The modern era energy grid and the role of energy integrator

Introduction

Disruption in the energy sector worldwide, across all sources of energy, is the pervasive strategic discussion within the industry. While new attention is being paid to the issues, disruptions in the industry are not new. In the late 1970s, the first oil crisis drove a shift to alternative fuels for electricity production globally (in addition to structural shifts in the use of oil for transportation). Deregulation of natural gas and its better environmental—albeit still negative—footprint started a trend still seen today in electric production. In the 1990s came a wave of electric deregulation, spawning the break-up of vertically integrated utilities in many parts of the world. The associated implementation of market-based structures forever changed the rules of engagement between utilities and customers. Deregulation continues today as a core norm in the industry globally, so one can understand when industry leaders have a "been there, done that attitude" toward the current wave of disruption talk.

However, the disruption the industry is undergoing presently is more profound. This is because the changes driving this disruption are more than "alternatives," but instead viable substitutes that are driving structural, technical and commercial changes in the industry. These substitutes are emerging from outside the domain of regulation and operate easily without the legal and operational encumbrances of the traditional utility. Other industries have seen similar disruptions with startups like Uber and AirBNB.

Current industry disruptors include:

- Distributed solar photovoltaic (PV) and its attainment of grid parity
- Storage technology that is mainstreaming within the industry
- Alternatives to supply such as energy efficiency and dispatchable demand response.

These substitutes are introducing a host of challenges, from business disintermediation ("cutting out the middleman") to technical issues of supply intermittency and demand response dispatchability.

In the midst of this disruption a strategic imperative for the industry has emerged. That imperative is to embrace the role of the energy integrator. This role can be viewed from many divergent perspectives, from incumbent utilities to new entrants, and even third party disruptive technology innovators. However, wherever the technical and commercial solution for the grid of the future lands, the role of the energy integrator will be essential to its viability.

Figure 1. The role of the energy integrator.

Energy integrator strategic context

Three precepts frame the role of the energy integrator. Each is a cornerstone to the energy integrator foundation. Important separately, collectively they operate accretively to optimize the benefits for all stakeholders. Whether it is building the modern era energy grid, leveraging the power of markets to achieve economic goals or drawing more energy from sustainable sources, the three precepts are at the core of what it means to be an energy integrator:

- The essential grid
- The power of markets
- The mantle of sustainability

The essential grid

Figure 2. The essential grid.

It has long been technically possible for enterprises, both residential and commercial, to effectively disconnect from the grid. This capability was usually exercised in limited forms either in some type of backup generation capacity or in remote locations with borderline network connectivity. The gas generator is a prime example of this capability and while technically viable, it is not economically sustainable for long-term base energy requirements.

Recent advances in distributed generation capability, such as PV technology, coupled with reductions in energy intensity globally has fostered a popular narrative that today's electric grid will not be needed in the future. With this new distributed energy production technology and the addition of emerging battery technology, the world can disconnect from the grid as it will no longer be necessary.

There are, however, both technical and demographic reasons to support the premise that the electric grid will be a central element of the electricity system for the foreseeable future. One needs only to integrate the global trend for urbanization with the energy density required to support this future electric load (watt/square meter, for example) to understand that centralized production of electricity and the transmission and distribution of it will endure. It likely will be at a smaller scale than historical norms and resultantly more distributed, and it will undoubtedly be more sustainable, but it will need a grid to get its output to world.

There are two aspects to this assertion that are important to consider, however. The first aspect is that the design point for the grid in the future is fundamentally different than the design point of the past. Thus the energy integrator will have to operate a new grid—one whose operating characteristics are more complex than the grid of today.

The second aspect to consider is that the new grid will have to be operated by a structured entity—operations of the grid are unlikely to be "crowd sourced" and left to totally distributed unregulated entities. Although significant amounts of automation and new technology can be used—and even new market models far different than regulated monopolies will exist—the role of a structured entity to operate the grid will be required. And that entity is the energy integrator.

