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In 2013 end-use electricity customers in the U.S. paid some $364 billion to their suppliers for electricity service.[1] The economic cost of outages that customers experienced in that year, however, amounted to approximately $112 billion, not including the full cost of outages that were attributable to extreme weather.[2] That failure of service represents $1 loss to an

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[1] See http://www.eia.gov/electricity/monthly/current_year/december2013.pdf - Table 5.2

[2] *See* K.Hamachi-LaCommare and J.H. Eto, Understanding the Cost of Power Interruptions to U.S. Electricity Consumers,Sept. 2004 at http://certs.lbl.gov/pdf/55718.pdf; "Berkeley Lab Study Estimates $80 Billion Annual Cost of Power Interruptions in 2003." http://newscenter.lbl.gov/2005/02/02/berkeley-lab-study-estimates-80-billion-annual-cost-of-power-interruptions/. This estimate has been scaled to 2013 levels using the relative change in electricity consumption. *See* http://www.EnergyCollection.us/Energy-Reliability/Understanding-Cost-Power.pdf. Also, according to an Electric Power Research Institute (EPRI) paper published in 2001, "The Cost of Power Disturbances to Industrial & Digital Economy Companies," the U.S. economy is losing between $104 billion and $164 billion annually due to outages and another $15 billion to $24 billion from power quality issues. http://www.EnergyCollection.us/Energy-Reliability/Cost-Power-Disturbances.pdf

end customer for every $3 the customer pays for service.

No one would ever fund or enter a business with such a poor record for reliability,[3] yet electricity service is a fundamental and central engine to our economic productivity and way of life. It drives the motors and systems that industry relies on. It lights, heats, and cools our buildings. It is vital to our banking and investment systems and our computer-driven information networks. It powers our appliances and entertainment systems. This incongruity between revenues paid to the industry and the cost of outages customers is astounding, but it is rarely discussed. Why?

The answer is a combination of factors, some historical, while others have the seed of a solution in forward-looking actions. In any case, it is time for a new paradigm. Energy companies and suppliers to energy companies are taking notice of new opportunities to squarely address the cost to customers of outages.

The $112 billion in customer losses are almost all attributable to outages on the low voltage Distribution System (DS). The Bulk Electric System (BES) is managed with a much higher level of sophistication—with complex communications, software, and built-in reliability mechanisms—so that the random failure of any one large generation plant or transmission line will not result in a customer outage. The reliability of the BES represents an engineering marvel unparalleled in human history, yet the troublesome economic losses that are rooted in the DS persist.

Customer losses are caused by a variety of factors. Extreme weather,[4] overgrown vegetation, failing components, and animal entanglements are the major sources of distribution outages. The electricity industry measures such outages with a variety of unemotional indexes—CMI, SAIDI, SAIFI, MAIFI, CAIFI[5], etc.—and indeed attempts to improve these indexes over time. If these indexes represent one side of a coin, the other side is, of course, the costs to

[3] While delivery of electricity is almost perfect, being well over 99% in reliability, it is the cost of outages to customers, in lost economic activity or damage that is at the root of the problem.

[4] Energy companies have supported development and use of a standard to remove big weather events from the reliability index measures. *See* http://standards.ieee.org/findstds/standard/1366-2012.html. This exacerbates the focus on non-customer related metrics, but reflects an understandable motivation to identify a stable measure over time for regulators to judge progress. Going forward however, everyone should realize that costs to customers are real, – no matter the cause of the outage. Indeed, all the discussion in the industry today about "resiliency" is a large-event weather discussion – and there are many Distribution investments that can address large-event weather situations. It is time to move on and focus on the customers in terms of measurements. In 2014, the White House issued a report specifically relating to extreme weather and the value of investing in the grid. *See* http://www.EnergyCollection.us/Energy-Reliability/Economic-Benefits-Increasing.pdf

[5] See http://en.wikipedia.org/wiki/CAIDI - as an example

customers of outages: the $112 billion. Given how difficult it is to improve DS performance with previous technology, the electricity industry has chosen to focus on the indexes, rather than actual customer costs. Such a strategy lessens the chance of uncomfortable discussions with customers, and most distribution companies are legally protected costs resulting from customer complaints and lawsuits to try and recover losses due to distribution outages anyway. One could also make the case that outage costs to customers are hard to calculate as a reason for an index focus, but there have been many good studies of these costs over the past decade. Lawrence Berkley National Laboratory now has an ICE Model[6] to bring calculation of customer losses down to individual distribution feeders.

From a regulatory perspective, the opportunity to improve the figure of $112 billion in losses due to inadequacy of the distribution system clearly falls to the state utility regulators rather than the Federal Energy Regulatory Commission. Today, however, only some state regulators routinely require that utilities submit data on DS reliability, and none requires estimates of related customer losses. Of the states that do require distribution reliability data, a smaller set actually requires performance targets and penalties for non-performance[7]. Also, state regulators are not in a position to specify how a franchise holder should go about improving DS reliability. Rather, they rely on the utility companies to come forward with recommendations.

