How Will a Transition to a Distribution System Operator Model Impact the Distribution Grid?

There was a time when the bill from one's electric utility was simply called "the light bill." This is because lighting was the primary thing for which people needed electricity. But this behind-the-meter world underwent a technological revolution, and electricity became the lifeblood of homes, businesses, hospitals, and places of learning.

A similar shift is occurring today, this time on the other side of the meter. A technological revolution is creating new forms of energy generation, storage, and other grid-enabling services that are changing the operation of the grid from a simple "generate-transmit-distribute" model into something more complex that, if properly leveraged, could deliver huge amounts of value to customers and the wider economy.

The International Energy Agency (IEA) issued a report in October 2020 outlining three major threats to the security of global electricity systems.[1] In that report, the IEA identified the rise of variable renewables, cyberthreats, and climate change impacts as the three top issues policymakers must address. The IEA's first recommendation to battle these threats was that "establishing clear responsibilities, incentives, and rules across the electricity system is imperative for ensuring security in the face of shifting trends and threats." Specific recommendations included:

- Regulators: Offer a clear framework to provide every power-sector stakeholder with a clear set of obligations to prevent threats and to react in exceptional circumstances.
- Regulators: Assign responsibilities for coordinated action between the operators of the transmission and distribution systems, including where systems are interconnected.

Those "obligations" and the "coordinated action" are giving rise to a new way to view the utility role–not as an all-encompassing energy solution, but as a grid operator focusing narrowly on the distribution grid while facilitating a market of solutions operating within it.

Customer needs for reliable electricity, the complexity of the energy system, and those threats to grid stability the IEA identified are all on the rise. This creates challenges, but it also opens up exciting opportunities.

During all of this, traditional cost-of-service regulation appears ill-equipped to foster the rapid modernization and capabilities expansion needed for the grid of the future. As S&C discussed in its paper "How Reshaping Regulation Will Reshape the Grid," the likely outcome of this regulatory movement would be utilities taking on the role of distribution system operator (DSO).[2]

The transition from conventional distribution utility to DSO would change the priorities and considerations for long-term grid planning. Moreover, the capabilities of the grid would need to evolve to cater to this new role. This white paper discusses these changes and how utilities may make the transition.

The transition to the DSO role

Today's electricity-distribution utilities are charged with developing and maintaining the electricity grid serving all customers in their area. In certain states, those utilities can also own transmission lines and even electricity generation. As natural monopolies, investor-owned utilities are regulated by state commissions, with their profits limited to what those commissions deem reasonable. In today's "cost-of-service" model of utility remuneration, those profits are connected to how much money the utility is investing in system expansion and upgrades. This approach was put in place decades ago when the primary goal was to ensure utilities were building out a network that would deliver service to all customers.

Today, universal service is not the primary driver of regulatory oversight of utility investment. Other priorities, such as customer satisfaction, reliability, and carbon impact, are making their way into policy and regulatory schemes. Utilities, however, have limited incentives to go beyond the bare minimum with these new priorities because the very nature of today's regulatory model encourages them to maximize traditional forms of grid-infrastructure investment. Utilities are also faced with the competing priorities of maximizing their own profits and engaging the potential for distributed energy resources (DERs), demand response, and virtual power plants to contribute the grid.

The increasing demand for system reliability and carbon reduction, coupled with the increasing capabilities of DERs to contribute to these goals, means the market needs new signals. Utilities require incentives to pursue a wider range of alternative options to traditional wires investment (such as through performance-based regulation), and this may mean the core role of the utility itself must change.

The solution championed by many and implemented by a few countries and states is to change the role of the utility itself–moving from a cost-of-service electric utility role to that of a DSO. A DSO operates the grid like a marketplace, ensuring access to the services and creating outcomes that benefit customers and society. The Energy Networks Association in Great Britain defines a DSO model succinctly:

"A DSO securely operates and develops an active distribution system comprising networks, demand, generation, and other flexible distributed energy resources (DER). As a neutral facilitator of an open and accessible market, it will enable competitive access to markets and the optimal use of DER on distribution networks to deliver security, sustainability, and affordability in the support of whole-system optimisation. A DSO enables customers to be both producers and consumers; enabling customer access to networks and markets, customer choice, and great customer service." [3]

Essentially, the DSO will shift the utility away from its monopolistic roots toward more of a platform-operator role. This could take a myriad of forms, ranging from highly centralized to decentralized.

