Future of U.S. Electric Distribution

Prepared by Paul De Martini

Introduction

This paper is the second in the Future of Distribution series that summarize the historical and future evolution of the US electric distribution system to reliably and securely meet changing customer needs and energy policy objectives. Specifically, this paper provides a foundational overview of the future of U.S. electric distribution systems. The opportunities and challenges regarding accelerating technology advancements, infrastructure investment, reliability, and cyber security are highlighted. A list of recommended articles, reports and books on topics in this paper is included for further reading.

Future of Distribution

Thirty years of energy policy and industry structural changes are combining with accelerating social and technological evolution are bringing the electric industry toward a tipping point for disruption. Over the past few years, several prominent government, academic and industry forecasts for the future of the electric grid have been developed. EEI sponsored a multi-stakeholder future scenario analysis in 2010.[1,2] These future scenarios and forecasts have attempted to frame many of the characteristics and implications of the electric industry transition that is underway. The five trends below are adapted from the EEI analysis and are consistent with many other assessments:

It's not whether… it's when, and it's likely sooner than you think
The industry will be transformed by advanced technology for distributed and renewable generation, grid operation, customer energy efficiency/management and social networking technologies. Scenarios differ mainly in the pace and shape that change occurs. Bill Gates said, "We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten."

Technology advancements will be game-changers
Technology advancements are expected to have an enormous impact. Given that much of the investment decision making in the electric industry involves time periods of between 5-30 years, it is essential to understand the rate of technological change. One challenge is understanding the range of technologies under development (energy storage) and appreciating the reality of unforeseen

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[1] These documents are listed in the "Further Reading" section at the end of this paper.
[2] Berst, J., Smart Grid Scenario Workshop Summary, Edison Electric Institute, October 2010

advancements (like smart phones and energy apps in 2007). To underscore the pace of change, noted technologist and futurist Ray Kurzweil[3] observed, “An analysis of the history of technology shows that technological change is exponential, contrary to the common-sense 'intuitive linear' view. So we won't experience 100 years of progress in the 21st century—it will be more like 20,000 years of progress (at today's rate).”

Choice and diversity are key drivers

Many options will be available for generation, storage, grid management and demand management. The rise of distributed options will create a hybrid structure of large centralized resources on the bulk transmission system with an equally import mix of utility, merchant, and customer distributed energy resources connected via distribution. Added to these options will be a variety of hardware and software to manage load, far beyond the basic energy efficiency and demand response offerings developed to date. This will result in a many-to-many relationship between the various market participants.

Consumers become Prosumers

Business and residential customer adoption of a wide range of distributed energy resources (demand response, distributed generation, energy management, and energy storage), participation in markets and providing grid (transmission and distribution) support services create a new class of grid customer that is not just a consumer, but also a producer - a “Prosumer”. As has been seen in the breakdown of traditional value chains in other industrial sectors over the past 20 years, the resulting change in value creation becomes more customer-centric as opposed to biased toward the upstream.

New business models will emerge and existing models will need to evolve

The US electric industry is at a tipping point in several regions caused by distributed energy resources and other options affecting utility distribution system that is triggering the need for fundamental change in the roles and relationships for not only utilities but also customers as they also become providers of energy and services. This evolution necessitates redesign of retail rates, business models for utilities, access rules for third parties, and changes in the traditional institutional tools used by state utility commissions and other policymakers. Also, the convergence of Web 2.0 technology[4] and business models using social networking is creating a new category of “Social Business” that looks to reshape business models over this decade and beyond in many industry sectors, including the electric distribution business. A key consideration in any new business model for utilities and competitive firms is product/service differentiation based on deeper understanding of customer wants and needs. As such**,** competitive energy services businesses are evolving their business models to take advantage of social business innovations as well as defend against competition from new entrants and those from adjacent industries look to expand their offerings to include energy related services.

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[3] Raymond Kurzweil, The Singularity is Near, Penguin Books, 2005

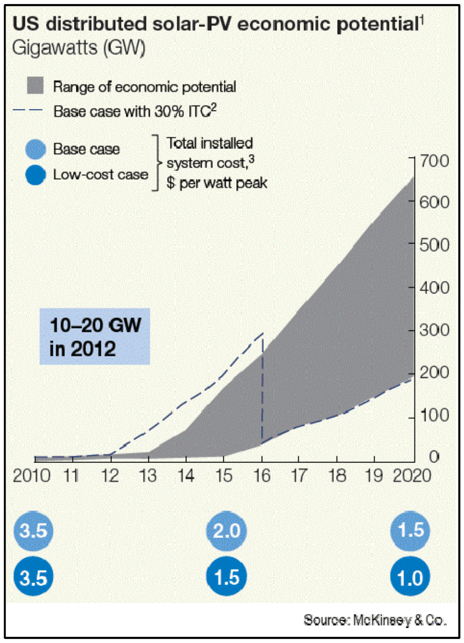
[4] Wikipedia defines Web 2.0 as a term for the concept of the internet as a platform for information sharing, interoperability, user-centered design, and collaboration.

