA should not just respond to disasters but provide funding to reduce their impact in advance. Potentially, DHS could make grants to enhance the cyber security of the grid; FEMA could subsidize investments to mitigate widespread hurricane damage; and DOD could help provide secure power to significant military facilities.

For the past several years, many utilities have been hardening their systems and replacing old systems to reduce the impact of catastrophes and improve efficiency. It's often called "grid modernization," and is generally funded through existing electricity rates or riders. These efforts are commendable, and the CROPS funding analysis would determine what is needed over and above such improvements.

But resilience can be improved through diversification as well. In recent years, many more distributed energy resources such as microgrids, rooftop solar and community solar projects, combined heat and power and local storage banks have appeared.

Wide-scale energy efficiency also can reduce the stress on existing facilities, the loss of power and the impact of disasters. Efficiency can increase resilience by making it easier for such customers to restart their power supply even if the rest of the grid is disrupted.

Could taking these actions and making these investments to enhance resilience marginally increase the cost of power or taxes in the near term? Yes. But the tradeoff - the key benefit - is that mitigating or avoiding those major outages would be cost-effective and worth the investment, taking longer-term economic impacts and customer welfare into account. State regulators and policymakers would need to decide how to share the burden of such near-term costs fairly, and not regressively.

There is a key role for private insurance as well. Homeowners and businesses generally have insurance against fires and floods, to rebuild their facilities after a loss. Rarely does such insurance protect a family's or company's livelihood, operations, revenues and profits.

Nor does it protect against the cost to the economy or our nation that can occur in case of a widespread, extended power outage.

What's the bottom line? To create resilient power networks, we should begin today to determine the tradeoffs among potential measures to prevent or recover from catastrophes. We should use an in-depth process that includes a benefit-cost analysis to analyze the value of electric power to the economy of the affected area.

We should expand current efforts and engage in a Comprehensive Resilience and Operating Planning System review every few years, involving the right stakeholders. With the frequency and economic impact of disasters on the rise, we need to be proactive. It's not just about how much to pay for which resilience measures before such events strike, but also about who should pay for such measures. In short, let's now plant the seeds of resilience through CROPS.

Endnotes

1. The U.S. real-dollar GNP in 2017 was approximately $19.39 trillion. If seventy-five percent of the U.S. economy is dependent on electricity, then that is worth $14.54 trillion. When we divide

that by the demand for power in 2017, which was 3,682 billion kilowatt-hours, each kilowatt-hour produces $3.95 in economic value.

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