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WHITE PAPER

Enabling a Digital Marketplace for Distribution-Level Flexibility for Electric Utilities

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The Push to Net Zero Will Force Massive Change — Will Your Utility Struggle or Succeed?

It's a time of transition for the electric utilities industry — one that will continue for decades. As the world urgently pursues net zero objectives, electric utilities must significantly increase their usage of renewable energy sources. This is a necessary transition, but one that's fraught with difficulties for electric utilities. The renewables that will serve as foundational energy sources for the foreseeable future, such as solar photovoltaic (PV) and wind, are intermittent and somewhat unpredictable. Increased dependency upon these sources of energy could affect the safety and reliability of the grid.

Digital flexibility is the answer. It's estimated that grid operators' need for flexibility will quadruple by 2050, and digital flexibility is the only realistic, affordable pathway toward fulfilling that need.[1] Distribution system operators (DSOs) must adopt a new set of business capabilities to procure flexibility and balance the grid at any point of time — and that means adopting flexibility market design approaches. They must develop the strong digital capabilities required for flexibility — building specific digital use cases and bolstering digital capabilities such as product setup, integrations and trade-matching logic options. Technologies such as the Internet of Things (IoT), edge computing and data management will form the new digital backbone for DSOs, supporting an economically efficient flexibility procurement marketplace.

This white paper defines the transitional challenges facing electric utilities and provides guidance on the implementation of DSO-level flexibility market design approaches, including a deep dive into the digital components required.

For electric utilities that successfully implement digital flexibility based on open market principles, the time of transition ahead represents a massive opportunity for achieving disruption on a scale that vastly differentiates from competitors.

1 Patel, S. (2022, January 3). "Disorderly transitions: Eight enduring global power sector trends." www.powermag.com. Retrieved April 19, 2022.

The Energy Transition

On the afternoon of September 4, 1882, a steam-powered generator nicknamed Jumbo — namesake of the famous circus elephant — first began supplying power to commercial and residential customers in Manhattan. Designed and built by Edison Electric Light Company, Manhattan's Pearl Street Station was the world's first commercial power generation and distribution plant. Thomas Edison's pioneering design for the generation and distribution of electricity would serve as a model for the burgeoning electric utilities industry; the elemental components of Edison's design remained little changed for more than a century. [2]

But change is on its way. Thanks in large part to the increasing role of renewable sources of energy such as wind and solar PV, the electric utilities industry finds itself in a time of transition. The International Energy Agency (IEA) forecasts that renewables will account for almost 95% of the global power capacity increase through 2026. The most capricious and unpredictable of renewable energy sources, solar PV and wind, are expected to make up the fastest-growing components of global renewable energy resources through 2026. [3]

Multiple drivers are steering the global transition away from traditional energy sources to renewable energy sources.

The 2021 United Nations Climate Change Conference (COP26), held in Glasgow, is one such driver. COP26 produced the Glasgow Climate Pact, an agreement among 200 nations to reduce the global emission of greenhouse gases by more than 40% over the next 20 years. COP26 also mandated phasing out coal-fired energy generation plants, strengthening the use of renewables as utility-scale primary energy sources, and modernizing the grid infrastructure to accommodate renewable energy sources. The conference's Green Grids Initiative promotes the sharing of sun, wind and water resources planetwide under the tagline "One Sun One World One Grid." [4]

Newer green technologies under development are also expected to spur the transition away from traditional energy sources. Green hydrogen, for example, is expected to represent a €10 trillion addressable market for the utilities industry by 2050.[5] And the capture, utilization and storage of carbon (CCUS) is expected to grow from a global market of $1.9 billion in 2020 to $7 billion by 2030. [6]

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The global drive to attain net zero by 2050 will require massive investments in the global grid, including the increased digitalization of energy grids, according to the IEA. Annual investments in global grid upgrades are expected to increase from $260 billion in 2021 to $820 billion by 2030.[7] This includes $1.2 trillion in the 2021 U.S. Bipartisan Infrastructure Investment and Jobs Act — which allocates $73 billion to upgrade power grids, $15 billion in electric vehicle investment and $39 billion to expand public transit.[8] And nearly a third of the of the EU's 2021-2027 $2.3 trillion budget has been allocated to climate objectives.[9]

For several years, government regulators have been consistently mandating industry transformation by introducing new regulations, changing market participation rules, pooling public funds targeted for transformation innovations and encouraging innovation in the energy sector. The coming decades of transition faced by the electric utilities industry will likely be expensive and disruptive.