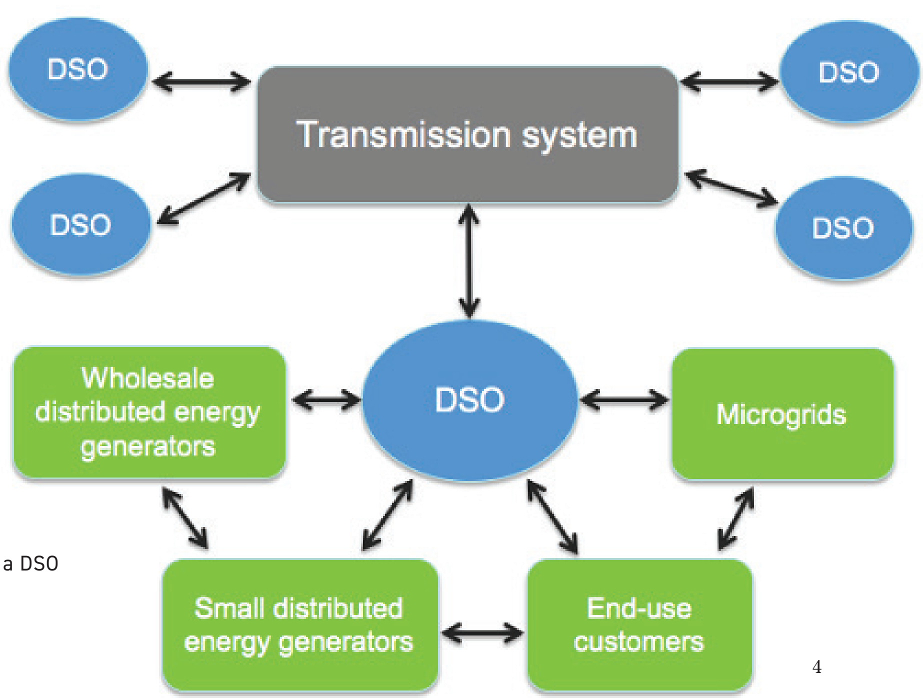

Figure 1. The players in a DSO environment.

In a highly centralized model, third-party energy services would be sold to the DSO (through the transmission-run wholesale and ancillary service markets), which would obtain and balance these services to meet the needs of both the transmission and distribution grids. In a highly decentralized model, those services would be traded directly between customers, third parties, and utilities at the distribution level, with the DSO serving as a neutral facilitator of those transactions. See Figure 1 on page 2.

There are also scenarios that include the creation of a separate entity to manage the real-time operations of the distribution grid (with utilities focused solely on building and maintaining the grid). This third party may be referred to as a distribution market operator (DMO)[5] or as an electricity system operator (ESO).[6]

Whatever model is adopted, a DSO approach must include certain elements:

- There must be clarity around roles and responsibilities of all players in the system.
  - One organization (be it DSO, DMO, or ESO) must be solely responsible for playing the role of neutral market facilitator.[7]
  - It must be clear what that organization can and cannot do in terms of market participation.
  - There can be no confusion about which level of the system will operate under which rules (i.e., will there be an open marketplace for services at the transmission level, distribution level, or both?).
- There must be a remuneration policy that will allow utilities to remain profitable while also tempering costs to customers.
- There must be an initial and continuing functionality to remove barriers to entry for new market players to increase the scope for innovation and offerings in the energy services arena.
- The technology developed for this system must allow the system operator to have excellent visibility into the demands and resources of the system and be able to leverage system assets rapidly (through direct controls or rapid-response price signals).

A DSO that can do all these things well is going to have some clear advantages for tackling electricity industry challenges. It will allow the system operator to focus more attention on the system itself–the development of new capabilities we will need for the future grid and the engagement of third parties to deliver services to the grid (without confusion or disincentives). It is inherently flexible and scalable because, instead of having utility customers pay for large investments in new generation or distribution, the DSO will have the flexibility to access those same benefits from the market–and do so faster and when needed.

