Electricity Advisory Committee

MEMORANDUM

TO: **Honorable Dr. Ernest Moniz, Secretary**
Honorable Patricia A. Hoffman, Assistant Secretary for Electricity Delivery and Energy Reliability

FROM: **Electricity Advisory Committee (EAC)**
Richard Cowart, Chair

DATE: **October 3, 2013**

RE: **Recommendations on U.S. Electric Grid Resiliency.**

Introduction

National security, public safety and our nation's economy can be compromised when electricity is not available. Consequently, enhanced electric grid resiliency is increasingly embraced as an important goal for our nation. Super Storm Sandy in 2012, geomagnetic disturbances from the current peak solar storm cycle, and other potential threats have increased the urgency of electric grid resiliency. Certainly, 100 percent security cannot be guaranteed or afforded, but the electric power delivery system can be hardened and made more resilient over time as the electric industry replaces aging assets and deploys new assets.

The electric industry has performed admirably to protect and restore the grid from hurricanes and other natural phenomena. The grid has shown remarkable resilience for these phenomena and other widespread events over the years. However, the 21st century customer expects a better grid, and with the growing dependency on the grid, the 21st century customer deserves better. Super Storm Sandy in 2012 and other storms in recent years have demonstrated these dependencies and the low tolerance of customers for long outages. Furthermore, as documented in the DOE EAC recommendations on grid security dated October 20, 2011 (copy attached for reference), additional work is needed to better understand potential steps for addressing other widespread high-impact, low-frequency (HILF) events.

EAC
ELECTRICITY ADVISORY COMMITTEE
U.S. DEPARTMENT OF ENERGY

A more flexible, resilient, and interconnected power system will be required to successfully meet the challenges posed by these uncertainties. In turn, the success of the utilities and the companies involved in building, operating and maintaining the power system will be measured by their flexibility, resilience, and connectivity. To transition to a more robust power system with these characteristics, it will be necessary to develop and deploy a portfolio of technologies that can address the many issues emerging from the evolving transformation. DOE can lead efforts to coordinate with other government agencies as they assist the industry in fulfilling the needed grid transformation.

Sensible & Affordable Grid Resiliency Goal

The premise of resiliency [as applied to power systems] is that institutions and systems can be designed to "better absorb disruption, operate under a wider variety of conditions, and shift more fluidly from one circumstance to the next." (Resilience 2012) In general, the resilience of any system implies a menu of interventions which (1) ensures sufficient reserves, (2) diversifies inputs, (3) collects quality, real-time data about operations and performance, (4) enables greater autonomy for constituent parts, and (5) utilizes firebreaks so that a disturbance in one part does not disrupt the whole.

Electric grid resilience can be increased in a multitude of ways at large, remote power stations, across transmission and distribution circuits, at load pockets, and even at isolated individual loads. Methods can be as time honored as clearing or trimming trees around overhead lines, or as cutting edge as combining rooftop solar, lithium-ion battery backup, and smart inverter technology to form micro-grids to increase resiliency for critical and other loads.

However, resiliency gains must be weighed against the probability of the events being addressed with affordability by those paying for the enhancements, i.e., the consumers of electricity. Too often the solutions discussed immediately after a large disruption include undergrounding all facilities and other expensive measures until the price tag is too high to accomplish. As time passes, the remedies are forgotten until the next event. The EAC envisions a sensible approach over time as assets are replaced, and offers samples of sensible solutions, including improved technology.

Addressing the Threat of HILF Events

Most often HILF events are cited as those which can threaten electric service reliability and can potentially result in loss of service for extended periods of time over wide areas of the nation. Some believe that HILF events are the greatest threat to national security. HILF events can result from a variety of natural and manmade disasters as well as unintended failures of major equipment. These may include storms, flooding, earthquakes, tsunamis, geomagnetic disturbances, cyber and physical attacks, major component failures, pandemics, and abrupt loss of power plant cooling water or fuel supply.

The State of the U.S. Grid Today

The U.S. grid is comprised of three synchronous grids and connected directly to Canada and northern pockets of Mexico. The Eastern Interconnection connects systems from the Rocky Mountains to the east coast, the Western Interconnection connects systems from the Rocky Mountains to the west coast, and the Electric Reliability Council of Texas (ERCOT) connects systems within most of Texas. Each grid is synchronous, but interconnected with each other via asynchronous high-voltage direct-current (HVDC) ties. Disturbances within each grid are felt nearly instantaneously and directly by all systems within the grid. Delicate supply-demand balances are maintained every moment of every day. In parts the U S., large grid operators and defined markets run by Regional Transmission Organizations (RTOs) maintain this balance. In other parts of the U.S. there are smaller balancing authorities to maintain the balance between supply and demand.

The transmission system is the “backbone” of each grid or power delivery system and is networked or part of a "mesh" that provides at least "N-1" or single contingency reliability nearly 100 percent of the time. It transmits large amounts of electric energy from supply points and among regions and sub-regions to load centers. Transmission system equipment failures cause power outages much less frequently than distribution equipment. However, when transmission equipment fails, especially multiple failures at one time, many more customers are affected, and outage costs can be much higher, compared to the impact of a distribution equipment-related outage. This fact, combined with the high cost per mile or per piece of transmission equipment, has historically led to greater attention to transmission system reliability.