The power of markets

Figure 3. The power of markets.

Discussions about deregulation, implementation of markets, and restructuring the electric sector have been ongoing for quite some time. The reality is that we are quite early in the process. Large portions of electric supply distribution continue to be managed and regulated under traditional mechanisms, such as asset-intensive operating bases, a bias towards capital investments, and commercial reward structures operating under the "use and useful" rule of regulation.

The direction in many parts of the world is to use marketplace constructs of supply and demand to create an energy marketplace in place of the traditional utility energy grid franchised and regulated monopoly operations.

Marketplace mechanisms are well defined and used across most commodities in the world. Beneficial outcomes of liquid and transparent markets include:

- Stimulation of innovation
- Efficient allocation of capital and resources
- Efficient and transparent establishment of price

All of these are attributes that can benefit the industry and the consumer.

The energy integrator will use these marketplace mechanisms to support a robust marketplace for electricity and associated required products and services. And although an open market construct for price is not a requirement for the energy integrator, it is certainly a preferred structure for all of the above outlined reasons. This is particularly true as attempts are made to integrate renewable technology and demand-side technologies into the supply mix as dispatchable resources in the future.

The mantle of sustainability

Figure 4. The mantle of sustainability.

Sustainability as a social objective and political imperative increasingly is being adopted on a global basis. There are undoubtedly differences by location as to the approach and pace of implementation, but nearly every nation in the world is focused on how we can make our electric supply—and indeed our lives—more sustainable. This is driving a migration away from primarily fossil fuels and their byproducts. This shift will change the underlying infrastructure of the electric industry globally.

How sustainability is embraced as a core business element in the electric industry varies globally, ranging from complete adoption, most aggressively by new entrants, to reticence by incumbent utilities heavily invested in assets based on fossil fuels.

But even the most fossil dependent utilities do not deny the direction of sustainability, instead arguing that changes must be measured against the economic disruption a fast-paced transition would create.

For the energy integrator, embracing, fostering, and even promoting sustainability is a foundational concept. There are many issues in the sustainability discussion that are yet to be resolved, but the energy integrator is in the perfect position to drive this global trend, as such energy production is a fundamental aspect of the energy integrator's mission. And, as outlined below, this is an opportunity for innovation to be exercised—under financial rewards structures that need not be traditional regulatory in nature.

The modern era energy grid

The above precepts for the energy integrator provide context for the transition the industry is navigating through presently. As noted, this is not the first time the industry has gone through a transition. But this one is structurally more disruptive, both technically and commercially, than most prior transitions. Indeed this disruption establishes the basis for a new era in grid design, management and use. The industry is rapidly leaving behind the industrial era energy grid (IEeG) and is planning—and in many cases building—the modern era energy grid (MEeG).

The IEeG was designed for electrification, driven primarily by centralized supply. Utilities (both public and private) enjoyed underlying financing and reward structures that minimized risk while providing strong incentives for providing electricity to everyone (duty to serve) safely and reliably. Electricity was understood to be a public good, and the result was what the Academy of Engineering named the single most important invention of the 20th century.

The MEeG will have an eye toward the 21st century. It will have to support an economy that is more electric than in the past, with electricity delivered through an electric infrastructure that is more distributed and more variable in operation than its predecessor. It will be designed for sustainability and driven by a diverse set of supply and demand resources that will require optimization to deal with the underlying technical uncertainty inherent to newer energy technologies. And the underlying financing and reward structures will be increasingly more market-based than regulatory- and asset-based.

There are a number of technical, commercial and regulatory elements of this new approach that will need to be developed and evolved as the MEeG is conceived, engineered and deployed. This new era grid will not be totally disassociated from the IEeG. There are many elements of the MEeG that were developed and optimized for the IEeG. There is no reason to reinvent the wheel for these elements. However, there is a need to bridge to the requirements of the MEeG and the key to this is how utilities, regulators and customers embrace innovation in the transition, because the key to bridging the best of the IEeG with the requirements of the MEeG is innovation.

