Hype Cycle for Digital Grid Transformation Technologies, 2023

Published 28 July 2023 - ID G00792465 - 147 min read

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Initiatives: Energy and Utilities Digital Transformation and Innovation; Energy and Utilities Technology Optimization and Modernization

A digital grid can host higher volumes of renewable energy and interact with resources, both generators and loads, to deliver operational resilience. This Hype Cycle provides utility CIOs with insights on technologies to enable digital grid transformation.

More on This Topic

This is part of an in-depth collection of research. See the collection:

- 2023 Hype Cycles: Deglobalization, AI at the Cusp and Operational Sustainability

Analysis

What You Need to Know

Renewable resources are penetrating the generation mix at both transmission and distribution voltages. System operators must adopt intelligent operations to orchestrate participants at speed and scale across organizational boundaries. Leading transmission system operators are aggressively adopting advanced digital technologies, such as phasors, and processing them with AI and machine learning (ML) techniques on wide-scale operational grid twins, as anticipated by Gartner's intelligent operations model. Generative AI is emerging as a useful assistant for engineering design and simulation.

The grid is emerging as a bottleneck to the energy transition triggered by delayed connections and stability concerns.

A digital grid uses intelligent operational capabilities to manage bidirectional energy flows by orchestrating energy assets above and behind the meter. The digital grid uses physical and digital connections as well as market prices to orchestrate participants' decisions.

Data exchange is needed across generation, demand and delivery channels to reliably deliver metered commodity services at a customer premises. This Hype Cycle covers technologies that support the digital transformation of the grid, enabling new, transformational business models.

For other generic utility technologies please see Hype Cycle for Utility Industry IT, 2023.

The Hype Cycle

The Hype Cycle reflects the modernization investments of the "smart grid," which focuses on physical measurement with smart metering and meter data management systems. The data generated is used to support decisions such as an advanced distribution management system, seen in the cluster just after the Trough in Figure 1.

Utilities have seen a rapid acceleration in distributed energy resources (DER) beyond the meter, requiring new tools, such as the Internet of Things (IoT), to integrate process-oriented information from operational technologies (OT), along with information from consumer technology (CT). Distributed energy resource management system (DERMS), with its focus on operations, is an example that has moved rapidly across this Hype Cycle.

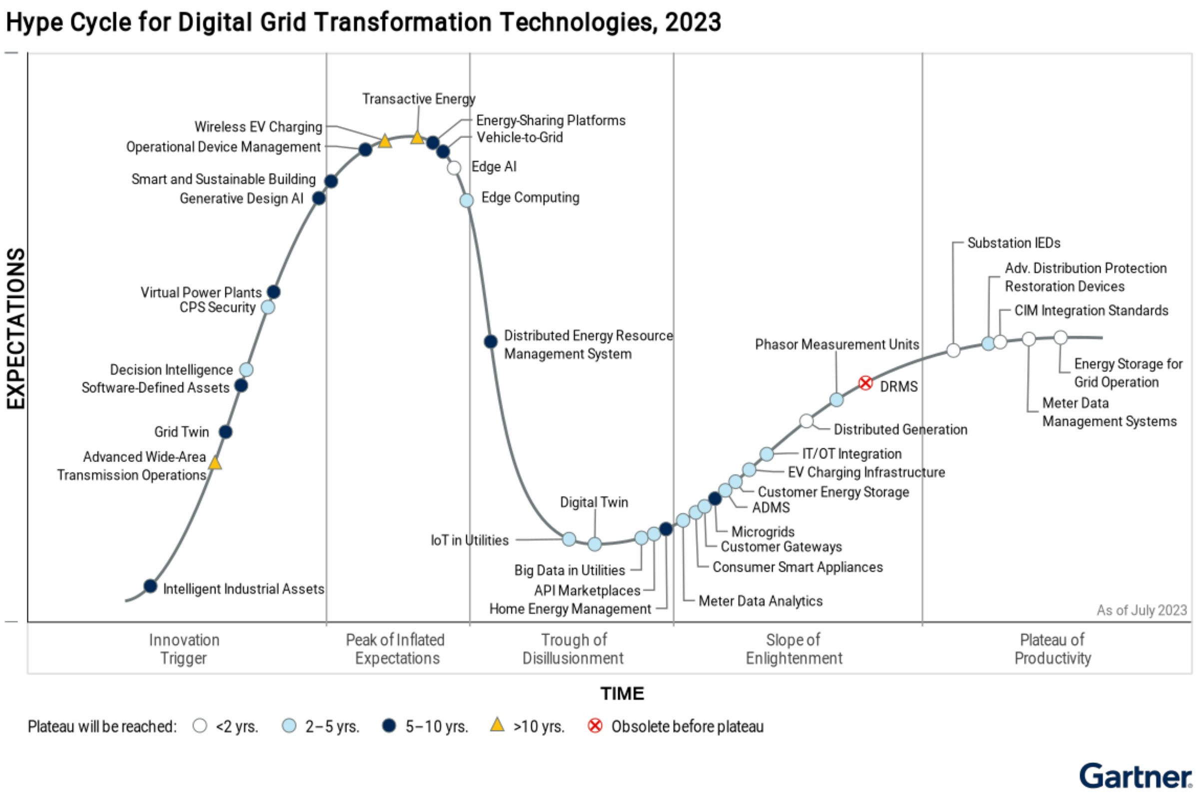
More recently, AI and ML focused on hyperautomation use cases are moving from pilot to scale-out, particularly in grid edge and high-speed operations use cases. Intelligent operations describe an orchestration pattern where decisions are delegated to the asset through decision intelligence as well as market-driven price points from transactive energy and flexibility markets. API-driven energy-sharing platforms are enabling platform business models. For example, virtual power plants (VPPs) that orchestrate DERs through commercial contracts and permissions. The rapid increase in participants is creating complexity with novel computation demand for hosting and operations use cases solved with wide-scale digital twins creating the new profile of a grid twin.