The distribution system is largely radial in nature from transmission-fed substations to local demand points (customers). Distribution circuits in urban centers tend to be shorter, some underground, serving higher densities of customers as compared to suburban and rural areas. Load centers such as New York City have much higher reliability than remote rural towns. Outages in urban centers tend to affect more customers with high degree of complication to remedy. However, urban centers tend to have more distribution automation and redundancy to self-heal. The advent of Smart Grid (many projects supported by the DOE) have greatly improved automation and the ability to reduce outage times.

The distribution system has had the most transformation in recent years due to Smart Grid and distributed energy sources such as rooftop solar. Micro-grids, small distribution pockets that can disconnect from the grid and be partially or fully self-sufficient, are nascent but advancing.

Many of the assets that comprise the U.S. electric grid were built soon after World War II, with a pronounced growth spurt in the 1960s and 1970s. These assets are being replaced at a good pace by grid owners today as these assets reach end of life stages. Fundamental to the EAC recommendations is the timeliness of DOE actions to ensure that, as these assets are replaced, they include reasonable enhancements to improve resiliency of the grid for probable natural events and to a reasonable degree for improbable HILF events.

The age profile of assets is also discussed to show the urgent replacement need and the opportunity to enhance as the assets are replaced. Although not all assets need to be replaced, and like-for-like replacements may not be warranted, many assets will undoubtedly be replaced and enhancements at time of replacement are less costly than retrofits.

The 21st Century Electricity Customer

Reliability expectations vary across the country. Many in urban centers tend to have lower tolerance for outages than those in rural areas. However, one can logically reach the conclusion that the majority of 21st century customers want better reliability. At what price? Herein lies the balancing act of improving the reliability of the grid without costs beyond which the customer is willing to pay for that improved reliability.

The challenge with improving reliability (including resiliency as part of the reliability equation) is that demand has slowed to the point where EIA predicts higher kWh demands in 2030, but at levels around 1 percent annual growth. Part of this slowing includes admirable energy efficiency gains (some efforts led by DOE), and another factor in this slowing growth is "behind-the-meter" distributed energy resources. With utility business models premised on growing kWh usage, there will be an affordability challenge for improving reliability. Some of this challenge can be bridged by technology and sensible resiliency solutions over time as the industry replaces assets.

Electric Grid Resiliency Options & Industry Recommendations

The EAC acknowledges that several initiatives are underway by the North American Reliability Corporation (NERC), the Electric Power Research Institute (EPRI) and others to address the issue of resiliency, including prevention, recovery and survivability. However, DOE is uniquely positioned to ensure that these efforts are conducted with no exposed seams and with optimum effect in coordination with other agencies, such as the Department of Defense (DOD) and the Department of Homeland Security (DHS).

The EAC recommends that any actions by DOE be complementary to actions taken by the industry and other governmental agencies. We include excerpts from recent activities below that should be reviewed prior to developing a detailed plan of action.

NERC's Critical Infrastructure Strategic Roadmap

The EAC specifically cites one of the most aggressive resiliency initiatives being **NERC's Critical Infrastructure Strategic Roadmap** developed by the Electricity Sub-Sector

Coordinating Council and approved by the NERC Board of Trustees in November 2010. According to Roadmap, the goals of the NERC effort are:

1. Enhance situational awareness within the electricity sub-sector and with government through robust, timely, reliable, and secure information exchange.
2. Use sound risk management principles to enhance physical and cyber measures that improve preparedness, security, and resilience.
3. Conduct comprehensive emergency, disaster, and business continuity planning. Conduct training and large-scale exercises involving electricity industry and government entities to enhance reliability and coordinated emergency response.
4. Clearly define critical infrastructure protection roles and responsibilities.
5. Enhance understanding of key interdependencies and collaborate with other critical infrastructure sectors to address them, and incorporate that knowledge in planning and operations.
6. Strengthen public and government regulatory agency confidence in the sub-sector's ability to manage risk and implement effective security, reliability and recovery efforts.

Severe Impact Resilience: Considerations and Recommendations Report

Recommendations to mitigate HILF risks are contained in the report by the **NERC Severe Impact Resilience Task Force (SIRTF), "Severe Impact Resilience: Considerations and Recommendations."** Some of these are also appropriate for lower-impact, higher-frequency events.

Resilience measures considered for more general transmission grid events include:

- Prioritized hardening of circuits based on criticality.
- Selective use of steel, instead of wood, ***[The EAC adds selective "guying" of critical dead-end structures or replacing these structures with steel.]***
- Prefab retrofit control buildings with greater tolerance for High Altitude Electromagnetic Pulse (HEMP).
- Greater inventory for storms.
- Maintenance and/or Capital Replacement Program optimization, including "right-sizing" or "hardening" of transmission on existing rights-of-way to satisfy larger, future needs whenever material condition warrants replacement of existing lines or substations (sometimes as appropriate, or even before need to accommodate other replacements).
- Targeted design improvements against common failure modes such as lightning strike, or flooding or ice accumulation from major storms (additional static wire coverage or phase-to-ground arrestors, selective undergrounding, rebuilding of stations out of flood/surge prone areas, higher standards for wind/ice loadings).