Disruptive Technologies on the Horizon

A number of advancements in energy technology and information and communication technology related to distribution systems have reached or beginning to achieve commercial viability at scale. The summary below highlights key technologies that have significant potential to shape the pace and scope of distribution system design and operation:

Distributed Generation (DG): Distributed generation is at the inflection point of the adoption curve in the US market for both commercial and residential markets and will be a significant factor in reshaping the electric industry. Pike Research's recent analysis of US industrial distributed generation (IDG)[5] observes that traditional natural gas fired combined heat and power generation are now competing with fuel cells and solar PV technologies. In addition to traditional reliability and efficiency adoption drivers, access to wholesale electricity markets are creating additional revenue streams from selling energy, capacity, and ancillary services to grid operators. Pike's forecasts total IDG capacity will increase by 46-85% between 2011 and 2016, rising from 91 gigawatts (GW) to between 133-168 GW during that period.

US distributed solar-PV economic potential[1]
Gigawatts (GW)



Source: McKinsey & Co.

Today, 43 states have net metering policies and twenty-nine states have renewable portfolio standards. Of the states with RPS, seventeen states have added mandates/programs for solar and other DG. McKinsey's recent solar PV forecast[6] estimates the levelized cost of electricity (no margins) from an installed solar PV system to reach $0.10/kWh by 2020. McKinsey concluded, "Growth is likely to continue in these segments after 2012, potentially reaching a tipping point in 2014 or 2016 that could enable unsubsidized demand for solar PV to grow to between 200 and 700 GW by 2020. Demand is likely to be concentrated in 10 states. Indeed, 50 percent of the available power delivered to the residential and commercial segments in some of these states may be generated by solar PV in 2020."

Plug-in Electric Vehicles: Plug-in electric vehicles (PEV) are a key technology to achieve the societal benefits of electrification of the transportation sector – the largest consumer of oil in the US. PEVs also have unique operational attributes related to the onboard batteries. These batteries can also be used to provide grid support services in terms of both reduction of demand while charging and storage of energy. PEVs may be parked, connected and available for dispatch as much 95% of the time at work, home or other locations. A challenge today in consumer adoption of PEVs has been vehicle cost and driving range, both due to mostly to current battery technology. This may be about

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[5] Pike Research, Industrial Distributed Generation, December 2011
[6] McKinsey & Company, Solar power: Darkest before dawn, July 2012

to change as McKinsey in a recent report[7] forecasts that, "complete automotive lithium-ion battery pack could fall from $500 to $600 per kilowatt hour (kWh) today to about $200 per kWh by 2020 and to about $160 per kWh by 2025." Technology advances through 2030 will likely result in increased adoption of PEVs over the period and become an important consideration for grid planning and operations.

Energy Storage: Energy storage has the potential to enable the electric system to be more reliable and stable. Also, provide better power quality and customer-side energy management. Distributed energy storage (DES) technology typically involves chemical (battery), flywheel and thermal based solutions. Thermal solutions are commercially viable and in use, while battery solutions are at an early stage of development but expected to reach commercial viability in distributed scale by 2020. Battery technology using various chemistries remains a key technology for DES and PEV advancements as noted above. Solar PV adoption rates may further stimulate interest to fully commercialize DES. According to Pike Research[8], while the energy storage market is immature the total number of utility scale projects deployed and announced (including inactive projects) still rose 8%, from 600 to 649 during the first half of 2012. Pike also forecasts that total worldwide installed capacity for community and residential energy storage systems (CRES) will reach 780 megawatts in 2022. At an average CRES installation size of between 5-50 kWh this could be 50,000 units or roughly one storage unit on 10% of US's 500,000 distribution circuits.

Power Electronics: Power electronics based devices including inverters, converters, Volt Ampere Reactive (VaR) compensators, fault current limiters and solid state transformers are increasingly part of distribution systems for power flow control or interface with generation and storage equipment. Specifically, power electronics devices provide an interface between electrical systems, such as an interconnection of two alternating current (AC) circuits to manage power flows or a means to convert AC to direct current (DC) to charge electric vehicles and vice versa as in the case of inverters for solar photovoltaic systems. According to the Department of Energy[9], approximately 30% of electricity flows through power electronics today and by 2030, the amount will reach 80%.

Sensing & Measurement: Wide spread deployment of sensor technology across distribution systems is occurring in the form of intelligent electronic devices in substation and distribution equipment, fault current indicators, transformer and conductor temperature sensors, dissolved gas sensors, phasor measurement units and power quality and energy meters. Today's activities appear to be the tip of the iceberg of what is expected by 2030 as cheaper, more energy efficient, and communicating sensors[10] will be increasingly deployed by utilities and both commercial and residential customers[11]

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[7] Hensley, Newman and Rogers, Battery technology charges ahead, McKinsey Quarterly, July 2012

[8] Pike Research, Community and Residential Energy Storage, July 2012

[9] DoE Office of Electricity Delivery & Energy Reliability, Power Electronics Research & Development Program Plan, April 2011

[10] Koomey, J., The Computing Trend that Will Change Everything, MIT Technology Review, April 9, 2012

[11] Lohr, S., The Internet Gets Physical, New York Times, December 17, 2011

providing streams of Nano data[12] that can support the higher resolution needed for greater operational situational awareness and equipment health in the future.

