TRANSFORMATION OF THE ELECTRIC GRID

By Laura Ipsen

There is a transformation taking place in the energy arena today that is fast becoming a global movement. It will redefine the energy landscape; how the world generates, distributes and consumes energy, as well as our lifestyle and the environment. The result will be a connected energy superstructure for the 21st century and beyond.

Like other industry transformations of this magnitude, this diverse path to change can only be deemed an “Energy Revolution.” Its manifestation will lead to global social, political and economic changes similar to the Industrial Revolution of the early 20th century.

The “Energy Revolution” will be enabled by 21st century technology. And while technology is often viewed as literally “replacing” an existing creation, this change will be one where technology “improves and enhances” energy usage. The latter requires a major paradigm shift as well as a global vs domestic mindset.

As a result, energy will no longer be seen as simply as an electron but rather data; data that can be transported, manipulated and altered as required. The one-way communication of today will transform into an n-way communication system, optimising communication between all relevant channels in the electronic value plane.

Within this transformation lies a key foundation, the smart grid – a superstructure to be deployed throughout the electrical infrastructure that integrates all the key facets required to deliver on the promise. Essential to creating this foundation will be three intersecting components, policy, technology and economics.

POLICY

Policy makers globally are viewing the transformation of the electric grid as an opportunity to address broad policy objectives related to climate change, energy independence and development of clean technology. They realise that energy independence and infrastructure stability and security is a means of ensuring sustainable economic growth.

The resulting legislation and regulation has triggered the fundamental electric industry transformation underway. While the specific policy goals differ across the world, there are generally five general themes related to smart grid policy:

- Improved grid efficiency reducing system losses
- Integration of large amounts of renewable resources (both central and distributed)
- Broader market participation by independent energy resource suppliers and customers
- Improved system utilisation through improved power flow management
- Improved grid resiliency and reliability (including cyber security).

Not only will these five themes help ensure sustainable economic growth, they will also help reduce carbon emissions and positively impact global climate change. Given the significance of these five policy themes, the resulting legislative or regulatory rules are driving massive global investments. While the objectives are desirable, it is essential that coordinated national and local regulatory policies consider the impacts to customers involving new pricing and programmes, technology adoption and the potential for resulting rate increases.

Additionally, the societal and customer value from these policies must be articulated clearly and consistently. In the US, policymakers and key stakeholders need to do a better job of educating customers on the benefits and costs associated with implementing a thorough climate change policy – which includes shifting energy use from fossil fuels to electricity supplied by an increasingly cleaner portfolio of generation and demand side resources. Likewise, utilities need to develop long term smart grid strategies and roadmaps to clarify the direction and value to the customer, investor and regulatory bodies for acceptance and to guide future investment.

TECHNOLOGY

Spurred by new energy policy, utility planners worldwide are considering designs for the grid of the future. The best designs are including innovation in both energy technology and information communication technology (ICT). While the smart grid is often associated with just ICT investment, it is actually the integration of both energy and IC technology that results in a smarter grid. This is because it is increasingly clear that a 21st century grid will need to accommodate n-way, or many way, power flows and transactions across the grid irrespective of the old transmission and distribution paradigm. As a result, the physical arrangement of the grid and new technological components is just as important as the intelligence in the grid. We believe it is essential that utilities develop an overall smart grid architecture that reflects the physical changes to the electric system as well as the integration of ICT. Key technology trends that will have a significant impact on the development of a smarter grid are the following.

Distributed generation (DG)

Distributed generation is at the inflection point of the adoption curve in the North American market, well past in Europe, and emerging in Asia-Pacific. In Europe, energy from renewable resources in some countries is reaching 50% or more of energy delivered on a given day. In the United States, 38 states have Renewable Portfolio Standards or Renewable Portfolio Goals. The increased adoption of feed-in tariffs suggests that we will see continued exponential growth in renewable DG (e.g. a California utility reports 60% annual growth the past two years). The focus on distributed resources to reduce the complexities of building new transmission means renewable generation on distribution circuits will continue to grow for the foreseeable future.

Sensors

Widespread deployment of sensor technology across the electric grid is occurring in the form of synchrophasors, intelligent electronic devices in substation and distribution equipment and smart meters. Synchrophasors will be vital to integrating renewable sources on the grid, increasing the amount of energy that can be reliably transmitted and reporting information to utility control centres.

Plug-in electric vehicles (PEV)
PEVs will be coming to mass market over the next 12 months and based on the popularity of hybrids, will likely establish a solid foothold in new car sales that will increase over this decade and beyond. In Europe, analysts anticipate perhaps nearly 500,000 PEVs by 2015 and in the US research suggests PEVs will make up 20% of new car sales by 2020. The research by the Electric Power Research Institute and several North American utilities is instructive on the potential adoption patterns and grid impacts. The current analogue electrical grid was built over fifty years ago and not set up to handle “appliances” of this nature being plugged into the grid all at once, or even one at a time. Coincident charging and charging during system peaks are serious grid reliability issues to consider and ICT can help address them.