[The EAC adds that these standards need to be updated to reflect anticipated severe weather.]

- Increased use of emerging technology such as synchro-phasors and flexible AC transmission system (FACTS) devices.
- Modeling and simulation advancements (including load research to identify concentrations of sensitive, harmonic-producing, or induction motor loads).
- Installation of renewable generation (e.g., wind, solar) at critical Bulk Power System (BPS) facilities to supplement standby generators. (NERC SIRTF, Recommendation #11) ***[The EAC adds that use of advanced energy storage in conjunction with renewables must be part of this and the NERC recommendation should be revised to incorporate.]***
- Performance of selected studies in advance (e.g., equipment interchangeability) that could help speed restoration (NERC SIRTF, Recommendation #16)

Additional Recommendations

The EAC identified several additional recommendations from other sources such as the **York State NYS2100 Commission following Super Storm Sandy,** and several reports from the Electric Power Research Institute (EPRI):

- Selective undergrounding of transmission systems in: dense urban areas, congested substation exits, and around airport runways, sensitive environmental areas, long water crossings, and where there are public objections to new transmission.
- Special protection from flooding by use of reinforced design of towers, substations and underground systems and equipment. Specific actions may include increasing flood walls, adding to spare parts inventory, increasing the use of submergible transformers and switches, and use of weatherproof enclosures.
- Protection from tsunamis primarily applied to power plants and substations. Actions to protect these assets can include belts of trees and mangroves to provide barriers to wave "run-up," offshore location of cooling water intake structures, use of design principals which inhibit the scouring or erosion created by waves, and prevent damage from the debris left behind.
- Standby, Backup Power Generation and Transformer Deployment – The design and manufacture of storable and easily transportable backup power generators and transformers is a means of restoring damaged facilities.
- Stored and Shared Spare Components – Another essential component in the recovery process is to stockpile and pool components needed in the event of an emergency. These components could be shared among all stakeholders and geographically dispersed for quick access.
- Recovery Transformer – A consortium of the U.S. Department of Homeland Security (DHS) Science & Technology Directorate (S&T), transformer

manufacturing company ABB Inc., CenterPoint Energy Inc. and EPRI has developed a prototype transformer that could be deployed to replace a damaged or destroyed transformer in about a week instead of several months to prevent sustained power outages.

- Optimal Black-start Capability – Use of Optimal Black-start Capability (OBC) tools as a decision support tool to evaluate the blackstart capability based on currently available blackstart capable unit(s).
- Substation Seismic Protection – The Institute of Electrical and Electronic Engineers (IEEE) Standard 694, Recommended Practice for Seismic Design of Substations, is used by electric power utilities to qualify substation equipment for seismic movements.
- Shielding – Adopting the U.S. military specifications, specifically under the MIL-STD-188-125 standard, deploys technology for shielding components from BMD/EMP/HEMP. Ground-based shielding detailed in MIL-STD-188-125 designates "subscriber terminals and data processing centers, transmitting and receiving communications stations, and relay facilities for both new construction and retrofit of existing facilities."

The EAC believes other innovations can also be employed to develop and demonstrate new technologies now undergoing research and development including:

- Energy Storage – Energy storage has the potential to transform the electric power infrastructure by enhancing resiliency through use of storage technology which facilitates the integration of variable energy resources such as wind and solar and by improving the capacity factor or utilization of the transmission and distribution system as well as that of conventional generation.
- Hydrophobic Coatings – Hydrophobic coatings can be applied to various components in the transmission and distribution system. By helping components shed precipitation, these coatings mitigate water damage on non-ceramic insulators and can facilitate ice removal.
- Asset Health Center - Remote monitoring of critical equipment by asset management and operations engineers can be used to determine imminent failures of critical equipment.

Distribution Specific Options

The resilience of the distribution system is based on three elements: Prevention, Recovery, and Survivability. (Source: EPRI Report 1026889) "<u>Prevention</u> refers to the application of engineering designs and advanced technologies that harden the distribution system to limit damage. <u>Recovery</u> refers to the use of tools and techniques to quickly restore service to as many affected customers as practical. <u>Survivability</u> refers to the use of innovative technologies to assist consumers, communities, and institutions in continuing some level of normal function without complete access to the grid. Improving the distribution system's resiliency requires advancement in all three aspects." (Source: EPRI Report 1026889)

The EAC believes that events as recent as Super Storm Sandy point to the need to rebuild distribution stations outside of flood/surge prone areas and to give strong consideration to whether buried or overhead service is better for a given area. Micro-grids and customer self-sufficiency impacts certainly also belong in any consideration of resiliency in the longer term.

"Hardening" the distribution system to mitigate or prevent damage will require changes in design standards, construction guidelines, maintenance routines, inspection procedures, and recovery practices, and will include the use of innovative technologies. (Source: EPRI Report 1026889)

And let's not forget using the Smart Grid elements already deployed to enhance restoration. DOE has piloted a distribution solution that stands above, yet works well with, the other options. As DOE has demonstrated, Smart Grid implementation offers significantly improved performance to the distribution grid in impact mitigation and quicker restoration. When DOE awarded $111.5 million in Smart Grid stimulus funding to Chattanooga, Tennessee's Electric Power Board (EPB), President and CEO Harold DePriest had a goal to reduce outage duration by 40 percent, which represented an annual $40 million savings to customers. By July, 2012, the reduction was at 55 percent. By April, 2013, EPB was saving in excess of $12 million annually in operating costs and power outage losses. Its customers were saving approximately $50 million in avoided business costs.