Connectivity: Utilities worldwide are rethinking their telecommunications needs and infrastructure architectures for the next two decades to reflect enterprise technology advances and migration of consumer technology trends[13] into business and utility operations. These architectures are also addressing requirements for highly available, low latency[14] wired networks to link substation and control center operations, as well as robust, secure wireless field area networks to support distribution automation, mobile field force automation, smart metering and DER integration. Utilities are moving away from single point and single purpose telecom solutions toward enterprise-type multi-point and multi-purpose technology solutions. Cyber security considerations will play a more prominent role in electric distribution telecom network design and technology selection.

Analytics & Advanced Controls: Transmission *and distribution* operations will increase their reliance on machine-to-machine interaction for grid protection and control as sensing and reaction times decline in response to highly variable resources. Economic and engineering decisions by utilities and customers are being informed and initiated by powerful algorithms converting large amounts of data into valuable information feeding both operational decision support and advanced control systems. This rich set of situational intelligence will be mashed-up with asset, weather and other external relevant information in a geospatial context for operators, engineers and other decision makers. Smart meter systems increase energy consumption and other related service data by more than 10,000 times. A phasor measurement system on 500 distribution substations could stream 15,000 operational data packets every second. In addition to controls, management of assets will also rely on the information sources to increase asset utilization and improve asset management. Key to these controls and decision support applications are advancements in algorithm design and programming are far outpacing those in computer processing. The President's Council of Advisors on Science and Technology recently noted an example of a production planning model using linear programming that would have taken 82 years to solve in 1988 whereas in 2003 it took about one minute due to a combination of 1,000x improvement in processor speed and an improvement in algorithms by a factor of 43,000.[15]

Social Networks: Social networking will become a critical element of how consumers and prosumers will interact with utilities, grid operations and markets. Customers' expectations for utilities and competitive energy services firms have likewise been raised, particularly for digital natives and increasingly for digital immigrants[16]. Additionally, utility interfaces with customers are no longer just

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[12] Nano data refers to very small data sets produced by small, ultra-low powered sensors

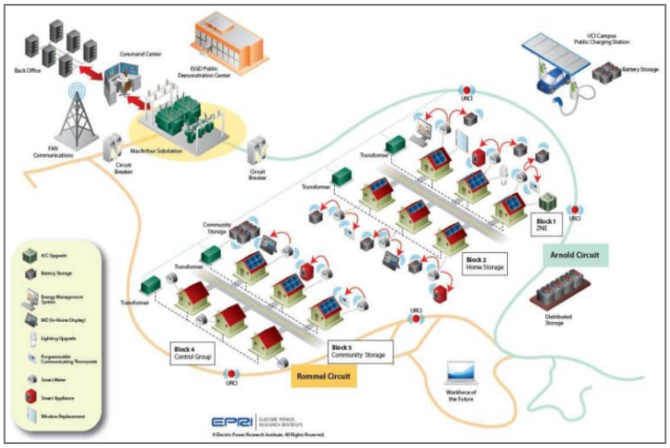
[13] According to Cisco, the number of devices connected to Internet Protocol (IP) based networks will be nearly three times the global population in 2016 - up from over one networked device per capita in 2011. And, over 60% of the resulting video, voice and data traffic will be from wireless devices by 2016.

[14] Latency refers to the time from the source sending a voice/video/data packet to the destination receiving it

[15] President's Council of Advisors on Science and Technology, Designing a Digital Future: Federally Funded Research and Development in Networking and Information Technology, December, 2010

[16] Prensky, M., Digital Natives, Digital Immigrants, MCB University Press, 2001. Digital natives are those people born after the PC was introduced and have grown up with the personal computer, internet, digital media and social networking. Immigrants are those born beforehand and have had to adapt.

business-to-customer, but also increasingly machine-to-machine/s and organization-to-communities of customers through social networks. According to the Pew Research Center, 80% of US adults are now online, 88% have cell phones and 46% with smart phones, and half are using social networking sites. IBM's 2011 Global Utility Customer Survey[17] found social networking was twice as likely to be a primary source of information for those 18-24 than for those 25-34, and six times more likely than for those 35 and older**.** On-line video content was five times as likely to be a primary source of information for those 18-24 than for those 25-34, and nine times more likely than for those 35 and older**.**



Planning & Operational Considerations

The challenge for regulators, utility decision makers and engineers is to effectively overhaul the nation's distribution infrastructure while continuing to provide reliable, cost effective, and secure services as the system is used in a manner inconsistent with its original design. Technology adoption decisions are compounded by accelerating technological change. A brief discussion of the considerations related to Distribution Design, Investments and Operations are provided below to facilitate the public-private dialog.