2 Peltier, Dr. Robert. (2010, August 1). "The Edison of 1879." www.powermag.com. Retrieved April 11, 2022.
3 IEA. (2021, December). "Renewables 2021 - Analysis and forecast to 2026." www.iea.org. Retrieved April 11, 2022.
4 United Nations. (n.d.). "COP26: Together for our planet." www.un.org. Retrieved April 11, 2022.
5 Goldman Sachs. (2020, September 22). "Green hydrogen: The next transformational driver of the utilities industry." www.goldmansachs.com. Retrieved April 11, 2022.
6 Allied Market Research. (n.d.). "Carbon capture, utilization, and storage market overview-2030." www.alliedmarketresearch.com. Retrieved April 11, 2022.
7 IEA. (2021, May). "Net zero by 2050: A roadmap for the global energy sector." www.iea.org. Retrieved April 12, 2022.
8 The United States Government. (2021, July 28). Fact sheet: Historic bipartisan infrastructure deal. www.whitehouse.gov. Retrieved April 12, 2022.
9 Congressional Research Service. (2021, November 9). "EU climate action and U.S-EU relations." sgp.fas.org. Retrieved April 19, 2022.

Electric Distribution and the Flexibility Challenge

The key to success during the decades of transition ahead can be summed up in a single word: flexibility. The more challenging the transitions, the greater the flexibility that will be required to accommodate and adapt. In particular, the surge toward renewable energy sources will be inexorably linked to flexibility; the higher the renewable penetration, the more difficult the flexibility and balancing challenges.

In the past, ancillary services at the level of transmission system operators have been effective at managing both the reliability and stability of the transmission grid. But the energy ecosystem has significantly changed at distribution levels. The growing dependence upon intermittent, sometimes undependable renewables at distribution levels has created frequent supply-and-demand imbalances. System operation challenges have forced regulators to morph the role of distribution network operators (DNOs) into the more authoritative role of distribution system operators (DSOs). DSOs are charged with the ever-more-difficult responsibility of balancing the portion of the grid that falls under their purview.

Simultaneously, the increasing demand resulting from the electrification of both commercial and residential heating and cooling, as well as transportation — primarily electric vehicle (EV) charging — has drastically altered load curves and exacerbated local flexibility challenges.