Smart Grid efforts within the 600 square-mile service area included installation of around 1200 "IntelliRupter" smart switches at 12 kV, more than 200 smart switches on 46 kV lines, and 170,000 smart meters on business and residences. Power is now rerouted to minimize impacts and self-heal the system such that customers around an outage are often completely unaware of the disturbance. Outage durations are greatly reduced as maintenance crews are directed without delay to the sources of problems by the new grid intelligence.

Promotion of similar initiatives across the nation, leveraging the impressive results of DOE's recent and ongoing pilots, promises resiliency gains in distribution. A sampling of other options follows.

Excerpts from EPRI Report (#1026889)

What Can Be Done Now?

Several actions can be taken to prevent damage to the distribution system. These actions include:

- Vegetation Management –Tree trimming is a fundamental practice for mitigating local distribution outages.

- Undergrounding –Installing distribution lines underground takes them out of harm's way of trees, cars, and most lightning strikes.
- Reinforcing Overhead Distribution – Some of the most effective actions are relatively simple and straightforward, such as adding structural reinforcement to existing distribution lines. Examples include adding guy wires or using steel poles to increase the strength of the lines to withstand higher wind loading.

Where Can Innovation Be Employed?

- Pole and Line Design – Certain pole and line design configurations are less susceptible to damage from trees and falling limbs. Although hardening of the system is the intuitive solution, significant interest exists in better understanding the way that overhead systems fail and innovating new technologies to ensure that the systems fail in a manner that minimizes the restoration effort.
- Dynamic Circuit Reconfiguration – This operational design offers the opportunity to combine advances in information technology, communications, and sensors with innovations in restoration practices.

Recovery

Proper resiliency planning must provide for rapid damage assessment and crew deployment. To enhance the ability to respond and recover quickly, the U.S. electric industry has developed effective mutual assistance programs, in which transmission and distribution utilities call in crews from across a region to help restore downed lines, poles, and transformers.

What Can Be Done Now?

- Load Reduction – During outages, an established industry practice is to use load reduction programs to reduce demand on the system from customers who still have service.
- Restoration Management – Utility restoration management practices include procedures and systems to shift from centralized to decentralized restoration management.

Where Can Innovation Be Employed?

- Airborne Damage Assessment – EPRI recently completed preliminary tests showing that both small piloted aircraft and unmanned aerial vehicles (UAV) equipped with high-resolution cameras, global positioning systems, and sensors can be valuable tools for damage assessment.
- Outage Management System (OMS): At the heart of any storm response and damage assessment is the outage management system, which gathers outage information from a variety of sources and helps to predict outage locations and direct restoration efforts.

- Geographical Information System (GIS): GIS is rapidly becoming the foundation of distribution system documentation, because the map-based database is suited perfectly to tracking assets and monitoring the state of geographic dispersed assets.
- Asset Management System: As with any industry, keeping track of assets is crucial for utilities, because this management provides an interface between the engineering and the accounting sides of the business.
- Field Force Data Visualization – Use of data visualization technology for utility engineering and field operations.

Survivability

Survivability refers to the ability to maintain some basic level of electrical functionality to individual consumers or communities in the event of a complete loss of electrical service from the distribution system.

What Can Be Done Now?

The concept of assisting customers with survivability features is relatively new to the electric industry. Historically, many customers such as hospitals, banks and data centers have assumed responsibility for their own survivability, relying on generators or uninterruptible power supplies (UPS), and occasionally alternative distribution feeds.

- Communicating with Customers – Utilities are beginning to use both the Internet and smart phones to enhance the targeting and speed of their communications.
- Community Energy Storage – In the future, the electricity enterprise may benefit from cost-effective and reliable bulk energy storage to help balance and optimize supply and demand of bulk power resources.

Where Can Innovation Be Employed?

- Using PEVs as a Power Source – Plug-in electric vehicles (PEVs), both all-electric and hybrid, could be used to supply energy to a home during an outage.
- Using Photovoltaics (PV) Systems as a Backup – Increasingly, consumers are installing rooftop PV systems to augment grid-supplied electricity. (Use of advanced storage and inverters that are capable of islanded operation and re-synchronization are needed. Today's PV systems are generally not capable.)
- Matching Consumer Load to PV Capabilities – The existing controls associated with PV arrays are not sufficiently functional so as to match the electrical demand of a residence without presence of grid supply or local storage.
- Urgent Services – An opportunity exists to identify innovative technologies that can provide limited services or "urgent services" to critical aspects of community infrastructure. Examples include:
  - Cell phones
  - Use of conventional vehicles

– Traffic lights

Resiliency Improvement Opportunity as Aging Grid Assets are Replaced

Asset owners are being squeezed to manage opposing objectives and to seek new and better approaches for managing and maintaining transmission and distribution line and substation equipment. Although each asset owner's situation is unique, three predominant drivers are applying this pressure. The first driver is increasing stakeholder demands to improve performance. The second driver is financial pressure to control costs, avoid service interruptions, work more efficiently, and extend equipment life. The third driver is aging infrastructure—which in combination with the need to accommodate new growth has increased demand for capital and maintenance spending on a large scale. To help address these challenges, utility managers have turned to formal asset management strategies for controlling and directing resource investments.