Energy storage
Energy storage has the potential to enable the electric system to be more reliable and stable, and provide better power quality and customer-side energy management. Climate and energy policies are advocating energy storage as an asset that can be used to mitigate renewable energy intermittency, and storage technologies that can provide adequate dynamic response are becoming commercially viable at grid scale. It’s possible that battery based systems leveraging similar technologies used in electric vehicles could achieve breakthroughs on the engineering economics such that wide spread adoption could occur in this decade.

Networks
Utilities worldwide are rethinking their telecommunications needs and infrastructure architectures. These architectures are addressing requirements for highly available, low latency wired networks to link substation and control centre operations as well as robust, secure wireless field area networks to support distribution automation, mobile field force automation and smart metering. The electric utility industry is adopting Ethernet/Internet Protocol (IP)-based architectures; specifically, utilities are deploying multi protocol label switching (MPLS) networks in order to manage the transition from legacy systems to the emerging demands of syncrophasor and teleprotection systems.

Likewise, utilities are evaluating their field communications needs of both utility grid operations and customer engagement. The prevailing field architecture is a two tier network comprised of a field area network (FAN) and a second tier of special purpose networks like a neighbourhood area network (NAN) for smart metering or a low latency distribution protection and control system. The FAN leverages broadband wireless technology, either privately owned or via a leased virtual private network using licensed or unlicensed spectrum. The purpose is to enable monitoring and control of increasing levels of distributed energy resources and allow for the coming shift from centralised to distributed peer-to-peer control of network devices.

A comprehensive, end-to-end, IP-based communications network will allow utilities to manage proliferating smart grid sensors and devices (including those located behind the customer meter), enable advanced mobile workforce automation, backhaul for the smart metering system and support high volume, near-real time system state measurement and control.

Data analytics
Analytics will leverage data from many sources including smart meters, distribution and substation intelligent energy devices, and phasor measurement unit (PMU) devices. Advanced analytics will enable smarter, faster decisions by automated utility information systems, utility personnel and customers. The challenge of managing this tsunami of data will be managed more effectively through the use of communication network based tools. Advanced data management technology will be used in both utility data centres and cloud services. The flood of data will require effective visualisation and intelligent alarming tools to provide useful and actionable information to system operators.

Cyber security
With the expansion of millions of intelligent devices on the grid and consumer smart devices, security becomes a challenge. Because of the critical nature of the technology and the services it provides, the grid is a prime target for acts of terrorism. Therefore, the transformation of traditional energy networks to smart grids requires an intrinsic security strategy to safeguard this critical infrastructure. That said, innovative utilities will not wait until regulations and standards are finalised to begin risk-based threat assessments and will start development of their security architectures and mitigation planning.

Distributed intelligence
As discussed, several trends are creating an increase in the number and diversity of distributed systems and devices that need to be connected and coordinated. This is driving the need to reconsider both the physical architecture of electric distribution systems as well as the information and communication architectures. As a result, utilities worldwide are considering the adoption of an architecture based on distributed intelligence.

Distributed intelligence embeds digital processing and software at many locations in and along the power grid infrastructure to implement flexible grid automation. Networking connects these processing elements together so that they can work individually but act collectively to carry out power grid operational and business functions in a non-centralised manner. Such systems may be completely distributed, or may involve distributed elements with centralised management and coordination. For example, advanced voltage/VAr control is an application that can leverage a distributed intelligence platform to reduce distribution grid losses and improve overall power quality. The use of distributed intelligence provides opportunities for utilities to implement scalable systems to integrate greater amounts of renewable distributed generation, enhance grid efficiency and operations.

ECONOMIES
Globally, trillions of dollars are being invested over the next twenty years in electrical infrastructure and technology to make the electrical grid more modern, secure, reliable and efficient. Much of the investment is being paid by customers through utility rates, as is customary. The current economic recession, however, has heightened the sensitivity of utility rate increases and capital investment. As such, it is essential that benefits to society, now and in the future, as well as to consumers and businesses will need to be clearly communicated for effective adoption.

Societal value
Societal value attempts to capture the climate and energy independence value, the economic value from increased reliability and customer value. For example, the societal value of the five smart grid policy themes identified above was recently estimated by McKinsey as $130 billion annually in the US by 2019. This forecast attempts to capture the entire value of US smart grid investment, what McKinsey calls the “value at stake”.

More specific estimates are being done for segments of potential societal value such as for climate benefits and grid reliability. On global climate benefits, the Climate Group recently estimated that smart grid technology can enable reductions up to 2.03 $GtCO_2e$ by 2020 representing a value of $264 billion in energy, fuel and carbon saved assuming a cost of carbon of $22. On US grid reliability, the Galvin Electricity Initiative estimates that power outages cost Americans $150 billion annually. While these numbers are helpful in highlighting the magnitude of the opportunities for modernising the electric grid, the same numbers are difficult to translate into specific rate cases, business analyses and value for individual customers.