The Distribution System has traditionally been a "run to failure asset." A distribution company could only deploy the limited technology that was available to achieve universal service at the lowest cost. Now, as we enter the age of "the Internet of Things," low cost communications, the digitization of components, and sophisticated software/associated algorithms, taken together allow for creation of a much more reliable Distribution System in the future.

However, the turn of the century has not only exposed the opportunity to address DS reliability, but also new challenges that require hands-on (or more appropriately – software-on) Distribution System management. Advanced Metering Infrastructure, for example, helps with the speed of reaction to an outage as well as other benefits, but also includes massive communications infrastructure added to the DS that needs to be managed, repaired, and optimized. In addition, the "Internet of Things" is an issue not only on the distribution side of the meter, but on the customer side as well. Several customer-side-of-the-meter deployments will require more sophisticated DS management as they grow in prominence—solar photovoltaic

[6] See http://www.icecalculator.com/

[7] See Ohio as a good example - http://www.puco.ohio.gov/puco/index.cfm/industry-information/statistical-reports/electric-reliability-performance-data/#sthash.Pv9O6bSi.cH4SEW3l.dpbs

and net metering, electric vehicle charging, customer storage, fuel cells, etc., to name a few. Some of these are even opportunities to help manage distribution reliability as distribution companies strive to balance customer demand with distribution supply side alternatives,[8] just as bulk power system operators do in the BES today.

In an informal survey over the past two years I have had the opportunity to ask many energy companies this question: "Do you include the impact to customer costs when you submit a rate case or recommendation for a Distribution System upgrade?" The answer universally is "no." Why? My belief is that momentum plays a large role, because opportunities to actually engineer the DS for greater reliability were not plentiful or inexpensive using previous technology. All system operators could do is to try to become aware of an outage and its location, and go fix it with the same technology—over and over and over again. Then wait for the next weather event, the next pin insulator to fail, the next squirrel to meet an untimely end, and on and on and on. Yes, the cost of replacing failing and failed distribution assets is high—but so are the costs of customer outages.

The natural monopoly status of the distribution system creates an intimate relationship between the distribution utility (the franchise holder), regulators, and utility customers. After asking my informal survey question, I always suggest that distribution companies should indeed include improvements to reliability—the estimated dollar amount of customer savings due to fewer outages—in their business case for DS improvements. Yes, these savings will not occur in the utility's financial statements – but they are real nonetheless and entirely appropriate to include in the business case. Indeed, inclusion of these costs in making the case for upgrading Distribution Systems with new technology completely and appropriately aligns the interests of the distribution company, state regulators, and, most importantly, utility customers.

Customer-side-of-the-meter deployment—solar panels, EVs, and much more—will require more sophisticated Distribution System management as they grow in prominence.

The electricity industry typically does not conduct substantive research and development activities aimed at improving technology. While individual energy companies have small projects that might be categorized as R&D, and while the Electric

[8] *See* New York's REV project - http://www3.dps.ny.gov/W/PSCWeb.nsf/All/26BE8A93967E604785257CC40066B91A?OpenDocument

Power Research Institute makes valuable contributions to the field, overwhelmingly the source of new technology and methods comes from suppliers to the industry. Fortunately, to meet the reliability challenges arising in the Distribution System and to address the opportunities presented there, suppliers are stepping up to the plate.

The supplier list is long, but to point out a few emerging leaders: Nexant[9] is providing distribution optimization tools on par with its BES tools. Exacter[10] is providing an MRI-like suite of technologies to find failing components. UST Global,[11] in partnership with Integral Analytics,[12] is providing analytics to better understand the distribution cost of service like those tools in use at the BES level to provide a balanced, stable, and reliable distribution system at the lowest cost. Innovari[13] is providing hardware and software to balance supply-side and distribution assets and to flatten the load duration curve. The list goes on, and it is long.

Utilities need to create long-term plans to modernize their Distribution Systems. These plans must be developed transparently, with involvement by state regulators, customers, and vendors.

Utility distribution companies need to create a long-term plan to modernize the Distribution Systems. This is a plan that involves increased investment. It is a plan that must be developed transparently with involvement by the state regulator. Most of all, it is a plan that sweeps in the appropriate technology vendors to optimize the Distribution System around the lowest cost, appropriately reliable system going forward. And it should rightfully account for decreased customer dollar losses due to improved reliability that results from the process.

The time has come for utilities to focus directly on their customers rather than on once-removed abstract indexes of reliability performance. ■

[9] Nexant – see http://www.nexant.com/products/nexant-grid360

[10] Exacter – see http://www.exacterinc.com/

[11] UST Global – see http://www.ust-global.com/en/index.php/utility-and-energy

[12] Integral Analytics - http://www.integralanalytics.com/

[13] Innovari – see http://www.innovari.com/