It is also critical at the time of review for significant replacement and upgrades that non-wires solutions (NWS) be analyzed for their effectiveness to delay or obviate the need for replacement. With the trend of lower cost and increasing performance records for distributed generation, demand response, energy efficiency, and innovative dispatch strategies, NWS may be a more cost-effective and lower risk approach.

Advanced asset ages signal that a larger population will need to be replaced in the relatively near future. This increase in asset replenishment provides a synergistic opportunity to not merely replace assets, but enhance grid resiliency as well.

Many critical components of the overhead transmission system and substations were installed in the boom years of the 1960s and 1970s and are now near the end of design life—the age beyond which the risk of failure becomes increasingly likely. Equipment engineers commonly use a value in a range of thirty to sixty or more years as an expected design life for power delivery equipment depending on the asset type, but this is not the exact end of life number.

Equipment may function reliably well beyond that age. However, it is generally accepted that the risk of equipment condition deterioration and wear-out failure and the corresponding needs for preventive and corrective maintenance increase as equipment is used and ages. Yet chronological age is not the only measure of equipment condition and remaining life. Service in harsh environments, lightning exposure, high levels of loading, fault history, and many other factors can influence aging and deterioration.

Figure 1 illustrates the average condition of critical infrastructure of a typical utility.

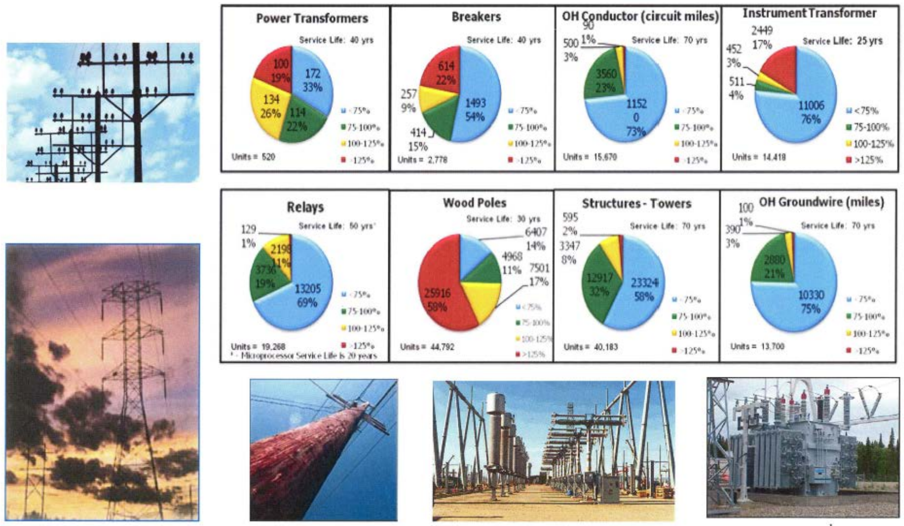

Figure 1
Aging Infrastructure – Typical Utility (Source: EPRI)

Aging Asset Proxy: Transformers

Substation transformers offer a key example of a critical asset in the power delivery infrastructure. Many are replaced when they fail. Will failure rates increase?

Many substation transformers were installed in the 1960s and 1970s and are approaching the end of their nominal design lives. Figure 2 below shows a typical age profile for over 7,000 units in a particular subset of in-service transformers contained in the EPRI transformer industry-wide database (IDB). Clearly depicted is the "asset wall" in the 35 to 45 year age bracket. This IDB data is aggregated from eight utilities with a variety of fleet sizes and service territories and is thought to be representative of the general industry in North America.

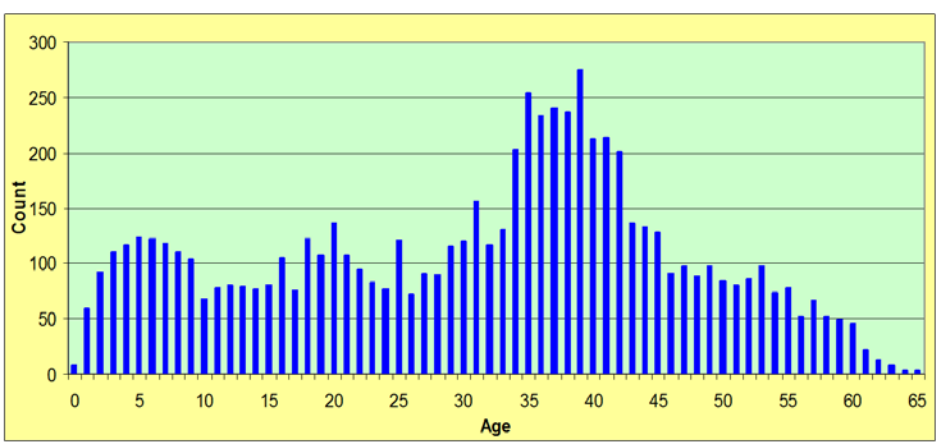

Figure 2
Typical Age Profile: In-Service Transformers

Like other types of equipment, transformers may follow a failure rate pattern similar to the familiar bathtub curve—an initially high rate of infant mortality failures, followed by a relatively low and constant failure rate during a long service life, then an increase in wear-out failures with impending end of life as depicted in Figure 3.