Distribution Design

Utility engineers, researchers and vendors worldwide are considering distribution systems designs that can enable the transition over the next 20 years and beyond. It is clear that the distribution system will play a critical role in enabling this future. However, the current infrastructure will have to be transformed to accommodate this future. Physical infrastructure, Operating Systems and Cyber-security are three important areas of engineering and design focus.

Distribution circuits of the future will need to accommodate bi-directional power flows from distributed and variable energy resources while incorporating self-healing devices to allow for automated circuit reconfiguration. To accomplish this, distribution designs will evolve from radial designs to other configurations, like the loop designs currently being tested in several utility demonstration programs.[18] Distribution will also need to become more like transmission by evolving from passive/reactive management to active management.[19] As described earlier, power electronics based devices that manage power flows and power quality will play a key role in the active management along with controllable DER.[20]

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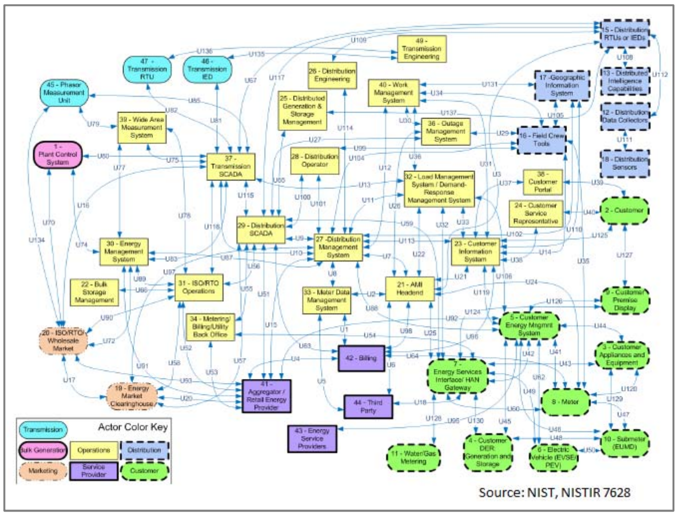
[17] IBM survey summary; http://aie.org.au/StaticContent%5CImages%5CMEL120417_Presentation.pdf

[18] Utility-EPRI Smart Grid demo projects: http://www.smartgrid.epri.com/DemoProjects.aspx

[19] McGranaghan, M., et al, Renewable Systems Interconnection Study: Advanced Grid Planning and Operations, Sandia, 2008

[20] Vartanian, C., et al, Circuit of the Future: Interoperability and SCE's DER Program, Joint Paper SCE, WVU, NETL, 2007

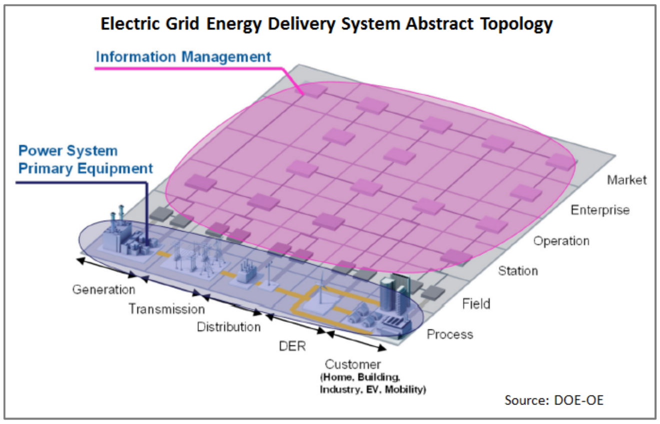


Source: NIST, NISTIR 7628

Distribution operational systems will also evolve in complexity and scale over time as the "richness" of systems functionality increases and the reach extends to greater numbers of intelligent devices. These systems are based on architecture that embeds digital processing, analytics and control software at many locations in and along the power grid infrastructure to implement flexible grid automation. Such systems may be completely distributed, or involve distributed elements with centralized management and coordination. This increased complexity requires new architectural approaches to manage data and controls across tens of millions of end points, federated controls to manage various latency requirements for certain grid operations, system security, reliability and extensibility. Carnegie Mellon[21] describes these Ultra Large Scale (ULS) systems as having three principal attributes:

- Decentralization: ULS will be decentralized in terms of data, development, evolution, and operational control
- Inherently conflicting and unknowable requirements: ULS systems will have a wide variety of stakeholders with unavoidably different and conflicting requirements
- Continuous evolution and deployment: ULS systems will be continually adding new functions and new content. Phased development or deployment is not possible
- Normal failure: Software and hardware failure will be the norm rather than the exception.