As in other operational-oriented industries where safety and reliability are paramount that have undergone transformations similar to what is envisioned for the electric industry, one can expect with the energy integrator framework that some elements of operations are more disposed to lightly directed innovation than others. This concept is called "multimodal innovation."

For example, in the airline industry, the actual process of flying the aircraft is a controlled set of processes with extremely structured, engineered and regulated avenues of innovation. But innovation has unquestionably been successfully implemented as evidenced by just a quick look at a modern aircraft "glass" cockpit. On the other hand, the process of marketing airline seats, managing passengers, and offering adjacent products and services, is substantially devoid of engineering and regulation, yielding to less directed innovation.

The electric industry will likely follow a similar pattern with grid operations evolving under a regime of tighter managed innovation, in contrast to the other extreme of customer-facing operations where innovations will likely be animated through more experimental and entrepreneurial modes. It is this balance between the well-established methods of providing safe and reliable electricity and the required innovations to fulfill future requirements—all to sustain an infrastructure that is essential to the world economy—that establishes the foundation for the definition of the energy integrator.

What is an energy integrator?

The energy integrator provisions the systems of engagement to sustainably balance distribution-side energy supply and demand safely, reliably and securely.

The energy integrator operates within three core spheres of operation as depicted in Figure 5. These spheres include:

- The physical operation of the distribution network
- A set of expanded roles driven by security and sustainability
- The management of price and participation within a market structure

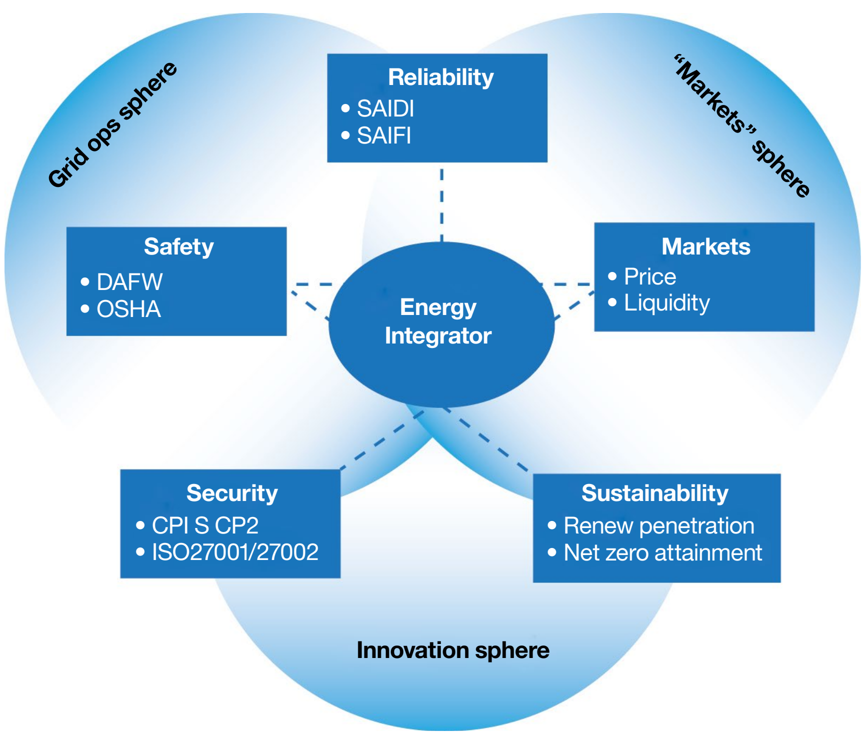

Figure 5. Energy integrator spheres of operation.