Such DSOs also will allow every form of innovation to be brought to bear on energy challenges, lowering barriers to entry for new players and diversifying the opportunities for existing players. They will create broadened opportunities for DER because they can now deliver power on-site or to the market at large, depending on where the need is at the time. Basically, this transition will take the aspects of energy solutions that are not natural monopolies and expose them to the power of the open market while ensuring the profit motive for utilities is focused solely on the aspects of energy delivery that are a natural monopoly.[8]

So, is this even possible? It’s a relatively new concept, but we are seeing it begin to be implemented (or at least designed) in several places around the world.

In a 2020 survey of European electric utility leaders, 98% of respondents agreed trends toward decentralized generation will continue, with 82.2% agreeing active control of distributed generation and demand response will become part of the role of DSOs in the next five years.[9]

At least in Europe, this transition is clearly coming, and S&C believes other parts of the world are not far behind. The “how” will be discussed more at the end of the piece, but Table 1 on page 4 includes examples of some of the locations leading the way.

Table 1: DSO Transitions Around the World.

Location	*Characteristics of the DSO Transition*
Great Britain	RIIO-2 (Revenue using Incentives to deliver Innovation and Outputs) is Great Britain's second iteration of performance-based regulation. Its purpose is to improve the noncapital investment market signals for utility performance and moving utilities into a DSO role. The regulator, Ofgem, has stated its goals with a DSO transition include: • Clear boundaries and effective conflict mitigation between monopolies and markets • Effective competition for ancillary services and other markets • Neutral tendering of network management and reinforcement requirements, with a level playing field between traditional and alternative solutions • Strongly embedded whole electricity system outcomes[10]
Northern Ireland	Northern Ireland Electricity Networks (NIEN) is moving forward with the transition to a DSO approach. This began in 2018 and is drawing heavily from Ofgem's lessons learned. NIEN is already funding transition efforts to operate as a DSO.[11]
USA – New York	New York's "Reforming the Energy Vision" effort began in 2014 and has ushered a slow but steady transition of utilities becoming "distributed system platform" (DSP) providers. Utilities are presently working through this transition with pilot programs and rate-case filings geared toward preparing the grid for this DSP model.
USA – Hawaii	A 2018 law directed Hawaii's regulators to develop performance-based ratemaking for utilities. These new rules, being finalized by the utility commission, may bring utility operation in Hawaii close to what would be considered a DSO role.
Australia	In June 2018, Energy Networks Australia and the Australian Energy Market Operator (AEMO) launched "Open Energy Networks," a joint consultation seeking stakeholder input on how best to integrate DER into Australia's electricity grid. This effort appears headed toward a full DSO approach.
Canada	Multiple provinces in Canada are beginning to use alternative ratemaking. Ontario is considering a full-scale shift to performance-based regulation, with utilities taking on a DSO role. A recent position piece by Ontario's Electricity Distributors Association stated that *"the EDA sees the Local Distribution Company (LDC) of the future playing a key role in Ontario's energy transition as a Fully Integrated Network Orchestrator (FINO). As a FINO, the LDC of the future will potentially enable, control, and integrate DER within its distribution service territory."*[12]

How that role will change the grid

As utilities begin focusing on their role in coordinating a marketplace of energy solutions, they will need a grid that can reliably leverage those solutions across geographies. As stated earlier, there are several potential forms of DSO transition, but all of them will require grid adaptation. Even without major shifts in utility regulation, these additional services are already coming to the wholesale market.[13]

Establishing a grid that can operate as a marketplace for energy solutions will not be free. Many of the benefits of the DSO transition will take years or even decades to fully realize, while most of the costs will occur upfront. The DSO will need to: 1) understand the capabilities and have greater visibility of the system at a given time, 2) predict the needs of the grid (in both the near and mid-term), 3) send effective signals to the market, and 4) be able to balance resources within the grid.

The market itself will require a structure enabling DERs to: 1) understand the market signals being sent by the DSO, 2) choose to participate by offering a service in a given moment, and 3) deliver that service instantly through the grid. Only a very "smart grid" can operate as a marketplace for distributed solutions. That is going to require a considerable investment up-front.

The major new capabilities (visualized in Figure 2) that will be needed include:

Highly reliable distribution networks–A grid that is merging DERs with new kinds of renewable generation and demand response will need to be even more reliable than today's grid. Even a momentary outage can trip off generation and act as a barrier to service provision. The future grid must incorporate system protection and controls that will reduce both momentary and sustained outages.