Utilities, vendors, the national labs and other leading research universities such as Caltech[22] are developing control system architectures to address these issues. These emerging control architectures go far beyond the necessary foundational aspects of service-oriented architectures and the use of interoperable standards currently being adopted in the industry.[23,24]


Electric Grid Energy Delivery System Abstract Topology

Source: DOE-OE

Cybersecurity

The transformation of traditional energy networks to smart grids requires an intrinsic security strategy to safeguard this critical infrastructure. As discussed in the "State of

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[21] CMU-SEI, Ultra Large Scale Systems: http://www.sei.cmu.edu/library/assets/ExploringArchitectureULSsystems.pdf

[22] Chandy, M., Gooding, J., and Mc Donald, J., Smart Grid System of Systems Architectures, Caltech-SCE, 2010

[23] Gridwise Architecture Council, Decision Maker Checklist v1.0, 2007

[24] Smart Grid Interoperability Panel, Catalogue of Standards, 2012

Distribution"[25] paper, the few distribution automation systems were largely closed, proprietary point-to-point systems that had very few interfaces to other systems. As described in this paper, this is changing as more systems are being introduced with a myriad of interfaces and a three orders of magnitude expansion of connectivity to millions of devices in the field. The increased coupling of transmission and distribution systems also increases both the system complexity and cyber security scope due to the increase in potential attack surface. The graphics above from the National Institute of Standards and Technology's (NIST) cyber security guidelines[26] and Department of Energy's (DoE) cyber security maturity model[27] illustrates these points for utility systems and interfaces to external parties. In the US, concurrent and complementary public-private efforts are underway to address the development and implementation of such a lifecycle approach for the electric industry.[28,29]

Additionally, more sophisticated risk management based methods and holistic systems engineering approaches are required to address the coming scope and scale of the distribution systems at large. The recent DoE Risk Management Process guideline [30] addresses important aspects by defining methods to "implement a new cybersecurity program within an organization or to build upon an organization's existing internal cybersecurity policies, standard guidelines, and procedures." Combined with DoE's recently released maturity model and the work products of the SGIP Cyber Security Working Group, EPRI and other utility working groups, a substantial body of knowledge and practice is available.

However, the very difficult task still lies ahead with the implementation of these methods, tools and technologies as the distribution system and distributed energy resources grow in critical importance to the operation of the electric system as a whole. The distribution system is starting at a very low level of sophistication and application of secure technology. While much attention and investment in security requirements and measures have been directed at the bulk power system over the past decade, comparatively little has been done at distribution. Verizon's Energy & Utility Practice estimates that 97% of the US electric grid circuit miles – from transmission to distribution – are not covered by any cyber security mandates. However, this also means that there is an opportunity to build the security in from the beginning as new systems are deployed and older systems are replaced. This has begun with smart meter systems, customer interfaces and now with distribution automation. More is needed as identified in the Government Accounting Office's report[31] earlier this year.

Investments

Distribution investment today is directed toward achieving the objectives below in a cost effective manner and mindful of customer rate impacts:

- Improved grid reliability and resiliency (including infrastructure refresh & cyber security)
- Improved grid efficiency reducing system losses

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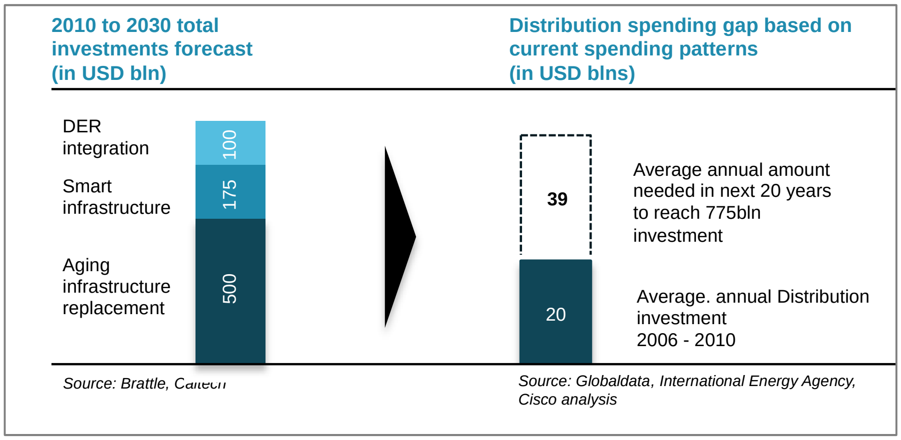
[25] De Martini, P., State of Distribution, EEI, July 2012
[26] NIST, NISTIR 7628 Guidelines for Smart Grid Cyber Security, 2010
[27] DOE-OE, Electricity Subsector Cybersecurity Capability Maturity Model (ES-C2M2), May 2012
[28] SGIP-CSWG, Introduction to NISTIR 7628: Guidelines for Smart Grid Cyber Security, October 2010
[29] EPRI, Cyber Security Strategy Guidance for the Electric Sector, July 2012
[30] DOE-OE, Electricity Subsector Cybersecurity Risk Management Process, May 2012
[31] GAO, Challenges in Securing the Modernized Electricity Grid, February 2012

- Integration of large amounts of renewable resources both central and distributed
- Broader market participation by independent energy resource suppliers and customers
- Improved system utilization through improved power flow management