It is important to understand from the outset that when defining the spheres of operation, the energy integrator is independent of two definitional attributes of grid operations globally. The first is that the energy integrator, and the role these companies play in the grid ecosystem, is independent of any particular type of supply source. It does not discriminate against a source of energy—supply or demand—unless by regulatory mandate. The energy integrator simply balances energy sources optimally.

The second attribute of an energy integrator is that it is not prescriptive of any particular market design. It can, and must, accommodate all forms of market design. Accordingly, the energy integrator role is as applicable in a completely deregulated retail market environment as it is in a vertically integrated regulatory environment.

These two definitional elements of what the energy integrator is *not* is critical to understanding the spheres of operation framework. It is also critical not to assume that an energy integrator is necessarily a single entity. It could be a constellation of entities that manage according to a common, but orchestrated, set of processes.

Energy integrator spheres of operation

There are three key spheres of operation that are affected by the energy integrator.

Grid operation sphere: Safety and reliability

The first sphere of operation is traditional and born out of requirements driven by grid essentiality. The roles within this sphere are necessary to ensure the continued expectations of both customers and regulators that the grid will provide safe, reliable and secure electrical energy. Many of the core functions found within the traditional utility structure of the historical industrial grid are sustained within this sphere. They are, however, transformed by the requirement for a new design point inherent to the the MEeG. In short, the functional objectives are the same in this sphere as in the past, but the methods and processes used to achieve those objectives will be different, so as to deal with the increased complexity the the MEeG introduces.

Innovation sphere: Security and sustainability

The second sphere of operation expands on a cornerstone of traditional industry functions that address both threats introduced by the the MEeG and societal objectives that are well-suited for an energy integrator to steward.

The first of these expanded functions revolve around system security. System security has a double meaning in the utility industry. Historically, system security has referred to the electrical stability of the network, particularly transmission level frequencies. Measured through well-established metrics of CP1 and CP2, system security is maintained and managed within well-defined engineering and management constructs. Undoubtedly these measurements and processes will endure in the MEeG. Additionally, it is likely that metrics analogous to these transmission level metrics will be developed at the distribution level of operations as the architecture of the MEeG deepens along multiple dimensions—complexity, interconnectedness and variability of supply and demand among them.

The second meaning of security in grid operations is cyber security. In the MEeG, the importance of cyber security—particularly because of the success of smart grid technology and the accordingly more open access to control systems—is an increasingly significant factor in the reliable management of the grid. The management of cyber threats traditionally was limited within substation and enterprise inward boundaries. The grid of the future, however, will face threats that reach to, and even originate from, the meter and customers' premises. Thus, the management of this threat surface becomes a core role of the energy integrator.

Also within this sphere of operation is a considerably expanded role for the integration of sustainable energy resources within the distribution grid. This sustainability integration encompasses more than distributed renewable generation. It includes all forms of renewable generation, whether distributed or centralized. It includes demand response programs focused on managing peak loads, and it includes fundamental energy efficiency programs and their effectiveness.

This innovation sphere also opens commercial opportunities for those assuming the role of the energy integrator, as the roles addressed in this sphere are not generally within the jurisdiction of traditional utility regulation. They are roles that will be well served by a high degree of entrepreneurial innovation—a notion that traditional regulators are starting to understand. Accordingly, the permission for the energy integrator to innovate commercially may be quite large.

Market sphere: Price and liquidity

This sphere of operation revolves around markets that establish pricing for a host of services through a liquid and transparent set of mechanisms enabling energy resources to participate in the energy provision process regardless of the source, be it fossil, nuclear, renewable technology, demand response or energy efficiency.

Market-based constructs contemplated in this sphere of operation have been one of the hallmarks for deregulation processes globally over the last couple of decades. Many of the required mechanisms are well established. However, many more need definition and "animation" in the vernacular of the New York REV proceeding.

As with the previously mentioned innovation sphere, the market sphere offers the opportunity for energy integrators to operate commercially under non-traditional regulatory mechanisms. It is also a sphere where the introduction of third parties that operate within the energy integration role, in concert with more traditional entities, will likely emerge.