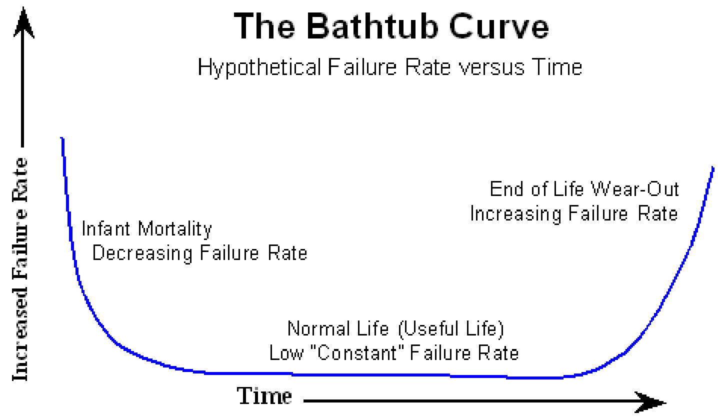

Figure 3
Failure Rate Over Time

One application of the IDB is to assess whether this curve accurately describes historical transformer performance. If the bathtub curve applies to transformer life,

- What are the parameters of the curve—especially the wear-out portion of the curve?
- Do the curve parameters change with different transformer makes, models, vintages, and applications?

Answering these questions is more important than ever as transformer fleets age and high replacement costs and uncertain lead times put more pressure on asset managers striving to meet high reliability standards. Figure 4 shows the relationship between a fleet demographic profile and a possible failure rate curve. As can be readily seen, the position of the asset wall relative to the point of increasing failure rates, the "back end" of the bathtub curve, will determine the number of expected failures. Understanding the failure rate parameters is a major objective of the IDB work.

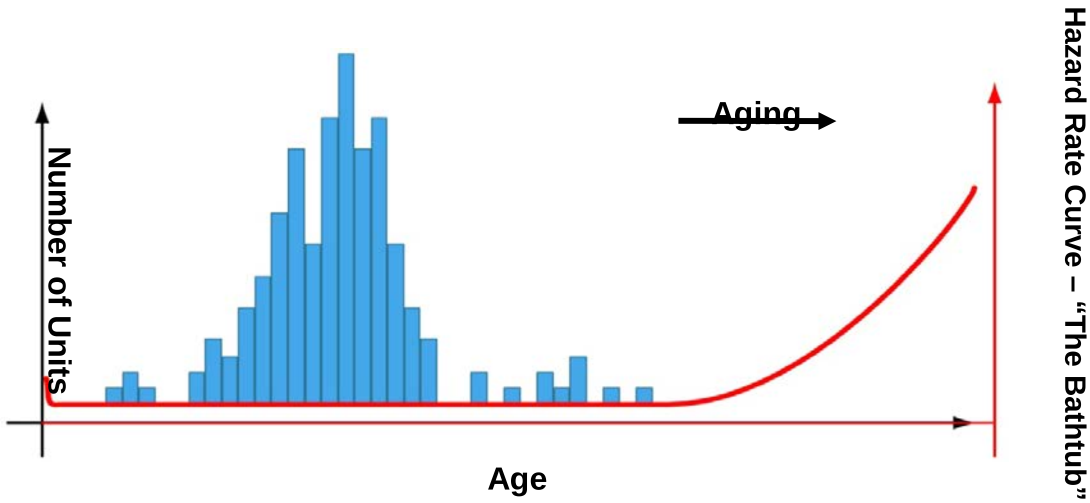

Figure 4
Relationship between Hypothetical Demographics and Failure Rate Curve

One goal of the IDB work is to develop appropriate hazard rates for transformer subsets of interest. The hazard functions can be convoluted with the corresponding in-service population to provide forecasts of anticipated failures.

In Figure 5, an application example for a set of transformers from a particular utility provides the probability distribution of the number of failures in the next year based on a hazard rate determined from IDB analysis. Also provided are 95 percent confidence bounds on these probabilities. For example, the expected probability of having two failures in the next year is about 0.27. The black bars are the upper and lower 95 percent confidence bounds on this individual probability. That is, there is 95 percent confidence that the true probability is between about .28 and .21. There is essentially zero percent chance of having greater than nine failures in the next year for this population. These results were computed using the appropriate hazard function and the transformer set demographic data. Such calculations can provide information useful for asset management and capital planning.