Utilities must rethink the integration of engineering technology (ET), information technology, OT and increasingly, consumer technology (CT) to create an interoperable ecosystem. This strengthens the case for cyber-physical system security at the physical asset level.

Operational systems are moving from reactive dispatch to predictive, and in some limited cases, autonomous operations. Systems will reconfigure software-defined assets (SDAs) when discrete digital twins are deployed to the edge to automate the asset, to create intelligent industrial assets both in front and behind the meter.

In addition to this Hype Cycle, our companion utility-focused document, Hype Cycle for Utility Industry IT, 2023 provides insights on more generic utility technologies.

Figure 1: Hype Cycle for Digital Grid Transformation Technologies, 2023



The Priority Matrix

Distributed generation and energy storage for grid operations enable high levels of renewables without compromising grid stability, offer short-term transformational gains and should be in capital plans. VPPs and DERMS are technologies with longer lead time and high benefits, depending on customer adoption.

Other transformational profiles integrate operations at the grid edge both above and beyond the meter, with a data fabric to integrate customer- and utility-owned intelligent industrial assets (IIAs). IIAs can combine into systems such as smart sustainable buildings to contribute to grid balancing. Edge computing and edge AI enable composable digital twins from assets to customers to improve observability. Decision intelligence is needed to manage decision-making rights across participants. The digital grid uses observability to generate intelligent operational insights using AI and ML. Operational insights, in turn, will be actioned by software-defined assets, which will optimize local operational envelopes to meet rapidly changing operational demands.

A range of moderate benefit technologies are the base building blocks of the digital infrastructure. These range from Common Information Model (CIM) to APIs. As IT and OT continue to converge, operations technologies such as gateways, energy management and operational device management are needed to round out the portfolio.

Table 1: Priority Matrix for Digital Grid Transformation Technologies, 2023

(Enlarged table in Appendix)

Benefit	*Years to Mainstream Adoption*			
↓	*Less Than 2 Years* ↓	*2 - 5 Years* ↓	*5 - 10 Years* ↓	*More Than 10 Years* ↓
Transformational	Distributed Generation Energy Storage for Grid Operation	Decision Intelligence Digital Twin Edge Computing IoT in Utilities	Generative Design AI Grid Twin Intelligent Industrial Assets Smart and Sustainable Building	Transactive Energy
High	Edge AI Meter Data Management Systems Substation IEDs	ADMS Big Data in Utilities CPS Security Customer Energy Storage IT/OT Integration Phasor Measurement Units	Distributed Energy Resource Management System Energy-Sharing Platforms Microgrids Software-Defined Assets Vehicle-to-Grid Virtual Power Plants	
Moderate	CIM Integration Standards	Adv. Distribution Protection Restoration Devices API Marketplaces Consumer Smart Appliances Customer Gateways EV Charging Infrastructure Meter Data Analytics	Home Energy Management Operational Device Management	Advanced Wide-Area Transmission Operations Wireless EV Charging
Low				

Source: Gartner (August 2023)

Off the Hype Cycle

Removed Artificial General Intelligence — not specific or unique to digital grid

Removed Blockchain in Utilities — now on Utility IT Hype Cycle

Removed Energy Efficiency Gamification — now on Utility IT Hype Cycle

Removed Green Hydrogen — now on Disruptive Energy Technologies Hype Cycle

Removed Industrial Operational intelligence — now on Utility IT Hype Cycle

Retired Advanced Metering Infrastructure — Mainstream

Retired Digital Business Platform — morphed into product extensions

Retired Electric Vehicles — Mainstream

Retired Grid scale energy storage — Mainstream

On the Rise

Intelligent Industrial Assets

Analysis By: Rich McAvey, Lloyd Jones

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Gartner defines intelligent industrial assets (IAAs) as those with fully accessible and compatible datasets that support lean, automated and end-to-end processes that simultaneously optimize operations, engineering, maintenance, planning and economic performance for current market conditions.

Why This Is Important

Long-lived physical business assets, such as offshore rigs, refineries, pipelines, powerlines and generators, are the foundation for value in asset-intensive energy systems. Never-ending market turbulence and the demands of the energy transition mean new assets need fit-for-the-future designs that can be changed remotely through reconfiguration and orchestration. Intelligent assets can respond to changes in the external environment by intelligently coordinating to modify operations.

Business Impact

IIAs are strategic focal points that shape future digital investments. Future profitability relies on asset intelligence to drive four capabilities:

- Solving multiple objectives simultaneously
- Responding rapidly and without loss of efficiency
- Ultra-low-cost operations
- Full asset life cycle optimization

While the business impact will be transformational, it will take sustained effort over the coming years.

Drivers

- Commodity markets remain volatile, but companies are managing cash flows tightly and are generating profits. The near-term outlook is for a period of healthy cash flow that will support continued investment in oil and gas assets as well as alternative energy assets, such as renewable power and hydrogen. As energy markets continue to change faster than business asset designs, energy companies must employ IIA designs.

- Game-changing digital investment opportunities have come into focus. Virtually all energy companies have formal digital strategies and technology roadmaps. The situation is evolving very rapidly and most CIOs are supporting multiple digital investments at multiple levels.

- Technology markets have matured, enabling cheaper and faster change. Improvements made to connectivity, enterprise data management and edge computing have strengthened the digital foundations upon which new energy assets operate. These advances in digitalization have built organizational confidence in the potential of advanced technology and at the same time, narrowed the time frame to achieve the design and construction of intelligent assets.

- Business confidence in digital innovation is strong. The technology products and services available from vendors have also been rapidly evolving over the last few years. Today's digital environment is shifting toward modular and composable components of hardware, software, cloud/edge, SaaS and PaaS that can be easily integrated and reconfigured. This shift has greatly reduced the commitment needed to design and construct the basic building blocks of IIAs.