Two-way power flow–Most of today's energy grid is simply not designed for two-way power flows. The challenge lies not in the cable, but in the switching, protection, and controls equipment that was very much designed to operate in one direction. Without those controls, voltage swings can cause voltage to go out of regulation limits, resulting in power outages even when there is power aplenty.

A smart grid architecture–As the future DSO-operated grid will be blending a myriad of generation and demand response across different geographies, having a smart grid is critical. In this instance, "smart" must include sensors, communications, controls, and software that provide visibility into the operation of the grid and the status of every resource connected to it. The controls and intelligence of the smart grid must be distributed as well, collecting information and making decisions at the grid edge.[14]

Data analytics for both demand and generation forecasting–Data analytics must be coupled with the smart grid architecture to forecast the magnitude and locations of system demand. This is something utilities do now, but the presence of increased demand-response capabilities will make these models more complex.

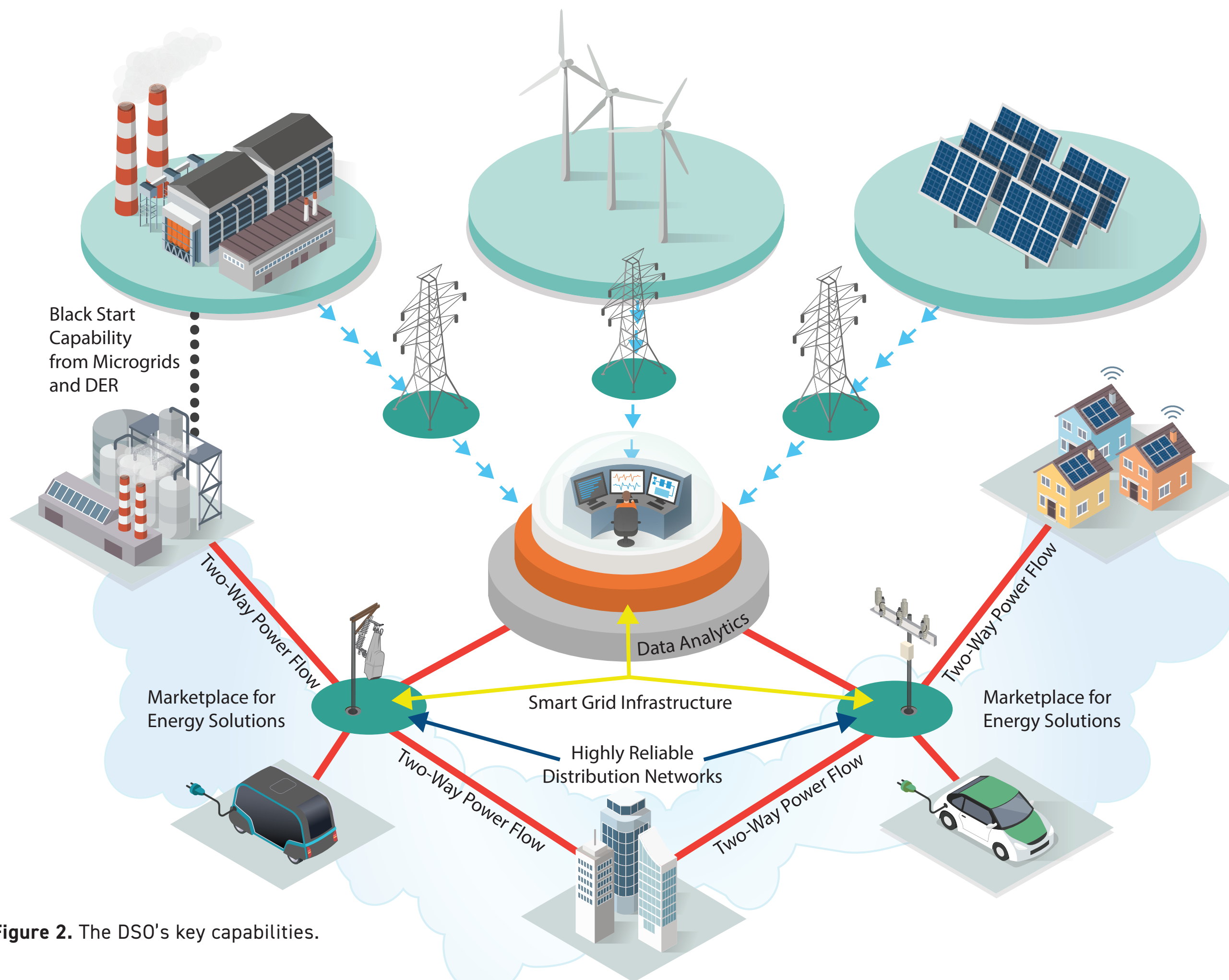

Figure 2. The DSO's key capabilities.