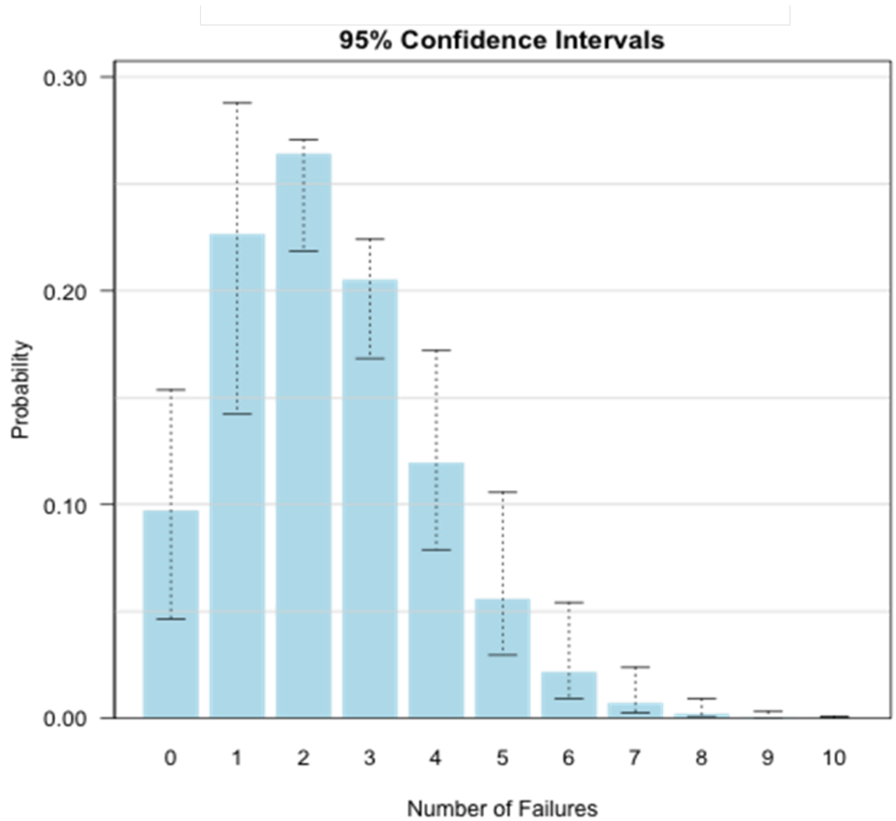

Figure 5
Application Example: Yearly Failure Projections

Electricity Advisory Committee Recommendations

There has been an increased focus on resiliency, especially after Super Storm Sandy. The EAC believes that DOE is well positioned to work with stakeholders to develop grid resiliency and component hardening guidance/shared practices that can be employed as asset are replaced/upgraded. These shared practices can be drawn from emerging technologies, new asset designs, and new service approaches to incrementally improve the existing grid or to create a new and radically different one.

We encourage a sensible approach to resiliency that factors in society's cost versus the benefits. We cannot protect against everything, but as the industry replaces assets, we believe feasible, less costly options can be incorporated to enhance resiliency anticipating many events that may come while also anticipating 21st century customer expectations.

The EAC recommends that DOE take an even more active, complementary role in industry resiliency efforts. Specifically, the DOE has outstanding resources that can be tapped (e.g., the national labs) and more direct liaison with DOD and DHS to do the following:

1. **Determine grid vulnerabilities, including sparing gaps, and develop grid component hardening guidance/best practices.**

   DOE should work with stakeholders to determine grid vulnerabilities (including sparing gaps) and to develop grid resiliency and component hardening guidance/best practices. These should be applied as assets are replaced in natural order as they reach end of life, or in some cases they might drive an accelerated schedule when benefits warrant. It is assumed that a risk-based approach will not generally result in aggressive time lines or material cost premiums. The EAC believes that a reasonable approach to grid hardening as assets are replaced will be as effective as similar programs such as the guidance/best practices applied to achieve energy efficiency..

2. **Use available R&D funds to support projects that fill gaps in the resiliency work of EPRI, NERC, and other organizations.**

   Important research areas include dynamic load flow control, grid level storage in conjunction with renewables, micro-grid implementation using storage with solar, smart invertors, innovative pole and line designs, structural reinforcement to existing lines, and non-wires solutions.

   DOE should coordinate with electric utilities and the Federal Energy Regulatory Commission (FERC) to ensure adequate support for the demonstration, commercialization, and resulting deployment of advanced transmission technologies. FERC is directed by statute, 42 USC §16422, in carrying out the Federal Power Act and Public Utilities Regulatory Policy Act, to "encourage ... the deployment of advanced transmission technologies." Additionally, the Federal Power Act, 16 USC §824s, mandates that, "Commission shall establish, by rule, incentive-based (including performance-based) rate treatments" that shall " ...encourage deployment of transmission technologies and other measures to increase the capacity and efficiency ... and improve the operation of [transmission facilities]..."

   DOE should explore with transmission utilities opportunities to support the commercialization, and thereby encourage the deployment, of advanced transmission technologies through appropriate recognition in transmission rates of costs associated with the demonstration and further development of these technologies. Appropriate rate recognition could leverage and help realize the economic benefits of DOE funded research and development.

   Likewise, DOE should encourage advanced technologies at the distribution level with utilities to support resiliency and work with entities such as the National Association of Regulatory Utility Commissioners (NARUC) to facilitate communication on resiliency needs to support funding.