- Environmental priorities are reshaping digital ones. Companies can no longer afford to take a wait-and-see approach to the energy transition. Transitioning to net zero requires energy assets capable of balancing their emission implications simultaneously with other business objectives, such as reliability, safety and financial performance.

Obstacles

- Near-term priorities are confusing. Rapid demand volatility, supply chain disruption, inflation, geopolitical crises, and decarbonization mandates are affecting energy markets. Governments and companies are focusing on energy availability and security, driving policy and investment decisions.

- Longer-term priorities are also confusing. Energy companies are entering an era where business models and operating models will be reconstructed. Achieving ubiquitous, affordable, available and acceptable energy provision in these conditions will require advances and innovation across a wide range of energy technologies.

- Digital foundations are weak. The digital environment at most energy companies is dominated by commercial off-the-shelf (COTS) software that is narrowly scoped, hard to integrate and expensive to sustain. Although new digital solutions have shifted toward modular and composable components, these architectures represent too small a fraction of energy company digital foundations.

User Recommendations

- Start now to lead the transition to IIA designs and make progress while market conditions remain favorable. Conceptualize, sponsor and fund a minimum viable product program for developing intelligent asset designs and roadmaps.

- Consider hosting competitions to build engagement and creativity. Empower self-actualized teams to develop innovative and practical advances toward intelligent assets and motivate engagement with social recognition.

- Assign department leaders to work with like-minded colleagues to develop goals, strategies and early solutions for intelligent assets and operations, and to ensure orchestrated action across the company. Identify the key challenges blocking progress, then develop workaround solutions.

Gartner Recommended Reading

Quick Answer: What Are Intelligent Assets and Why Are They Important?

6 Top Practices for Winning the Race Toward Intelligent Assets

2023 Oil & Gas Trend: Preparing for Intelligent Operations

Advanced Wide-Area Transmission Operations

Analysis By: Lloyd Jones

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Embryonic

Definition:

Advanced wide-area transmission operations (AWTO) is a collection of analytics and operational capabilities, addressing the increased complexity of managing long-range energy transmission in systems with rapidly rising renewable sources. Improved system resilience is achieved by measuring, analyzing and managing the grid in subsecond intervals to maintain stability.

Why This Is Important

As utility large-scale renewable penetration levels rise, renewables are displacing legacy fossil-fueled generators. The residual mechanical inertia of the grid drops, thus requiring new capabilities to measure and manage the grid in subsecond intervals to maintain grid stability. AWTO is an emerging capability spanning several technologies, using several levers to measure and maintain system frequency to retain operational resilience.

Business Impact

System operators have deployed synchrophasors and wide-area control systems to measure and manage grid stability. AWTO has the capability to collect real-time data with low latency. AWTO provides the event processing capability to analyze the data, making real-time recommendations and future operational decisions. AWTO helps avoid under and overfrequency incidents by mitigating disturbances and ensuring the return to stable operating states through monitoring and control.

Drivers

- System operator zones are commonly interconnected with both AC and HVDC interties, operators need to coordinate across multiple zones, owners and participants. This is facilitated by AWTO.
- Large thermal plants are retiring, replaced by low-inertia renewable energy resources, such as wind and solar. Renewables are reducing the overall system's mechanical inertia and limiting the power system's ability to smoothly ride through disturbances created by supply-demand imbalances.
- AWTO provides advanced learning and computational models (AI & ML) to support high-speed intelligent operations using prescriptive modes of operation based on observations, to generate lookahead windows for system operators, so they can avoid disturbances.
- Independent system operators (ISO) need insight into current system performance to predict upcoming disturbances, along with control capabilities to maintain stability. AWTO capabilities are based on high-speed event processing to address disturbances from abnormal incidents that impact stability parameters, such as frequency, voltage, system stability and power swings.
- AWTO control strategies could include signal injection and propagation measurements to develop topology-sensitive, transient transfer models. State and topology-based configurations are used to train static and recursive models that can supervise or take control action (including islanding and synchronization). The models consume synchrophasor data from phasor measurement units (PMUs) to create an observable picture of grid behavior during disturbances, enabling faster rebalancing and synchronization.
- Control algorithms already issue automated commands and in the future will become capable of learning to improve automation choices. Provided high-speed processing is in place, operational commands can be issued to a wide range of levers (from flexible AC transmission systems [FACTS] devices to switches and resource control loops), while acknowledging market and physical constraints.

Obstacles

- AWTO is enabled by fast-response FACTS devices.
- System observability needs to be improved, and this can be addressed by improving PMU deployment and synchrophasor fast signal processing.
- The cost of ultralow-latency signal measurement and acquisition across wide areas.
- The management of operational wide-area data networks that manage and share low-latency IP traffic to balance measurement and control signals.
- Within an ISO system, computational power is required to compute wide-area event streams. This suggests quantum computing capabilities are needed to prescribe control signals.
- Dispatch of smart inverters' operational setpoints to create clusters of virtual synchronous condensers.

User Recommendations

- Leverage industry associations to build analytics capabilities to parse high-speed event data, and find and monitor event flags to alert operators of angular separation, oscillatory stability, voltage stability and islanding detection.
- Improve data handling for OT devices.
- Add PMUs to the network to increase synchrophasor data volumes, creating large volumes of temporal data with high velocity (low latency) that needs to be acquired, processed as event streams and persisted for postevent analysis.
- Align IT and OT cross-teams, as advanced data management capabilities do not reside in OT and processing complex algorithms requires domain expertise that does not exist in IT.
- Pilot advanced wide-area measurements with your OT vendors to understand and model inertia zones that could be leveraged to control the rate of frequency change.
- Plan to invest in fast response resources such as batteries and or switch curve reconfiguration.