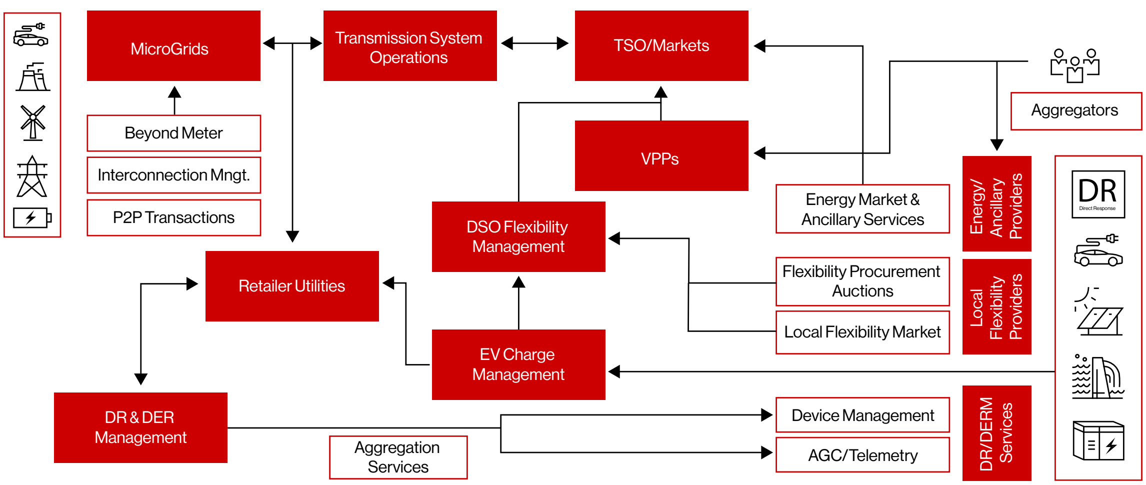


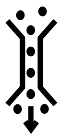
Fig.1 Depiction of an emerging market ecosystem, where distribution grid operations are most affected as a result of traditional-to-renewable energy source transition challenges.

The increasing utilization of EVs — which is expected to grow from less than 1% of the global light-duty vehicle fleet in 2020 to more than 30% in 2050[10] — provides an excellent example of the flexibility challenges that DSOs must manage. EVs are typically recharged late in the afternoon or evening when the majority of commuters return home for the day. That period corresponds with the time of day that renewable sources such as solar and, to a lesser degree, wind, are ebbing. The result is just one of many imbalances that must be managed by DSOs and is an example of the infamous "duck curve" that has become more problematic with the growing reliance upon renewable energy.

10 U.S. Energy Information Administration. (2021, October 26). "EIA projects global conventional vehicle fleet will peak in 2038." www.eia.gov. Retrieved April 13, 2022.

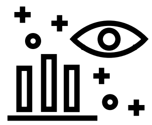
Digital Flexibility vs. Grid Hardening

DSOs are responsible for finding the best, most economical resolutions to ensure grid resiliency while minimizing capital expenditures on distribution grid enhancements (grid hardening measures such as adding physical lines and infrastructure). But the following three factors pose an increasing challenge to their efforts:



1. Local grid congestion:

Grids are undergoing a permanent shift in local demand curves, primarily resulting from EV charging and the increased electrification of heating and cooling systems.



2. Lack of control and transparency with EV charging:

Increased use of EVs in a specific area, along with associated daily charging behaviors, put tremendous pressure on distribution systems. DSOs need more visibility into EV charging systems and associated metering data.

3. Lack of visibility into microgrids (behind-the-meter systems):

DSOs need microgrid operations data, including usage forecasts, to maintain stable distribution grid operations. (This lack of visibility can be tempered to some extent by interconnection agreements between microgrids and distribution grids.)

Many DSOs participate in auctions to procure market-based flexibility — but auctions are expensive. DSOs need better alternatives for gaining local flexibility in grid management operations. In response, many energy regulators are modifying the rules that control and provide guidance to local grid management operations. One example is Article 32.1 of the European Commission Clean Energy Package, which incentivizes flexibility in distribution network management. This directive allows DSOs to define standardized market products for services procured in ensuring the effective involvement of all market participants. The directive also encourages DSOs to provide grid capacity information, as needed, to market participants.[11]

The IEA defines flexibility as a power system's ability to manage demand and supply across all relevant timescales, even in variable and uncertain situations. This management must not only be reliable and cost-effective, it must also ensure instantaneous supply and support long-term security of the supply.[12]

Greater flexibility can be achieved through physical enhancements and additions to grid infrastructure. But the more practical, effective and cost-efficient approach to achieving and maximizing flexibility is a digital approach. Digital flexibility uses open market economic principles and modern digital tools such as IoT, machine learning (ML) and artificial intelligence (AI) to help maintain balance between power availability and demand, and to enhance grid efficiency and resiliency.

11 European Union. (2019, June 5). "Directive (EU) 2019/944 of the European Parliament and of the council." eur-lex.europa.eu. Retrieved April 13, 2022.
12 IEA. (2019, May). Status of Power System Transformation 2019. www.iea.org. Retrieved April 14, 2022.

Flexibility Market Design Approaches

Distribution-level flexibility markets should be designed around local considerations and regulatory structures. The goal should be a market structure and process that ensures equal treatment, transparency and fairness for all participants, including flexibility sellers and buyers. Two major market design approaches are most relevant for local, distribution-level flexibility markets: DSO-controlled local flexibility markets and independent local flexibility markets.