The energy integrator role framework

There are five core functional roles the energy integrator will play as depicted in Figure 6. These roles are discussed in the sections that follow.

Advanced energy network management

The area of the network management, particularly with more sophisticated technologies from a system balancing and security perspective, is a direct ancestor of the current-day grid operations. In the grid of the future, this role continues to be a key element from the grid of the IEeG, and for good reason. Outcomes such as physical and real-time control, balancing energy resources, maintaining situational awareness, and measuring the energy dispatched, are all required in the MEeG. This has been the case for decades of past and present grid operations.

Distributed resource enablement

In the transition to the MEeG, the role of managing distributed resources will be greatly expanded. In the past, distributed resource penetration and applicability were limited by a host of factors. With the advance of distributed resources becoming economically and commercially viable, both the complexity of and requirements for managing these resources in the new era is larger and more challenging. Included in this new role is enabling a market of distributed energy resource (DER) offers, managing campaigns to induce DER participation, providing market transparency mechanisms, and, in some venues, being a core market maker for DER.

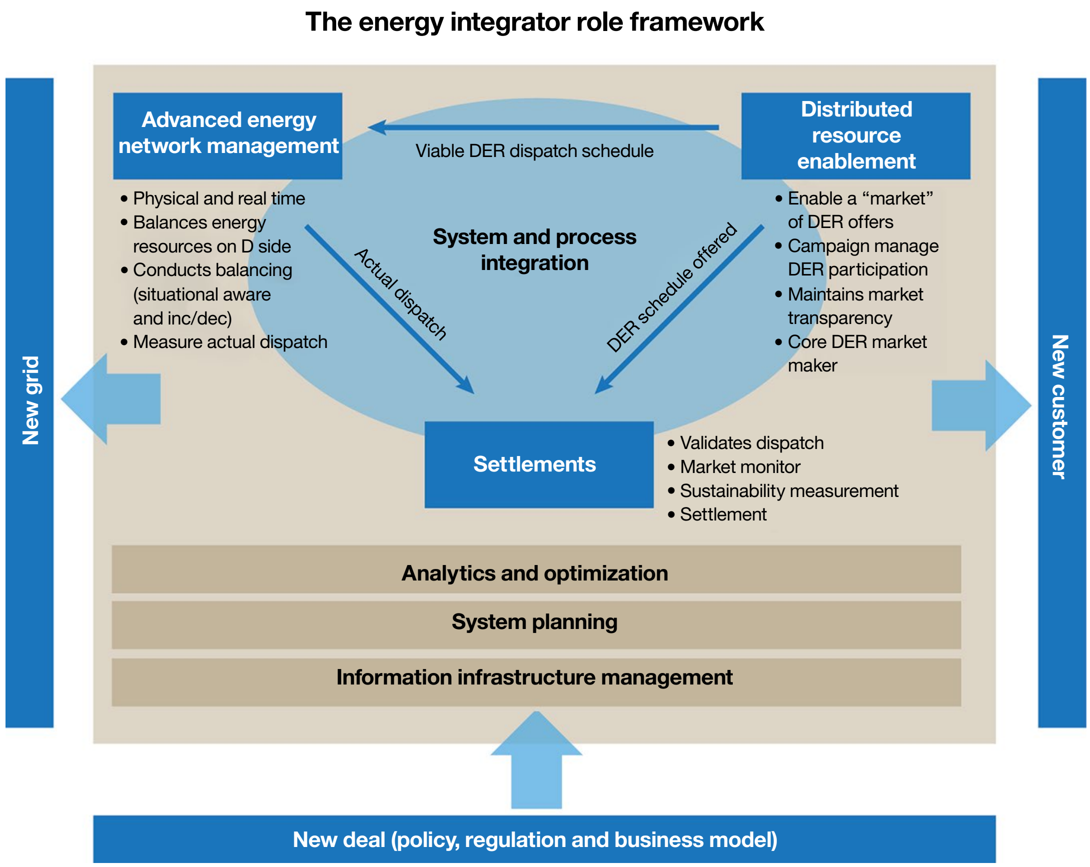

Figure 6. Energy Integrator role framework.