Sample Vendors

General Electric (GE); Hitachi Energy; Reactive Technologies; Siemens

Gartner Recommended Reading

The Impacts of Exponential Renewable Generation Growth Across the Energy Ecosystem

Essential Patterns for Event-Driven and Streaming Architectures

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Grid Twin

Analysis By: Lloyd Jones

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition:

A grid twin (GT) is an extensible analytic platform that can ingest, model and simulate the grid with loads, generators and full topology across time horizons to improve grid utilization across parties. A GT will automate and solve analytic use cases from operations such as load flex to system planning. Typical GT capabilities include DataOps, network modeling, simulation, capacity, energy, connections and hosting services across multiple parties.

Why This Is Important

Utilities struggle to maintain topology models of networks, and have not achieved an affordable maintainable topology model that can serve all use cases. A GT uses a range of analytics, ML and emerging AI tools to enrich data collected from data fabrics (such as OT and IoT, Metering). The GT attaches the time series data to a related business object that has been assembled and collated from a range of systems. The GT normalizes data to support repeatable decisions across time.

Business Impact

The GT creates a new pathway to build and maintain the network topology model. The GT ingests data from a range of channels including manual updates, compute vision, markets and direct measurements. The GT reduces duplicate data capture efforts and reduces processing time with automation. The GT can supply an appropriately filtered model to a participating system, which improves data alignment and consistency, supporting repeatable operational decisions.

Drivers

- The energy transition is driving new demand for connections to the grid both in the center, at grid scale, and at the edge, from large industrial to small residential systems.
- There is a huge customer demand for connection permission, which swamps system and grid planners triggering a business need for planning automation of hosting capacity.
- Network owners expend a huge effort maintaining discrete stand-alone network models across participating systems.
- DERs can interact with the grid requiring each connection to have a set of contract permissioned operations to ensure the resilience of the grid — that level of detail cannot be managed with conventional power systems studies at scale and volume.
- The rise of markets and third party aggregators who will need to exchange operational, control and price data at ever decreasing time intervals and finer levels of granularity.
- Operational control and dispatch of DERs will require data and models of beyond the meter resource models — which is not supported by traditional system modeling approaches.
- The GT is a cloud first set of aligned normalized data that automates the creation and maintenance of the topology model. The GT can support analytics use cases across planning, design, operations and maintenance use cases across widely varying time domains from years to subsecond.
- The GT can host analytic models, which creates automation opportunities for hosting and operations.
- The GT can round trip data to participating systems (such as Advanced Distribution Management Systems, Distributed Energy Management Systems, Geographic Information Systems and Supervisory Control And Data Acquisition) by consuming data updates, back testing and validations before updating and publishing — improving decision repeatability.

Obstacles

- Legacy process field based data capture processes are centered on manual updates to a GIS, with a heavy reliance on human power co-ordinated with workflows but with very limited automation.
- Consequently the user community of the network model is stuck in digital apathy, expecting low quality data that needs rework and validation creating a culture of busyness scrubbing data/
- Forgotten to record permission to capture and model customer owned resources — failing which nonintrusive load modeling to drive a customer digital twin that interacts with the grid.
- A perception that network model maintenance is too hard for AI/ML.
- A reluctance from system planners to accept ML approaches to DER capacity hosting.

User Recommendations

- Track electric vehicle and DER adoption by customers to understand the timing of an investment in a three-phase unbalanced network model to support model driven operations.
- Assess the effectiveness of the current business spend on maintaining the network topology model. Use this baseline to understand if an investment in a Grid Twin will pass the sniff test.
- Document the velocity of data capture efforts across the enterprise and the consequence of lagging data on operational decision integrity.
- Assess opportunities to automate data ingestion sources such as measurements, data capture and computer vision where current resources could be augmented with AI ML machines to process inbound data more efficiently.

Sample Vendors

Elpis2; General Electric; Greenbird; Hitachi; Plexigrid; Siemens

Gartner Recommended Reading

Quick Answer: What Are the Digital Checkpoints to Achieve Intelligent Operations?

To Enable Intelligent Industrial Assets, Strengthen These Digital Capabilities

6 Top Practices for Winning the Race Toward Intelligent Assets

Market Guide for Advanced Distribution Management Systems

Market Guide for Distributed Energy Resource Management Systems

Decision Intelligence

Analysis By: Erick Brethenoux

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Definition:

Decision intelligence (DI) is a practical discipline that advances decision making by explicitly understanding and engineering how decisions are made and how outcomes are evaluated, managed and improved via feedback.

Why This Is Important

The current hype around automated decision making and augmented intelligence, fueled by AI techniques in decision making (including generative AI), is pushing DI toward the Peak of Inflated Expectations. Recent crises have revealed the brittleness of business processes. Reengineering those processes to be resilient, adaptable and flexible will require the discipline brought by DI methods and techniques. A fast-emerging market (DI platforms) is starting to provide resilient solutions for decision makers.

Business Impact

Decision intelligence helps:

- **Reduce technical debt and increase visibility.** It improves the impact of business processes by materially enhancing the sustainability of organizations' decision models based on the power of their relevance and the quality of their transparency, making decisions more transparent and auditable.

- **Reduce the unpredictability of decision outcomes.** It does so by properly capturing and accounting for the uncertain factors in the business context and making decision models more resilient.