DSO-controlled local flexibility markets are operated by DSOs for their own flexibility requirements. This structure places the DSO in a commanding position relative to flexibility sellers. But that unfair market advantage is lost when the DSO is functioning merely as a participant and an independent market operator controls the flexibility market.

Independent local flexibility markets are owned and operated by independent entities. The operating entity does not have an existing relationship with flexibility buyers and sellers. Operating entities might also be co-owned and operated by a consortium of market participants, which may include DSOs.

A third, less common approach to flexibility markets is based on participant restrictions. In this approach to flexibility, a DSO may decide to increase standardization and participation requirements by permitting only flexibility aggregators to participate in the local flexibility market.

This scenario requires a local flexibility aggregator to bear the responsibility for placing flexibility bids and managing dispatch instructions from the market. The net result from this approach can be a simplified process of managing smaller flexibility providers.

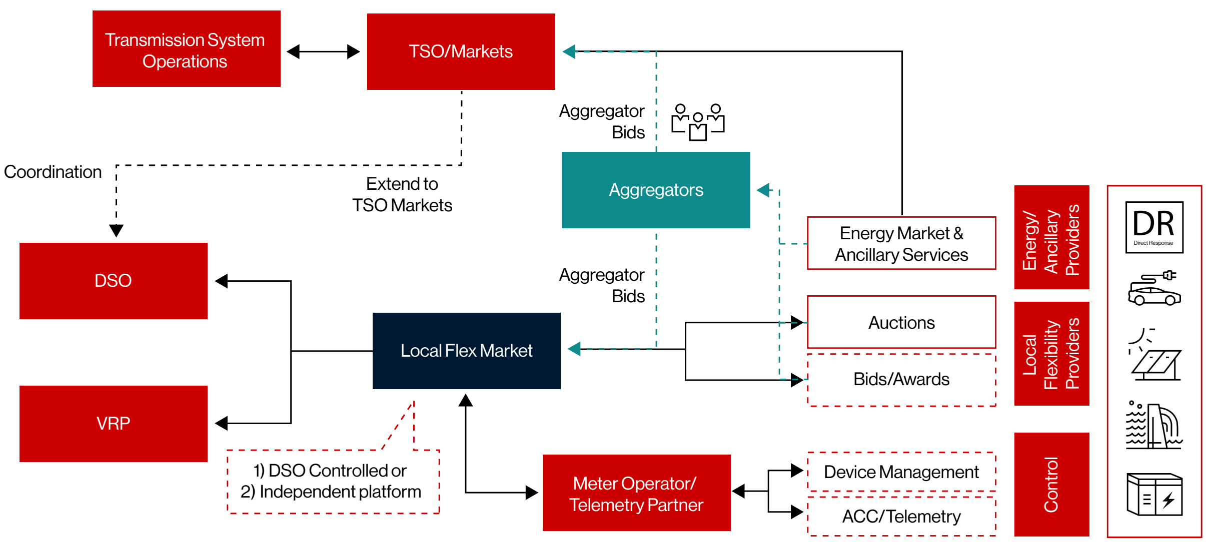


Fig.2 The local flexibility market platform is emerging as a central digital component in the distribution grid management landscape.

Enabling and managing a local flexibility market process is similar to managing any other ancillary service market process. But important variations include the need for congestion forecasting, and for continuously masking grid network information and making it available to market participants. The masking of network information is particularly crucial given that most nations regard both static and live transmission and distribution grid information as critical national security data.