As outlined in the beginning of this paper, the energy integrator role is generally independent of market design as well as supply mix. So the aforementioned use of the word "market" will vary from venue to venue. And in the context of the energy integrator, the word "market" is specifically used to outline a series of mechanisms more than a specific market structure. Examples of these market mechanisms include providing the ability for prospective distributed-side energy providers to make their resources available and being able to settle.

Settlements

The energy integrator will be in an important position of settling the energy transactions not only for itself, but also among multiple market participants. Once, customer information systems—specifically billing systems—were the extent of interaction, and providing a bill and collecting from customers was all that was required. In the new era grid, however, the number of participants creating transactions will be much larger and the type of transactions more dynamic. This will require a more sophisticated view of transaction management than a monthly bill.

Systems and process integration

Underlying the three aforementioned functional areas of the energy integrator in the new era grid is an integration function for these objectives that encompasses both technology and business processes. It is this integration that makes these three core functional areas work as a system and provides the underlying outcomes of the energy integrator.

Infrastructure

Supporting the integration and functional areas outlined above that enable an enterprise to operate is the fifth core role of the energy integrator. Included in this infrastructure is the traditional information technology infrastructure, the business and technical management infrastructure traditionally focused on system planning, and the analytics and optimization technology infrastructure that enables the optimal operation of the grid, markets and commercial settlements.

The path forward

There are more than a few things that need to be put into place to realize the energy integrator framework. Three good first steps are discussed in the following sections.

Evolution model

The five functional areas described previously make up the core foundation for the energy integrator role. It's important to note that the energy integrator role in the new era is not a "start from scratch" proposition. Many elements of the energy integrator role exist today within incumbent utilities or ISOs and the markets.

As the governance and market structures in each venue are constructed, there must be a method that enables the energy integrator in the new grid environment to create a roadmap for evolving, enhancing or replacing processes and systems. An evolution model similar to maturity models that have been developed in times before are good models to emulate.

Architecture

This paper described the roles of the energy integrator—not the functions or systems. This has been intentional. The marketplace has a wide breadth of traditional incumbents through to startups designing and proffering systems—and systems of systems—to address the roles outlined in this paper. Discussion of the systems of the energy integrator is an entirely different subject.

Nonetheless, implementation will require a foundational architecture. One option might be to let the market develop the architecture, similar to how the AMI architecture has evolved over the last decade. Another option would be for some entity to promulgate a baseline architecture that can be built upon based on locational diversity. The issue with this option is, of course, which entity should do this in such a venue diverse area.

Regulatory roadmap

The final potential step is to promulgate the energy integrator framework among the regulatory forums—most likely by would-be energy integrators. In some instances, most notably New York state, the regulators themselves are driving the development. In other venues, this role will likely resolve to either incumbents who want to assume the energy integrator role or new entrants who see opportunity to disintermediate (eliminate the middleman) the aforementioned incumbents.

Regardless of the source for starting the conversation, initiating it now is critical, as the driving forces that are creating the current disruption are only amplifying both positive and negative consequences. Safe and reliable energy supply to our economy is an outcome made better by robust public dialog and better left not to chance.

All three of the above prospective first steps are aimed at bringing focus and coherence to a complicated, but essential, critical infrastructure in which a new order is animated and provides growth opportunities to incumbents and new entrants alike, all while sustaining and evolving in the 21st century the promise created by the greatest invention of the 20th century.

For more information

To learn more about the modern era energy grid and the role of the energy integrator, please contact your IBM representative or IBM Business Partner, or visit the following website: **ibm.com**/energy

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