The DSO will need to add the additional dimension of forecasting available generation resources because these sources will now include more renewables and energy storage, which will change given weather conditions and local needs for that power. The analytics will need to extend to market activities and to more complex distribution analysis that incorporates real-time data.

Grid-building and black-start capabilities–As a greater portion of the grid's generation comes from renewables (both centralized and distributed), any outage is going to knock those resources offline. Bringing those feeders back online after an outage is going to require the DSO to route power from other places until those renewables are back online. In a major outage event, even large generation sources may need external power for black-starting. Resilient microgrids (dispatchable to the utility for rebuilding local grids) may be a perfect complement to grid-scale energy storage for this.

A marketplace for energy solutions–The DSO will not just be dealing with owners of solar panels connected to the distribution grid. The DSO will need to engage an increasingly complex "prosumer" environment where end-users are customers of the grid while also being able to provide certain services–be they generation, demand response, power quality, etc. And the position of each prosumer (as buyer, seller, or both) may change from moment to moment depending on the price signals sent by the DSO.

Some prosumers may even join as "virtual power plants," aggregating energy solutions from a group of smaller prosumers to sell on the wholesale and ancillary service markets. In the grid of the future, it will likely be more efficient to simply sell excess energy from one prosumer directly to the nearest neighbor load, a concept called "Transactive Energy."[15] The DSO needs an advanced, cloud-based marketplace where wholesale price signals and transactive energy deals can be posted and responded to in real time.

Making the transition work

So, how do we go from a traditional utility approach to a DSO model? The transition is not going to be a single set of regulatory and business model changes. In any of the different DSO approaches, it will require a long-term intention (a clearly stated outcome goal and commitment to reach it) coupled with an incremental evolution.

The particular capabilities and market components must rolled out over time and consider that jurisdiction's realities (e.g. speed of penetration of DERs, electrification of transportation, development of energy services markets, etc.). Early approaches have involved alternative ratemaking and rules relating to non-wires alternatives, weaning utilities away from traditional concepts of making money on capital investments and developing a nascent market of third-party energy solutions.[16]

Regulators attempting to implement a shift must be prepared for a lengthy process that involves a considerable amount of engagement with both utilities and stakeholders to develop a rollout plan that changes the system without shocking it into dysfunction. This slow and steady approach is what we saw with the most mature version of DSO transition (Ofgem's RIIO approach in Great Britain), and it's what we are seeing with the first DSO transition in the United States (the Reforming the Energy Vision process in New York).

Using Ofgem's RIIO approach as an example, we can see a representation of that incremental approach in Figure 3 on page 7.[17] It is clearly a complex process, and this graphic shows considerable thought must go into each step, understanding the interactions of activities and key milestones along the way.