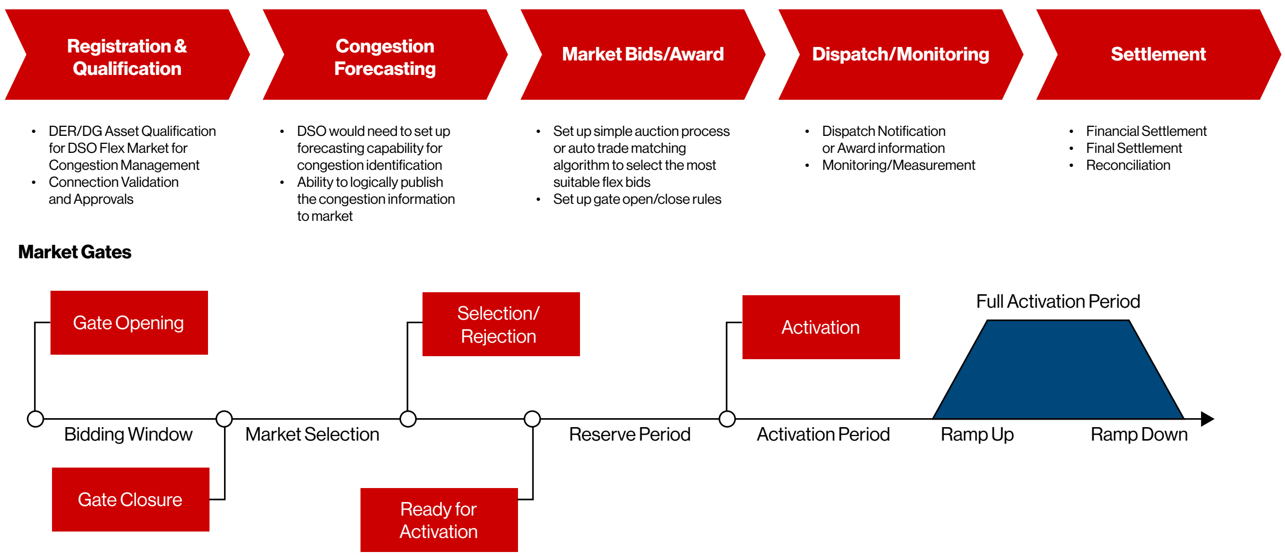


Fig.3 A flexibility management market follows a market process similar to that of an ancillary service market.

Essential Capabilities for Enabling Local Flexibility in the Digital Marketplace

Enabling flexibility in the local digital marketplace is essential. But how can utilities ensure that they have the digital flexibility they will need to remain adaptive and competitive in the coming years? The keys to success lie in the following four areas:

1. Maintaining sufficient visibility and observability into flexibility asset operations

DSOs must develop business capabilities that include the capacity to accurately measure asset performance abilities, as determined by the type of flexibility services and subscribed flexibility products or services they have deployed. The frequency of performance measurements may encompass quite a wide range, varying from as little as a few hundred of milliseconds to as much as 30 minutes. DSOs also need local meter data management capabilities to enable and support the collection of measurements, and they need to be able to validate, store and utilize this data for settlements. DSOs can benefit from establishing and maintaining a close integration with a metering data provider or systems operations provider, which can help them collect revenue-grade performance data.

On the digital side, utilities should establish and maintain a digital command center. An IoT-based command center can give market operators and DSOs an integrated view of flexible assets, real-time measurements and operations status. This command center serves as the backbone of local flexibility management — the central nervous system, so to speak, where asset operations, monitoring, optimization and performance management all come together to deliver real business value to DSOs.