Customer value

Central to smart grid investments and new business models is the creation and articulation of increased customer value. This value is typically thought to fall into either rewarding customers for changing their use of electricity or providing a new service that is enabled from a deployed technology platform. Many new customer value propositions being considered worldwide involve providing financial rewards for customers to dynamically change energy consumption. While demand response and energy efficiency programmes have been in existence for thirty years, the evolution to programmes that emulate the characteristics of generating resources in terms of responsiveness and availability will substantially change the customer experience.

The question is whether the same level of participation is achievable under programmes that require greater customer participation, shift incentives, or introduce penalties for non performance. Specifically, customer perception of the economic utility of electricity as it relates to their business, lifestyle and/or comfort is a key consideration. The answers lie in a deeper understanding of customers' preferences and personas that is achieved through robust customer segmentation analysis. Product development and marketing efforts will need to also consider techniques for identifying and spurring latent demand and the lack of stickiness if repeated behaviour change is required. Therefore, continuous feedback mechanisms with relatively fast cycle development of new offerings to keep the customer engaged should be considered.

Exciting opportunities are emerging enabling new customer products and services that leverage the technology platforms being deployed. Increasing adoption of open standards and IP-based networks are enabling innovation in customer use and experience. A wide variety of new products and services are being developed and offered to customers worldwide. These include categories like information services, financial services, energy management, premise management and bundled services. Adoption of responsive electro-technologies (e.g. solar PV with intelligent inverters, electric vehicles, energy smart appliances) is also providing opportunity to develop compelling customer value.

Adjacent consumer technologies, like "Apps" for smart devices are enabling fast cycle development of new offerings that converge several platforms. An example is Cisco's recently launched Home Energy Controller (HEC) that allows a customer to link their smart meter, energy smart appliances in the home, a variety of 3rd party energy management apps on the HEC, the internet and Cisco's hosted cloud services to create a unique customer experience for managing their home.

Business value

The electric system in most developed countries was largely built 40-50 years ago and much of the core infrastructure needs replacement. To modernise this aging infrastructure and incorporate the technology necessary to accommodate millions of sensors being added to the grid, Cisco believes that smart grid related investments will be in the growth phase over the next 20 years as investment in replacing significant portions of the electric infrastructure takes place. In the United States, the Edison Electric Institute (EEI) forecasts that over $1 trillion will be expended over the next twenty years on electric infrastructure by their investor-owned utility members. The investment associated with smart grid technologies isn't clear, but Pike Research suggests that $200 billion could be spent globally, although this seems low as EEI forecasts $175 million in the US alone. In any event, the regulated return on this investment will mean that many utilities will have an opportunity to grow earnings for an extended period while providing better customer service and improved reliability.

Additionally, new business opportunities are emerging for both utilities, existing competitive energy services providers and new entrants to create customer value as described earlier. Multiple means of monetising these opportunities exist, ranging from traditional product sales, to wholesale markets for responsive demand and energy conservation, to financial services (e.g. prepayment, levelised payment and financing), and to potentially the several "free" market models that have emerged over the past decade in other commercial sectors. While the electricity sector is unique on many dimensions, it is clear that the traditional regulated business model will evolve and new business models will be used to create customer value and meet broader policy objectives.

CONCLUSION

The development of the smart grid will be a journey that will likely take twenty years or more, with key policy, technology, and economic milestones along the way. To accelerate the development, energy policy by legislators worldwide will need to encourage open standards and innovation; ensuring a smarter, more diverse electrical supply, a robust electricity infrastructure and the vitality of a nation's economy. However, policy makers will need to balance acceleration with the significant time alignment challenges related to the relative maturity and economics of the energy and IC technologies required to meet policy objectives.

Economics are also a critical factor in making policy and technology choices and include societal, customer, and business value. While there is much discussion by and between stakeholders, there remains a general lack of clarity regarding the value in each of these areas. This is further compounded by the many different and complex electric regulatory constructs that exist worldwide, and within the different local jurisdictions within countries. The result is having a significant influence on the industry's ability to plan for and operate successfully in this new electric economy.

Utilities, technology suppliers and new market entrants worldwide are managing portfolios of investments in infrastructure and new products and services to enable these objectives. In doing so, it will be critical that they deploy innovative energy and information communication technologies enabling them to provide service in a manner consistent with present and future customer needs, while remaining flexible enough to accommodate changes in market structures and participation.

It is the above efforts that will collaboratively usher in an "Energy Revolution" – the transformation of the electric grid, utility operations, and consumer services for a sustainable, reliable, efficient, and stable 21st century smart grid. MI

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