Drivers

- **A dynamic and complex business environment, with an increasingly unpredictable and uncertain pace of business.** Two forces are creating a new market around decision intelligence platforms (DIPs). The first is the combination of AI techniques such as natural language processing, knowledge graphs and machine learning. The second is the confluence of several technology clusters around composite AI, smart business processes, insight engines, decision management and advanced personalization platforms.
- **The need to curtail unstructured, ad hoc decisions that are siloed and disjointed.** Often uncoordinated, such decisions promote local optimizations at the expense of global efficiency. This phenomenon happens from both an IT and a business perspective.
- **Expanding collaboration between humans and machines.** This collaboration, supplemented by a lack of trust in technologies (such as AI), is increasingly replacing tasks and promoting uneasiness from a human perspective. DI practices promote transparency, interpretability, fairness, reliability and accountability of decision models critical for the adoption of business-differentiating techniques.
- **Tighter regulations that are making risk management more prevalent.** From privacy and ethical guidelines to new laws and government mandates, it is becoming difficult for organizations to fully understand the risk impacts of their decisions. DI enables an explicit representation of decision models, reducing this risk.
- **Uncertainty regarding decision consistency across the organization.** Lack of explicit representation of decisions prevents proper harmonization of collective decision outcomes. DI remedies this issue.
- **Emergence of software tools in the form of decision intelligence platforms.** DIPs will enable organizations to practically implement DI projects and strategies.
- **Generative AI.** The advent of generative AI is accelerating the research and adoption of composite AI models, which are the foundation of DIPs.

Obstacles

- **Fragmentation:** Decision-making silos have created data, competencies and technology clusters that are difficult to reconcile and that could slow down the implementation of decision models.
- **Subpar operational structure:** An inadequate organizational structure around advanced techniques, such as the lack of an AI center of excellence, could impair DI progress.
- **Lack of proper coordination between business units:** The inability to impartially reconsider critical decision flows within and across departments (also because of fragmentation) diminishes the effectiveness of early DI efforts.
- **Lack of modeling in a wider context:** In organizations that have focused almost exclusively on technical skills, the other critical parts of human decision making — psychological, social, economic and organizational factors — have gone unaddressed.
- **Lack of AI literacy:** Many organizations still suffer from a lack of understanding when it comes to AI techniques. This AI illiteracy could slow down the development of DI projects.

User Recommendations

- **Promote the resiliency and sustainability of cross-organizational decisions** by building models using principles aimed at enhancing traceability, replicability, pertinence and trustworthiness.
- **Improve the predictability and alignment of decision agents** by simulating their collective behavior while also estimating their global contribution versus local optimization.
- **Develop staff expertise** in traditional and emerging decision augmentation and decision automation techniques, including predictive and prescriptive (optimization, business rules) analytics. Upskill business analysts, and develop new roles, such as decision engineer and decision steward.
- **Tailor the choice of decision-making technique** to the particular requirements of each decision situation by collaborating with subject matter experts, AI experts and business process analysts.
- **Accelerate the development of DI projects** by encouraging experimentation with generative AI and expediting the deployment of composite AI solutions.

Gartner Recommended Reading

Innovation Insight for Decision Intelligence Platforms

Reengineer Your Decision-Making Processes for More Relevant, Transparent and Resilient Outcomes

How to Choose Your Best-Fit Decision Management Suite Vendor

AI Security: How to Make AI Trustworthy

Top Strategic Technology Trends for 2023: Adaptive AI

Software-Defined Assets

Analysis By: Lloyd Jones

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

A software-defined asset (SDA) encapsulates and virtualizes its hardware capabilities to manage its unique local constraints, by optimizing and modifying its capabilities, behaviors and/or states across control, automation, function and topology to meet global optimization goals. SDAs may orchestrate with other assets and/or systems to meet their assigned goals within a delegated decision envelope.

Why This Is Important

SDAs operationalize reactive and predictive analytics to control and operate cyber-physical systems (CPS). SDAs enable adaptive and orchestrated operations. SDAs dynamically change their control and automation patterns to achieve physical process goals with global optimizations such as lower production costs, and reduced defects or operator errors. SDAs are the building block that will open up machine-to-machine ecosystems across business boundaries.

Business Impact

CPSs need global and local optimizations. SDAs deliver the capabilities to meet a wide range of scheduling outcomes by coordinating CPS outcomes across asset classes and ecosystem participants. Intelligent operational practices across business boundaries will become common as SDAs optimize and orchestrate operations (and production), across operational and contractual envelopes. Orchestrated SDAs may optimize physical flow by changing topology and/or control and automation configurations.

Drivers

- Digital twin capabilities are maturing and have expanded beyond siloed use cases and are becoming truly composite, able to support a wide range of use cases across operations, asset management and performance optimizations.
- R&D developments are positioning distributed digital twins as edge capabilities.
- Intelligent operational practices are evolving away from setpoint optimization of a fixed process toward a dynamic reoptimization and even reconfiguration of an asset control loop.
- Distributed digital twins hosted on the edge with compute capabilities either at gateway and/or asset level, will become a critical lever — able to optimize exposed automation and control variables through software as operational contexts shift.
- Organizations are moving toward adopting intelligent operational practices by exploring AI and machine learning, to systematically orchestrate production (or operations) resources. Examples include distributed energy resources such as electric vehicles (EVs) and rooftop solar systems, and oil well control and coordination.

Representative industry applications:

- The energy transition is pushing utilities to become orchestrators of distributed resources (which are SDAs) owned by multiple participants. Utilities are stabilizing the grid by asking SDAs to orchestrate their operational envelopes to meet multiple and/or conflicting objectives. Use cases include smart chargers, smart thermostats, and solar PV.
- Oil and gas companies need to optimize vast collector networks assembled from discrete assets in remote locations that are hard to reach. These assets can become SDAs able to parallel and serialize their topologies to protect physical flows while enduring disruption, through local coordination and reconfiguration, to return to a preferred operating state, or seamlessly coordinate to align product delivery to market opportunity.

Obstacles

- Legal concerns around decision responsibility have so far constrained AI and edge AI deployment, leaving a person in the loop.
- The standards that will bring together the capabilities of industrial control systems, Industrial Internet of Things (IIoT) and digital twins to enable autonomous intelligent operations by the SDA are still in development.
- Examples of constraints that need to be resolved before operationalizing SDAs and their AI include authorizations, control, bounding, defining, testing, deploying, retiring, retesting and retraining.
- SDAs may not be delivered on a unified platform. In fact, we can expect that the design, deployment and even operation of SDAs will be composable, particularly for industry-specific use cases.
- Horizontal scale-out in some industry applications come with cyber-physical system security concerns.
- SDAs could be perceived as replacing field technicians, requiring human change management to resolve job displacement fears.