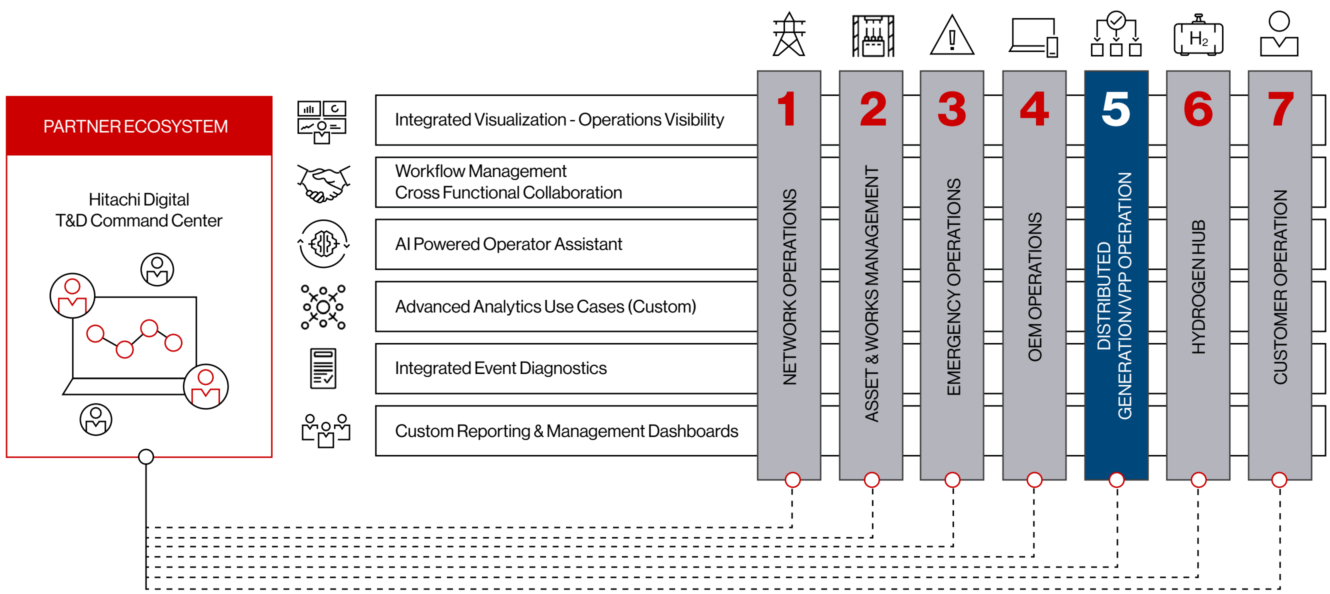


Fig.4 Conceptual view of a Hitachi digital command center.

2. Maintaining sufficient congestion forecasting capabilities

DSOs must also be able to forecast causes and durations of congestion, as well as identify forecasted grid constraints for sharing to markets before the close of bidding. They must be able to identify the forecasted nested grid constraints, which exist at multiple network levels within parent-child relationships.

The ability to expose congestion information to the market without revealing the organization's network model is also an essential business capability. The network operator should devise innovative methodologies to assure continued compliance with national security codes while avoiding the exposure of crucial grid information. One alternative for achieving this goal involves masking the grid hierarchy while treating grid constraints as logical groups of meter points, with valid active-from and active-to time durations. Grid constraint information must communicate the economic value of locational flexibility requirements to market participants.

Another capacity DSOs need is the ability to deploy robust data management platforms, such as data integration, data catalog, and extract, transform and load (ETL) products. They can deploy these platforms to collect and manage grid data sourced from multiple systems, including network management systems, advanced metering infrastructures and measurements from local flexibility assets. Collectively, this data should be used to predict local congestion, imbalances and voltage issues.

The ability to fully leverage the value of data is crucial, including the cataloging, classifying, blending, orchestrating, conceptualizing and prepping of data for analytics (DataOps). DSOs also need efficient, easy-to-use, customizable reporting abilities that allow for data export to preferred third-party business intelligence solutions.

Finally, they need to be able to build analytics models, such as AI and ML models. They'll need expertise to train and retrain models, enable the automated analysis of defects, and assign risk scores to assets sourced from AI-based image analytics. Necessary technologies to support these capabilities include asset performance management, analytics, DataOps and image and video analytics systems.

3. Maintaining sufficient controllability of asset operations

Bid award communication and the dispatching of assets are critical business capabilities for local flexibility management. Though the bid award is determined by the marketplace, it is typically the DSO's responsibility to send notifications that will trigger the activation — remotely, in some situations — of the flexibility asset. The market operator must ensure that flexibility bid award information has reached the market participant using a standard set of market application programming interfaces (APIs). The DSO can follow simple, notification-based dispatch instructions to notify the participant, and the participant would be required to activate the asset within a set number of minutes after receiving the notification. Alternatively, an IoT-based, automatically initiated telemetry signal can be established for activating the asset; this approach offers more accurate flexibility generation control that may, in turn, lead to improved compliance.