Source: Brattle, Caltech

Source: Globaldata, International Energy Agency, Cisco analysis

However, to accomplish these objectives, distribution investment will likely need to go beyond the current scale and scope to begin to integrate more sophisticated sensing, advanced protection and control systems, circuit designs and grid stability devices over the next 20 years. Specifically, Brattle estimated $675 billion through 2030 for distribution investment.[32] This projection included approximately $500 billion to replace aging infrastructure and $175 billion for smarter grid investments. However, these amounts do not include the additional advanced technology and distribution reinforcements to fully enable DER growth trends through 2030.[33] Caltech estimated another $100 billion may be needed to address the advanced grid modernization described in this paper.[34]

Growing cyber threats along with a larger attack surface may result in rising operating expenses. Bloomberg's cyber security spending survey[35] of 21 energy companies including 14 utilities found:

- Average of $45.8 million/year on computer security to prevent 69% of known cyber attacks
- To avert 88% of attacks, spending rise to an average $69.3 million/year
- To avert 95% of attacks, take an average of $344.6 million/year per company

The Bloomberg figures likely also include capital costs and have some overlap with the capital costs identified above.

The challenge is clear, these costs will be borne by utility customers at the same time there are increased costs due to the change in the generation mix and increased transmission investment. The need for policymakers and utilities to educate consumers on the need for distribution investment and to develop appropriate cost-recovery models will be unprecedented.

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[32] The Brattle Group. "Transforming America's Power Industry", 2008

[33] ASCE, Failure to Act report: http://www.asce.org/uploadedFiles/Infrastructure/Failure_to_Act/energy_report_FINAL2.pdf

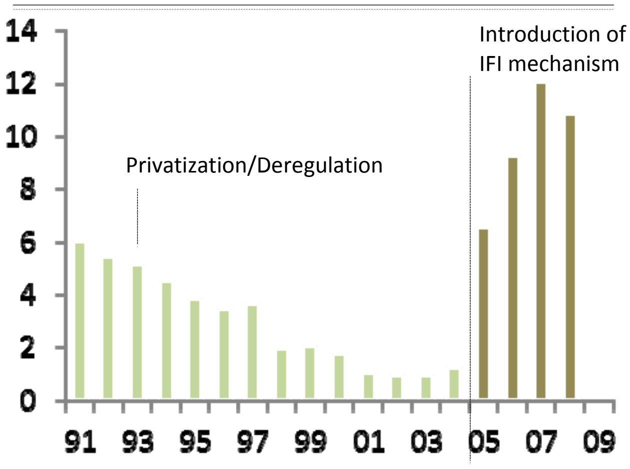
[34] Smart Grid investment is about 25% of Brattle's $675 billion estimate, plus Caltech estimated an additional $100 billion for more advanced controls and devices to be deployed 2020-30 identified in this paper.

[35] Bloomberg Energy Company Cyber Security Spending Survey: http://www.bloomberg.com/news/2012-02-01/cyber-attack-on-u-s-power-grid-seen-leaving-millions-in-dark-for-months.html

Aside from the important cost considerations, there are two additional aspects to consider. One is that many of the technologies discussed in this paper are at early stages of development. The energy technology and ICT industry has only begun the initial development of systems to address the scale and scope of distributed resources, devices and infrastructure over the next 20 years. While many papers and requirements have been developed over the past five years regarding the need for advanced distribution infrastructure and systems, only recently has there been sufficient demand for technology firms to invest in product development. Under favorable conditions, new product development can take between 3-5 years to become operationally viable to deploy at mass scale in grid operations. Achieving this rapid pace of development will require a close collaboration between technology firms and utilities to refine, test and demonstrate the products as part of a structured applied research, development and demonstration program (RD&D). Without utility RD&D, new technologies cannot reach commercial viability – "cross the chasm".[36] The US utility industry spends on average about 0.2% of revenues[37] on RD&D. As a result, technology development and adoption has historically taken 6-10 years or more for mass scale deployments. The recent accelerated adoption of smart meters augmented with federal taxpayer dollars rather than utility rates is an exception. State commissions have traditionally not been willing to fund major utility R&D initiatives through distribution rates, thus leaving investment by the private, non-government sector as a critical element. This approach is insufficient to achieve the level of modernization required. The United Kingdom's successful Innovation Funding Incentive model for distribution R&D is an alternative approach for the US to consider.[38]

Effect of UK's IFI on Dist. R&D spending

Investment amounts in GBP per year



Source: E.On Central Networks

Second, technology advances relevant to DER and distribution systems are evolving at rates roughly three times faster than the corresponding distribution system asset lifecycle. Distribution systems are comprised of various assets with different depreciation lives. Transformers and switches may have 40 year asset life, whereas a field area communications network may have asset life of between 7-15 years, distribution automation software has a seven year life and the computing hardware only 5 years. Given the level of investment in distribution infrastructure today, decision makers are increasingly concerned about the potential for stranded costs as technology deployed today becomes functionally obsolete

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[36] Moore, G., Crossing the Chasm, Harper Business, 1991

[37] NETL, Barriers to Achieving the Modern Grid, 2007

[38] UK Ofgem, Innovation Funding Incentive: http://www.ofgem.gov.uk/Networks/Techn/NetwrkSupp/Innovat/ifi/Pages/ifi.aspx

before its depreciation life. The problem, of course, is that no knows exactly how the transition will evolve and many of the technologies will make significant advancements by 2020, let alone by 2030. There are technology management approaches to mitigate, not avoid, the potential technology risk.[39] The magnitude of the distribution capital and operating expenditures are massive and the potential technology risk over the next 20 years present a very difficult set of decisions today in the face of forecasted declines in the growth of utility distribution revenues and rate pressures in the current economic climate.