User Recommendations

- Invest in advanced analytics and digital twin competencies to help enable this transition.
- Accept that SDA capabilities will not be rolled out across all assets, but will be an essential precursor to intelligent assets. Over time SDAs will evolve into intelligent assets with no central supervision.
- Transition incrementally by investing in discrete digital twins for individual equipment classes one by one and invest in composite digital twins for individual operations one by one. Over time, this will expand your portfolio of capabilities to increasingly build out more resilient grid capabilities.
- Raise your demands of OEM suppliers by specifying digital services that encapsulate asset capabilities in a structured manner to support SDAs.
- Leverage the lessons learned in your own and other asset-intensive industries.

Gartner Recommended Reading

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Quick Answer: What Are Intelligent Assets and Why Are They Important?

Quick Answer: What Are the Digital Checkpoints to Achieve Intelligent Operations?

Virtual Power Plants

Analysis By: Lloyd Jones, Lauren Wheatley

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Virtual power plants (VPP) manage distributed energy resources (DER) to flex contracted load and energy resources. VPPs trade across electricity markets, from capacity to energy and ancillary services, to provide system operators with additional controllable resources that offer similar reliability and economic value as traditional dispatchable power plants. Resources can include batteries, electric vehicles, smart appliances, flexible heating/cooling loads, and on-site generators.

Why This Is Important

Balancing the grid becomes harder with the adoption of renewable energy (RE). RE can be curtailed in periods of low demand but at a considerable cost. The alternative is to leverage customer-owned resources to manage energy volatility. VPPs can flex energy resources, both load and generators, beyond the meter and trade these resources on energy markets. VPPs provide the capabilities to enroll, measure and manage energy beyond the meter, making it tradable on the wholesale markets.

Business Impact

VPPs balance DER production and consumption with per-customer forecasts to predict and trigger customer behavior. VPPs orchestrate and flex resources against global and local constraints with automated interactions. Utilities can use VPPs to address energy volatility and grid issues. VPPs trade energy resources across markets, optimize energy generation and schedule consumption to defer capacity investments. VPPs democratize the grid by utilizing available capacity and sharing the benefits.

Drivers

- Rising volumes of intermittent renewable energy, at the grid center and beyond the meter, are creating balancing challenges for system operators.
- There is growing recognition by regulators of the need to incentivize consumer load flexing to ensure energy availability and stabilize the grid. Energy-intensive devices such as batteries, inverters and chargers are becoming software-defined, allowing the assets operating envelope to be orchestrated across customers and asset classes.
- As the energy transition matures, so does the need for an independent balancing services market. Legacy electricity markets, such as day-ahead markets, are still relevant but cannot solve the balancing problem. The balancing market will need to interoperate and coexist alongside other markets, leveraging price and capacity data and extending current settlement services. Mandates, such as EU-SysFlex and FERC Order No. 2222, require electricity markets to treat loads as dispatchable resources on the wholesale market.
- Older power plants need heavy investment for management and construction. VPPs package resources into a dispatchable energy package that can be used by system operators across markets, but with low capital investment needed to control numerous DERs.
- Technology is accelerating the adoption of VPPs. There is increasing acceptance of enhanced technologies in the power industry, including cloud platforms and the Internet of Things, increasing concentration on cost-effectiveness in power generation, ease of accessibility of power through VPPs, and rising knowledge about the advantages of renewable power.

Obstacles

- Enertechs and energy management providers are disintermediating utility companies with product offerings beyond the meter, offering loads as a dispatchable resource to the intraday and balancing markets. Utilities need to choose to either compete or cooperate.
- Successful operation means investment in new systems and processes, notably management and trading systems. There is a lack of standardization in the ecosystem, making it challenging for VPPs to communicate with DERs and control systems. This means that composable architecture with an API integration platform for managing API-based DER assets is needed.
- Utilities may need to offer rebates, credits or other incentives to drive prosumer adoption.
- Managing large volumes of data effectively to ensure that VPPs are running optimally and delivering the precise ancillary services required by the market to keep the grid in balance in real time will be critical. Privacy and security risks must be identified and addressed.

User Recommendations

VPPs are needed to manage customers:

- Monitor the rate of RE penetration, by the time RE reaches 40%, utilities must initiate investment in energy orchestration to balance the grid.
- Develop event-driven business capabilities by expanding digital products to influence and orchestrate transactive electricity in conjunction with the markets. Acquire or build a digital platform business that will orchestrate diverse flexible resources across external participants, such as virtual power plants, aggregators and customers.
- Agree on mutual processes and data exchanges with retailers, aggregators and VPP operators to guarantee reliable, efficient and affordable operation of the electricity system and grid.
- Maximize the impact of VPPs by enhancing capabilities in the metering, billing and consumer engagement areas.
- Drive industry standardization by requiring open protocols from hardware manufacturers and software platform providers.

Sample Vendors

AGL; Hitachi Group; Mitsubishi Electric Group; Next-Kraftwerke (NEMOCS); Plexigrid; Schneider Electric (Autogrid Systems); SwitchDin; Siemens; VIVAVIS

Gartner Recommended Reading

2022 Sustainability Survey: Energy CIOs Can Help to Retain C&I Enterprises as Customers

Quick Answer: How Are Electricity Markets Changing as the Energy Transition Accelerates?