These assets need a strong edge layer to enable them to respond quickly to telemetry signals, or to take local operational decisions based on frequency or voltage parameters. An edge intelligence product can enable localized, rules-based actions and data management, from edge to multicloud, for low-latency DataOps needs. An IoT layer is also a key digital capability to ensure that activation instruction and generation measurement data are closely integrated, in real time, to the digital flexibility command center.

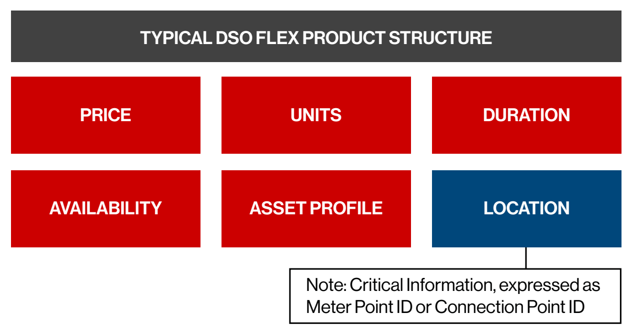


Fig.5 Typical DSO flexibility product structure includes price, units, duration, availability, asset profile and — most critical — location data.

4. Maintaining marketplace operations capabilities

Finally, DSOs need to be able to design and configure local flexibility products. These products must utilize location data as a key parameter, and they must take into account datapoints that include bid size, duration, activation period, ramping period, mode of activation, availability, recovery time, penalty conditions, frequency of activation and others.

Additionally, a flexibility marketplace should utilize trade-matching algorithms based on location-congestion constraint data. Aggregating resources from different constraint zones should not be allowed, for example, and all trade matching should occur within a single grid constraint zone. Marketplaces should be able to collect forecasted congestion information from a DSO's systems and use the data to inform the trade-matching process. And the DSO should be able to formulate financial settlements faster while processing key inputs such as traded price data, bid award information and activation duration. Final settlements should be calculated after the receipt of revenue-grade measurement data from DSO-approved measurement data providers.

This can be achieved via a digital marketplace platform that encompasses:

- Marketplace web applications that include a customer self-service market portal for flexibility sellers, and that automate most registration and onboarding processes. These should include a trade application that supports dedicated traders in managing trades on behalf of asset owners as well as an asset owner portal that provides information about business performance and the status of assets.
- Marketplace pricing capabilities that are built in for different customer categories and flexibility products.
- External market API gateways that facilitate easy integration with flexibility sellers and buyers. These may also integrate with transmission system operator (TSO) or wholesale energy markets.
- Energy trading and risk management (ETRM) capabilities, which are essential for aggregator-based flex models. In these models, a large portfolio of flex assets can be effectively used for multiple grid services simultaneously in distribution-level and transmission-level markets (such as TSO-level ancillary services, DSO-level flex services and energy arbitrage).

A Historic Window of Opportunity

The business and science of generating electricity are changing at such a pace that the industry itself would be unrecognizable to Thomas Edison. Globally, the electric utilities industry is embracing net zero, which means relying on less dependable and predictable sources of energy. Simultaneously, fluctuations in usage rates are becoming more extreme and difficult to manage thanks to the ever-increasing electrification of major energy consumers such as heating and cooling and transportation.

Navigating these challenges requires local flexibility management — a crucial capability for DSOs in ensuring grid resiliency in the face of an increasingly renewable grid scenario. And, rather than building new physical infrastructures to accommodate and enhance local flexibility, a digital marketplace brings greater economic efficiency and drastically reduces procurement costs for DSOs. Accordingly, DSOs must focus on best-in-class digital capabilities such as command centers, IoT, edge computing, data management and advanced analytics to truly enable the digital marketplace for local flexibility.

Electric utilities industry operators must change to keep pace with the unprecedented transformations occurring with both power sources and power usage. Yes, it's a massive challenge. But it's also a historic opportunity. After all, history teaches that evolutionary transformation within any industry always proves to be a springboard to greater success for some — and a pathway to failure for others. Utilities industry operators that successfully harness the power of digital will be among those that leverage a time of transition to unlock historic opportunity.

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