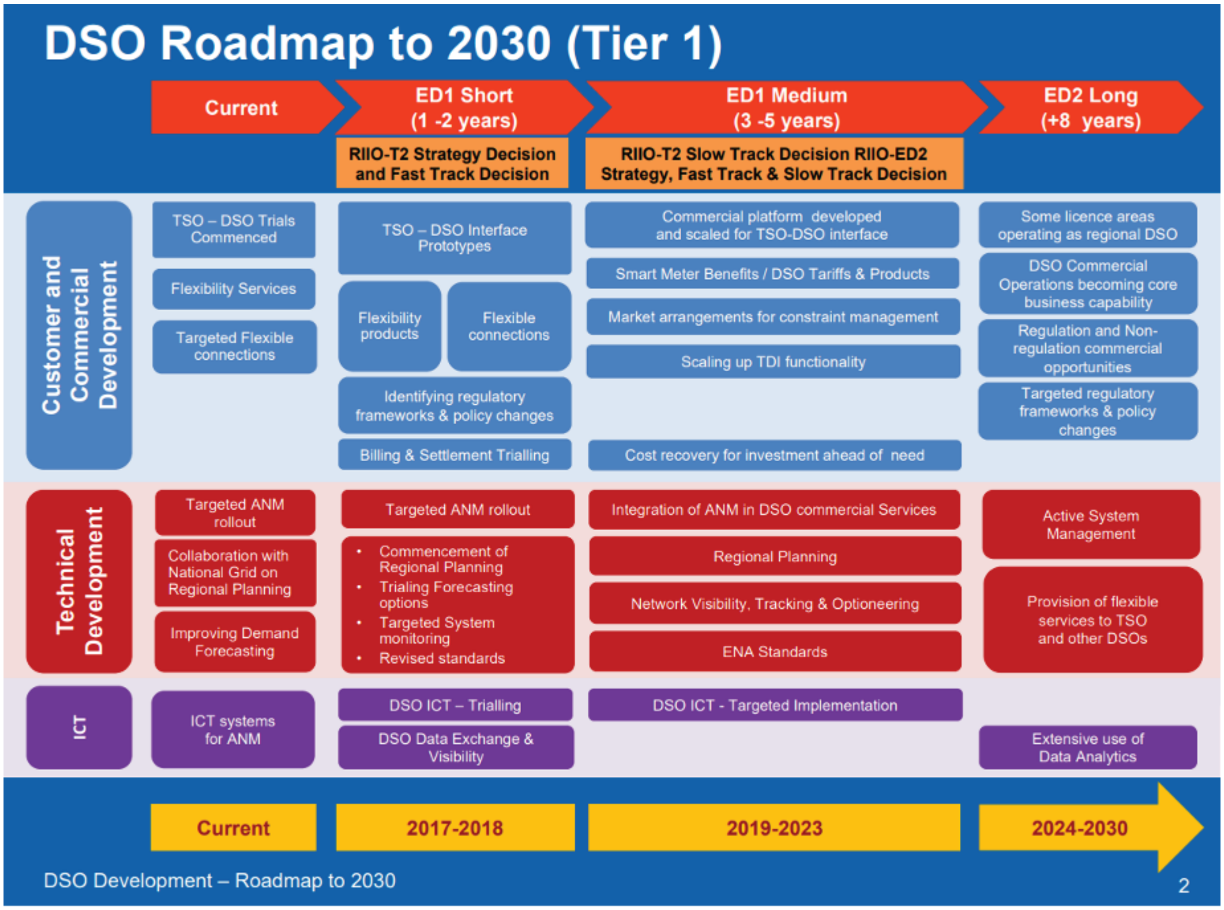

Figure 3. Ofgem's DSO Roadmap to 2030.

As the regulatory framework is put into place, utilities must begin making concrete changes. As utilities move to the DSO model, certain aspects of their present business must be separated out because they are inconsistent with the focused role of the DSO. David Butcher of Capgemini Consulting outlines the four broad options for separation the industry must consider:[18]

- **Accounting separation:** Separate financial accounts required for the asset owner (AO) and system operator (SO) but shared operational activities remain possible
- **Functional separation:** As with accounting separation, but separate operational and management activities are required
- **Legal separation:** As with functional separation, but the AO and SO become separate legal entities (Common parent-company ownership would be possible, but decision-making within each entity would be independent.)
- **Ownership separation:** No one legal entity holding a majority of shares in both the AO and SO

While these separations take place, the DSO would also be submitting investment plans to its regulators to prioritize and fund the development of the capabilities discussed earlier in this piece.

There are some clear challenges for the transition, even a slow deliberate one, including parties being amenable to this new approach. Among these challenges are:

Allocating the costs–While some end-users are going to become prosumers leveraging the capabilities of a smarter grid to sell ancillary services, a lot of customers are still just going to want to buy electricity. As mentioned earlier, the costs of a DSO transition will be considerable and primarily up-front. These investments may benefit all customers to some extent, but they will benefit the prosumers more. Traditional consumers may be less than enthused about shouldering an equal share of the rate burden to create new markets that will not change their service much, so it will be important to ensure they are not left behind.

Grey areas–Particularly early on in a DSO market, there will be areas where there is a lack of clarity as to whether this is a role for the DSO or for the market. This will be acute when the market is not providing some of the services desired and the DSO is well-positioned to do so. How much should the utility be investing in technology that will support power quality? Can energy storage be a grid asset owned and used by the DSO to help stabilize third-party resources? Can the DSO provide services to an ISO or RTO? Can generation be a grid asset owned and used by the DSO to enhance reliability?