Quick Answer: How Electric Utility CIOs Can Respond to Changing Customer Expectations

2023 Utility Trend: Utility Business Models Are Evolving From 'Ego-Centric' to Eco-Centric

System Operators Must Adapt to Embrace Flexibility Markets

CPS Security

Analysis By: Katell Thielemann

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Cyber-physical systems (CPS) are engineered systems that orchestrate sensing, computation, control, networking and analytics to interact with the physical world (including humans). They are created as physical assets become connected to each other or enterprise IT systems, and as drones and robots are deployed. CPS security is the overall discipline to ensure that CPS remain safe, reliable and resilient in the face of growing threats.

Why This Is Important

CPS includes the industrial control systems (ICS)/supervisory control and data acquisition (SCADA), operational technology (OT), Internet of Things (IoT), and industrial IoT umbrellas. This includes everything from utilities, smart cities and grids, to autonomous vehicles and smart manufacturing. They connect physical processes with digital technology, and underpin all critical infrastructure. CPS are increasingly targeted by attackers through stealing data, demanding ransom or derailing production.

Business Impact

Unlike IT systems that create, store, transact or transform data, CPS connect both the cyber and the physical worlds. They are usually deployed in production or mission-critical environments, which means that CPS security efforts need to focus on human safety and operational resilience, above and beyond traditional data-centric security efforts. These efforts need to consider all cybersecurity best practices, as well as laws of physics and industry-specific engineering decisions.

Drivers

- Focusing on CPS security is a pressing need due to rapidly increasing initiatives from governments and companies alike, in domains such as smart cities, utilities, healthcare, food, agriculture, public safety, and transportation.
- As risks extend to the physical world, concerns over physical perimeter breaches, USB insertion, controller area network (CAN) bus injections, GPS jamming, hacking, spoofing, tampering, command intrusion, or malware implanted in physical assets, also need to be addressed above and beyond cybersecurity.
- The last few years have seen a marked increase in attacks in enterprise IT systems, impact operations, and production environments in manufacturing and critical infrastructure. Because these areas are where value is usually created or essential services for societies are performed, CPS will continue to be targeted.
- The consequences of a successful attack on CPS go beyond cybersecurity-centric data loss to include operational shutdowns, environmental impacts, damage and destruction of property and equipment, and even personal and public safety risks.
- The generic OT security market has evolved into specific CPS security categories, such as protection platforms, cyber risk quantification platforms, unidirectional data flow solutions, secure remote access solutions, content disarm and reconstruction solutions, security services, network-centric solutions (e.g., cloaking, microsegmentation), onboard diagnostics solutions, embedded systems security, and supply chain security solutions.

Obstacles

- CPS are often deployed by business units without consultation with the security team.
- Most organizations still focus mainly on IT-security-centric risk management.
- The lack of collaboration across siloed teams running systems such as IT, OT and IoT, hamper CPS security efforts that require cross-functional collaboration.
- Many organizations do not have structured security programs or skills that sufficiently cover the scope of CPS, especially for those high-value/mission-critical assets.
- Because of standards in CPS products that guide security design and usage are still evolving, many manufacturers value “speed to market” over “secure to market”.
- Many devices lack storage and compute power to facilitate security mechanisms.
- The omnipresence of CPS devices in buildings, cities, homes and vehicles means that traditional security methods may not be scalable to address the risks in devices, areas or the entire value chain.

User Recommendations

- Prioritize security controls and "secure by design" practices in new procurements, such as for drones and robots.
- Discover all connected assets, whether born out of IT/OT connectivity or new IoT/industrial IoT/smart "X" programs.
- Evaluate which CPS assets are high-value or mission-critical, identify specific CPS security controls already in place, and determine whether any gaps need to be prioritized based on potential organizational impact.
- Create an investment plan to update security and risk management strategies and programs in relation to CPS, starting with those high-value and mission-critical assets.
- Engage functional business leaders to establish clear risk ownership and define domain-specific controls for CPS, to balance between growing the business and improving security.
- Evaluate the growing list of CPS security solutions, as there are more options than ever before.

Sample Vendors

Armis Security; Claroty; Dragos; Microsoft; Nozomi Networks

Gartner Recommended Reading

3 Initial Steps to Address Unsecure Cyber-Physical Systems

Predicts 2023: Cyber-Physical Systems Security — Beyond Asset Discovery

CPS Security Governance — Best Practices From the Front Lines

Innovation Insight for Cyber-Physical Systems Protection Platforms

Generative Design AI

Analysis By: Brent Stewart

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Generative design AI, or AI-augmented design, is the use of artificial intelligence (AI), machine learning (ML) and natural language processing (NLP) technologies to automatically generate and develop user flows, screen designs, content and front-end code for digital products.

Why This Is Important

Generative design AI has been introduced in several product markets, including user experience (UX) design tools, citizen design tools, image editing software and video editing software. Gartner expects generative design AI to lead to major leaps in UX design efficiency, quality and time to market. The technology will initially appear as feature-level support (for example, intelligent design recommendations) and will transition rapidly to full product design and front-end development capabilities.

Business Impact

In a future powered by generative design AI, sites, apps and software will be generated in minutes or days, rather than weeks or months. The resulting designs will be based on proven design principles and patterns that ensure maximum usability and accessibility. In this future, UX teams will become more strategic and directional, with the remaining practitioners focused more on research, strategy and design curation, and less on detailed design production.

Drivers

To understand the drivers for generative design AI, consider this hypothetical scenario for creating an online store:

- Tell the AI that you want an online store; the AI automatically generates the standard structural elements of an online store from the homepage to product detail templates to the shopping cart.
- Provide the app with your brand identity or style guide, giving the AI inputs on color, typography, iconography, photographic style, writing style, etc.
- Provide some inspiration to the AI by indicating a set of stores you'd like to emulate.
- Hit submit and, within minutes, the AI produces three high-fidelity design directions that you can evaluate and iterate.

Furthermore, every design element will have an associated code component that is updated as you tweak or curate the final design.