3. **Convene meetings and technical workshops with EPRI, NERC, and others to integrate system performance modeling and utility best practices for resiliency.**

4. **Develop presentations (based on results of the preceding recommendations) for industry and regulatory leaders that provide sensible and affordable "blueprints" for actions (based on cost/benefit risks) and regulatory cost recovery authorization.**

   These presentations should include best practices for enhancing maintenance, spare component, and capital replacement programs to increase grid resiliency, for non-wires solutions to ensure lowest cost and risk planning as well as best practices.

5. **Support the incremental investments to demonstrate how systems that already have distribution automation, smart meters and distributed generation can be designed to sustain critical social services in the event of large scale power outages of long duration.**

   By conducting and publicizing two or three such demonstrations, DOE might provide utilities, regions, and regulators the confidence for similar investments using local resources.

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Electricity Advisory Committee

MEMORANDUM

TO: **Honorable Steven Chu, Secretary**
Honorable Patricia Hoffman, Assistant Secretary for Electricity Delivery and Energy Reliability

FROM: **Electricity Advisory Committee**
Richard Cowart, Chair

DATE: **October 28, 2011**

RE: **Recommendations on U. S. Grid Security**

Introduction

The US economy and life as we know it are becoming much more dependent on electricity and it is a fundamental responsibility of government to ensure our national security. Certainly, 100% security cannot be guaranteed or afforded, but the grid can be hardened in smart ways over time as the electric industry replaces aging assets and deploys new assets. As we have built national security into the interstate highway system over time, we should do the same for the grid. Short, aggressive time lines are not recommended so as not to unduly burden consumers.

The electric industry has performed admirably to restore the grid for hurricanes and other natural phenomena. The grid has shown remarkable resilience for these phenomena and other wide spread events over the years. However, further work is needed to better understand potential steps for addressing wide spread high impact, low frequency (HILF) events, such as high altitude electromagnetic pulses (EMP). We acknowledge that several initiatives are underway by NERC, EPRI and others to address geomagnetic disturbances (GMD), coordinated terrorist attacks, and cyber attacks. However, DOE is in the best position to broaden and complement these efforts that can yield the development of R&D, guidance, and best practices to harden the grid for national security in coordination with other agencies, such as DOD and DHS.

The DOE Electricity Advisory Committee (EAC) specifically cites one of the most aggressive initiatives being NERC's Critical Infrastructure Strategic Roadmap developed by the Electricity Sub-Sector Coordinating Council and approved by the NERC Board of Trustees in November 2010. The goals of the NERC effort are:

1) Enhance situational awareness within the electricity sub-sector and with government through robust, timely, reliable, and secure information exchange.

2) Use sound risk management principles to enhance physical and cyber measures that improve preparedness, security, and resilience.

3) Conduct comprehensive emergency, disaster, and business continuity planning. Conduct training and large-scale exercises involving electricity industry and government entities to enhance reliability and coordinated emergency response.

4) Clearly define critical infrastructure protection roles and responsibilities.

5) Enhance understanding of key interdependencies and collaborate with other critical infrastructure sectors to address them, and incorporate that knowledge in planning and operations.

6) Strengthen public and government regulatory agency confidence in the sub-sector's ability to manage risk and implement effective security, reliability and recovery efforts.

Several task forces are underway as part of this effort, including: 1) Geomagnetic Disturbance Task Force, 2) Severe Impact Resilience Task Force, 3) Cyber Attack Task Force, and 4) Spare Equipment Database Task Force.

Electricity Advisory Committee Recommendations

The EAC recommends that the DOE take a more active, complementary role in NERC's efforts. Specifically, the DOE has outstanding resources that can be tapped (e.g., the national Labs) and more direct liaison with DOD and DHS to do the following:

1. **Determine Specific Grid Vulnerabilities to HILF Events and Cyber Attacks**

   The electricity industry is diligently working to determine grid vulnerabilities to GMD and cyber attacks. DOE can complement this effort to develop modeling and testing in support of grid component hardening guidance/best practices and identification of critical component sparing gaps. In addition, DOE in coordination with DOD and DHS can develop a risk-based approach to grid hardening that balances cost to the consumer with the need for grid security.

2. **Development of Grid Component Hardening Guidance/Best practices**

   Based on the above modeling, testing and risk-based assessments, the DOE should work with the electricity industry via the cited NERC efforts and manufacturers to develop grid component hardening guidance/best practices. These guidance/best practices should extend to components at generating stations and critical loads. These guidance/best practices should be applied as assets are replaced in natural order as they reach end of life. It is assumed that a risk-based approach will not result in aggressive time lines or material cost premiums. The DOE EAC believes that a reasonable approach to grid hardening as assets are replaced will be as effective as similar programs such as the guidance/best practices applied to achieve energy efficiency.

3. Determine Specific Gaps in Sparing Critical Components

The electricity industry via EEI, NERC and other actors has taken a reasonable approach to sparing large, long lead-time transformers. Based on the risk-based assessment cited above by DOE in coordination with DOD and DHS, there may be gaps in sparing these and other critical components. The DOE EAC recommends that DOE complement industry efforts to determine these gaps and to develop a reasonable implementation plan balancing cost to the consumer with grid security.

These three recommendations were unanimously approved by the Electricity Advisory Committee at its meeting on October 20, 2011.