Unintended Consequences–Any new set of rules for a system as large and resource-intensive as the electricity grid is going to be complex and will undoubtedly get certain things wrong. The DSO and market players may focus too much on certain activities or not enough on others because of imperfect market signals. There may be instances of service levels going down or costs going up because of some regulatory approach that resulted in an incorrect market signal.

The critical elements of addressing these and other barriers are going to be monitoring, communication, and iteration–monitoring each aspect of the grid through better data and better metrics; communicating with DSO's, market players, and stakeholders to understand their experience as it's happening; and adjusting elements of the DSO rules through iterative rulemaking. The regulatory bodies going through this process have found focusing on key enabling investments that support the development of new distribution system-operation functions and capabilities under a wide range of scenarios for future evolution of the grid has yielded the smoothest path to the DSO transition.[19]

Conclusion

Do we want our energy grid clean, reliable, or affordable? What kind of organization or regulatory structure is best positioned to deliver that? What financial incentives exist to ensure these organizations are focused on our priorities? These are the questions regulators and policymakers are asking themselves as they eye a transition to a DSO model. Once these regulators chart a course for a DSO transition, considerable planning and investments will be needed to establish a new market structure and network of service providers.

Existing DSO efforts will be closely watched to determine what works and what doesn't and how effective solutions can be transposed to new markets. As with so many things these days, the market will leverage new technologies to deliver stunning increases in capabilities, but at the cost of ever-increasing market complexity.

Footnotes

1. "Power Systems in Transition", International Energy Agency, October 2020
2. "How Reshaping Regulation will Reshape the Grid," S&C Electric Company, January 2020
3. "Open Networks Project DSO Definition and R&R," Energy Networks Association, June 2018
4. Graphic from "Distribution System Operator: A new model whose time has come for modernizing our energy system"
5. "Distribution System Operator (DSO) Models for Utility Stakeholders Organizational Models for a Digital, Distributed Modern Grid" Black & Veatch Management Consulting, December 2018
6. "Future World Impact Assessment" Energy Networks Association, February 2019
7. The Council of European Energy Regulators, for example, has stated clearly that DSO's should not be able to provide any services (such as energy storage) that are being offered in the marketplace.
8. An excellent discussion around the natural functions of a DSO versus the open market can be found in "The Role of DSO's in a Smart Grid Environment," European Commission, April 2014
9. "Outlook on the European DSO Landscape 2020," Vlerick Business School, 2020
10. "Position paper on Distribution System Operation: our approach and regulatory priorities," OFGEM, August 2019
11. "Greater Access to the Distribution Network in Northern Ireland Recommendations Paper," Northern Ireland Electricity Networks, December 2019
12. "The Power to Connect: Advancing Customer-Driven Electricity Solutions for Ontario," EDA, February 2017
13. In the U.S., the Federal Energy Regulatory Commissions recent orders 841 and 2222 have ensured that renewables and energy storage (even at relatively small levels) can participate in the wholesale market.
14. A detailed discussion of the Smart Grid Architecture Model can be found on pages 31-38 in "Modelling the DSO transition using the Smart Grid Architecture Model," Energy Networks Association, July 2018
15. "Transactive Energy: An Overview," National Institute of Standards and Technology
16. For a more in-depth discussion of this process, read "How Reshaping Regulation will Reshape the Grid," S&C Electric, January 2020
17. "Open Networks Project – DSO Transition: Roadmap to 2030," Energy Networks Association, 2017
18. "The DSO model: The objectives of a separated system operator," Capgemini Blog, December 2018
19. The Energy Networks Association has identified target areas within each utility function as part of their "Least Regrets" approach.

About the Author
Brian Levite is a Regulatory Affairs Director at S&C Electric Company, with more than 20 years of energy policy experience. Before joining S&C, he worked as a microgrid developer for an international firm, an energy policy specialist for the National Renewable Energy Lab, and as a consultant to the Department of Energy and the Environmental Protection Agency. Brian holds a master's degree in Public Policy from American University and is a Certified Energy Manager. He is the author of the book "Energy Resilient Buildings and Communities: A Practical Guide."