Operations

Complexity Management: The scale and scope of the grid as described above is vastly more complex than the existing electric system – which has been described as the largest and most complex machine on earth. This is in part, why a significant amount of academic interest from non-traditional departments has blossomed since 2005. For example, many of the complex systems have similar characteristics to those used in other industries like avionics and managing information flows over modern telecom networks. We are evolving from a human centric operational model to a machine centric model, much as the aviation industry has evolved to "fly-by-wire" systems. Similarly, many of the most advanced aircraft are inherently unstable and need advanced control systems to operate safely. The German electric system is an early example of this level of operational instability and complexity. Society is generally not tolerant of grid disruptions. Like aerospace systems, failure is not acceptable. This has critical implications as we adopt and adapt new technologies and designs into the existing operating system – like changing the engines and avionics on a plane during flight.

Modeling & Process evolution: Similar to the experience of other states, KEMA's assessment of Massachusetts DG interconnections[40] noted, "The total KW volume of interconnection applications reviewed by either the Expedited or Standard path has grown seven-fold over the years between 2004 and 2010. Continued growth is likely." The challenge with this growth is there is generally a gap with respect to regional planning for DER at the distribution substation and related feeder system. Given that power flows can be redirected across a substation and its feeders, a more holistic planning process would consider the impact of planned DER development/grow on the system – not just on one circuit. This is compounded by a lack of commercially adopted stochastic engineering models to assess the impact of variable DER on distribution systems at scale – there is a clear need to move beyond heuristics and deterministic models.

T&D Operational Convergence: Grid operations have classically been separated between transmission operations and distribution operations. While there has been coordination, the relationship has been very loosely coupled on the presumption that power flows from transmission to distribution, so what happens at distribution has little effect on transmission under most operating conditions. Conversely, transmission conditions can materially impact distribution operations. However, for the reasons discussed in this paper this is beginning to change. Distribution system conditions and distributed energy

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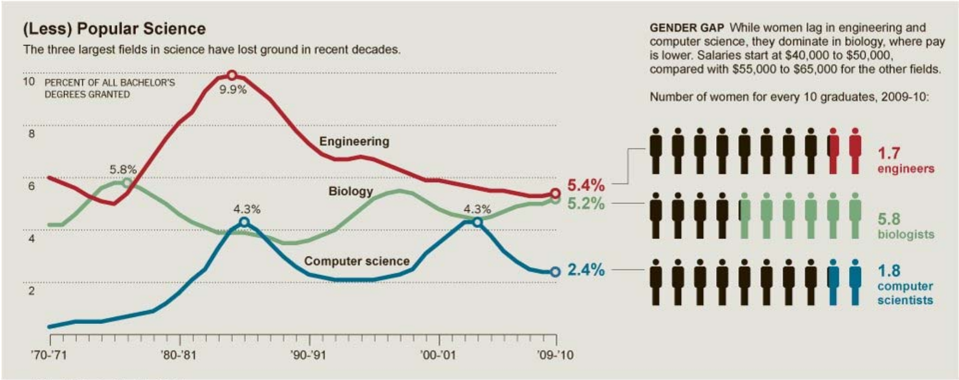
[39] EPRI, A Utility Standards and Technology Adoption Roadmap, October 2011

[40] DNV KEMA, Massachusetts DG Interconnection Study Final Report, July 25, 2011

resources will increasingly have a material impact on at least regional transmission systems[41]. Over the past few years, transmission operators have been discussing and requesting access to "deep situational awareness" to gain better understanding of DER operational state. Ultimately, if the level of distributed energy resources reaches the potential suggested by the various forecasts, transmission grid operational control systems will need to converge to ensure grid stability and reliability. Grid operators in Europe and Canada are already discussing the growing need and potential for more tightly coupled transmission and distribution operations.[42]

Utility Workforce: 50% of the existing utility workforce is expected to retire by 2020. Utility workforces are predominately comprised of baby boomers born between 1946 and 1964 that started reaching the traditional retirement age of 65 last year. Additionally, recent cost cutting measures have also contributed to the disappearance of utility personnel. The question is how to manage the transition of relevant knowledge and experience to the next generation of employees and at the same time introduce new thinking and approaches into utility operations. The utility industry has been particularly effective in engaging all level of the education system. Research collaboration and internships with research universities, curriculum design and co-teaching courses at university engineering, economics and other relevant departments, craft-skill training and work-study programs at community colleges and K-12 outreach and support for math and sciences along with energy related curriculum. A continuing challenge is the dramatic decline in math and science programs and graduates.[43] Also, job and career expectations of younger generations have changes significantly, with the US Department of Labor estimated that new entrants in the workforce will have between 11-14 jobs by the time they reach 38 years old.[44]



Source: National Center for Education Statistics

THE NEW YORK TIMES

Key Takeaways

US distribution systems and operations by 2030 will have significantly evolved. The transition is underway and the current pace place policy and utility investment and business model decisions on critical path to this future. The continuing public-private dialog by regulators and utility executives and other important stakeholders across the nation is essential to a successful transition.[45] Much has been

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[41] Roozbehani, M., et al, Volatility of Power Grids under Real-Time Pricing, MIT, 2011

[42] National Grid UK, Operating the Electricity Transmission Networks in 2020, June 2011

[43] Drew, C., Why Science Majors Change Their Minds (It's Just So Darn Hard), New York Times, November 4, 2011

[44] Bureau of Labor Statistics: http://www.bls.gov/news.release/pdf/nlsoy.pdf

[45] Example state level initiatives in California, Hawaii, Illinois, Massachusetts, Michigan, Ohio, Pennsylvania, Texas and Vermont

accomplished over the past decade to facilitate the evolution of a reliable and secure and cost effective distribution, but there is also more to be done. The following observations are suggested for further discussion.

1. Distribution investment for a 2030 future may be $775B: Raising customer affordability issues and the need for new business models, regulatory frameworks and relationships for policymakers, utilities, and the private sector.

2. DER Policy & Adoption is ahead of commercial solutions & engineering practice: Distribution planning, designs and scalable commercially available technology solutions are lagging.

3. Traditional boundaries will blur: Operational complexity will cause a transition to increased automation and integrated controls between transmission and distribution as well as with customers – there will no longer be clear demarcation points.

4. Technology adoption risk is rising: ICT & Energy Technology advancement cycle times outpace related utility infrastructure lifecycles by a factor of at least 3x – managing the integration and transition of technology has become a critical consideration.

The next papers in this series will discuss in more detail the business and policy implications of the key takeaways from the first two papers and webinar discussions.

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Further Reading & Resources

Berst, J., Smart Grid Scenario Workshop Summary, Edison Electric Institute, October 2010

MPSC Staff, The Smart Grid Collaborative Report To The Michigan Public Service Commission, Dec. 2011

MIT Energy Initiative, The Future of the Grid, MIT, 2011

Jamasb, T. and Pollit, M., The Future of Electricity Demand, Cambridge, 2011

National Renewable Energy Laboratory, Renewable Electricity Futures Study, DoE, 2012

Panel on Public Affairs, Integrating Renewable Electricity on the Grid, American Physical Society, 2010

DoE-OE, Grid 2030, A National Vision For Electricity's Second 100 Years, DoE, 2003

De Martini, P., von Prellwitz, L., Gridonomics, Cisco Systems, 2011

Cisco Systems, Cisco Visual Networking Index: Forecast and Methodology, 2011-2016, May, 2012

Rainie, L., Wellman, B., Networked: The New Social Operating System, MIT Press, 2012

Metcalfe, R., The Enernet, MIT, 2008 http://video.mit.edu/watch/the-enernet-9342/

Brown, M., et al, Plausible Grid Futures, UC-CIEE: http://uc-ciee.org/downloads/i4Energy%202011%20M.BROWN%20Plausible%20Grid%20Futures.pdf

TED Talks on the Future: http://mashable.com/2009/08/20/ted-future/

Bloomberg video, How Much Has the iPhone Accomplished in 5 Years?: http://www.businessweek.com/videos/2012-06-29/how-much-has-the-iphone-accomplished-in-5-years

Keogh, M. and Cody, C., Cybersecurity for State Regulators, NARUC Grants & Research, June 2012

DoE-OE Energy Delivery Systems Cybersecurity website: http://energy.gov/oe/technology-development/energy-delivery-systems-cybersecurity

Cyber Attack Task Force Final Report: http://www.nerc.com/docs/cip/catf/12-CATF_Final_Report_BOT_clean_Mar_26_2012-Board%20Accepted%200521.pdf

Cyber security scenarios: http://www.tyndall.ac.uk/sites/default/files/t2_24.pdf

Kitterman, B. and Dugan, J., The Disappearing Utility Workforce, Electric T&D Magazine, Issue 33

EPRI Papers

Distributed Generation Relaying Impacts on Power Quality, 2001

Distributed Energy Resources and Management of Future Distribution, 2011

Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects

EPRI's Distribution Research Area Strategic Plan (10 year plan)

2012 Distribution Program Research Overview

Success story of two utilities involved in EPRI's Green Circuits Demonstration Project

Alabama Power and Duke Energy Realize Efficiency Gains Through Green Circuits Project

Intelligrid Program link: http://smartgrid.epri.com/IntelliGrid.aspx

Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs and Benefits

Electric Energy Storage Technology Options: A Primer on Applications, Costs & Benefits - An EPRI

Distributed Energy Resources and Management of Future Distribution

Distribution System Cyber Security Architecture: Guidelines for Applying Security Measures to Meet Distribution Cyber Security Requirements

Advanced Metering Infrastructure Security Management Guidelines