The promise of operational efficiency and "democratization" of UX design contribute to the business case driving generative design AI. Key drivers in this category include:

- **Product delivery —** Generative design AI promises to accelerate digital product delivery more than any technology in recent history.
- **Accessibility —** Generative design AI design and code deliverables will account for assistive technologies and deliver the most accessible screen designs and code possible. This will drastically improve the digital lives of people with disabilities.
- **Democratization —** More and more nonprofessional (citizen) designers and researchers are engaging in UX tasks and must be able to produce high-quality experiences without deep design training or education.
- **User interface (UI) design standardization —** The overwhelming majority of digital products are based on established product types and UI design patterns. In general, the standardization of common digital experiences continues to expand.

Generative design AI will quickly apply three key technologies to common UX tasks as they expand:

- Visual AI (computer vision)
- ML
- NLP
- Large language model (LLM)

Obstacles

- **Cost** — Generative design AI is a heavy lift that requires deep talent, long time frames and deep pockets.
- **Jobs** — Generative design AI drastically reduces low-level UX production tasks, reducing the need for production designers, front-end developers and UX writers. These team members will need to retool and "move left" to become UX design strategists/researchers who can guide and tweak the output of design bots.
- **Originality** — Since generative design AI pulls from established product types and design patterns, it will not be notable for its originality. Many UX practitioners are concerned that user experiences will become too uniform and lack originality.
- **Ethics** — AI algorithms and associated training datasets may contain inherent gender, cultural and selection biases.
- **Maintainability** — AI-generated designs may have higher maintenance costs, as it may be more difficult to make small, custom tweaks to a design element and automate those adjustments in future builds.

User Recommendations

- Assess developments in generative design AI, specifically at Adobe, Figma, the citizen design market (for example, Canva), and the low-code/no-code market.
- Prepare digital product teams for the emergence of generative design AI — first through design-to-code technology followed by tools that produce high-fidelity screen designs and written content.
- Transition the role of humans in the design process from production-level creators to strategic curators.

Sample Vendors

Adobe; Builder.ai; Figma; Inmagine Group (Designs.ai); Locofy.ai; TeleportHQ; Uizard

Gartner Recommended Reading

Innovation Insight for Generative AI

How Can Generative AI Be Used to Improve Customer Service and Support?

Use Generative AI to Enhance Content and Customer Experience

Predicts 2023: How Innovation Will Transform the Software Engineering Life Cycle

Quick Answer: How Can Generative AI Tools Speed Up Software Delivery?

At the Peak

Smart and Sustainable Building

Analysis By: Gavin Tay, Tori Paulman

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

A smart and sustainable building is a facility where multiple functions cooperate to achieve work-life ambiance and broader sustainability outcomes. Such outcomes encompass automation, efficiency, experience, wellness, safety, sustainability and security through the analysis of contextual and real-time information, shared among Internet of Things (IoT), information and communication technology (ICT), and operational technology (OT) systems.

Why This Is Important

Smart and sustainable buildings advance with a heavy reliance on smart technologies although a common data environment is at the core. Building management system (BMS) adoption rates are fairly slow due to its legacy nature. Hardware for HVAC and lighting implemented with new construction has a lifetime of 10 to 20 years. System failure retrofits have heightened with stringent standards of safe management accelerating the importance of experience, well-being, safety and sustainability.

Business Impact

- Increasing people centricity and a growing focus on sustainability will demand not only decarbonization, but also a shift from energy efficiency to incorporating renewable energy.
- Building performance can be optimized and predictive and preventive maintenance can be improved by responding to real-time human preferences based on activities, emotions and reactions.
- Formulating holistic solutions will stretch alignment of cross-functional teams to address work-life ambience and sustainability.

Drivers

- Today, the operating elements of a smart building typically include space, environment and maintenance management, along with wellness, safety, energy management, sustainability and workplace experience. Such rapid evolution of smart buildings means that facilities and real estate professionals will want to leverage the CIO portfolio.

- Energy efficiency such as use of solar panels has long been a key area of investment for smart building technologies. However, incorporating or reselling surplus renewable energy is emerging at an exponential rate.

- As the pent-up delay of new building construction gets underway, demand for a reinvigorated experience particularly in commercial buildings and coworking spaces will rally a surge for an orchestrated AI-augmented infrastructure alongside expertise to bring it to reality.

- The demands and expectations of workers from workplaces are shifting from merely good air, temperature and hygiene to work-life ambience. As a result, a smart building experience requires the exploitation of an ever-growing number of IoT business solutions that are intelligently cohesive.

- IoT and AI have the potential to speed up the implementation of more IT into a common data environment by extending and augmenting existing equipment. Cost savings can be achieved by integrating the sensors with BMS software in older buildings. Sometimes, it is more economical to upgrade rather than adapt to an older system.

- Various nations and organizations have a strong commitment to sustainability, driving the focus of management from pure energy to broader environmental parameters such as water, air quality and waste.

Obstacles

- CIOs assembling smart and sustainable buildings lack a clear vision of the architectural building blocks comprising a common data environment and an understanding of the privacy and data security implications increasingly.

- Delivering total experience is diverse and complex, when managing a multivendor IoT landscape and technology architecture with limited exposure to governing moving parts and the flow of activities in buildings.

- Gartner estimates that by 2028, there will be over four billion intelligently connected IoT devices in commercial smart buildings, making it hard for CIOs to provision, manage, connect and analyze their data.
- Coordinating varied expectations, use cases and budgets from different stakeholders such as facilities management, HR, and CISO (security, privacy and data sovereignty) adds to existing complexity.

User Recommendations

- Broaden corporate priorities in construction and building management by focusing on decarbonization and other sustainability initiatives.
- Address energy inefficiencies by using real-time data from the IoT and IT infrastructure to enable communication between the different BMSs or energy management systems (EMSs) in a building. According to ENERGY STAR, average buildings waste 30% of their energy in lighting, heating and cooling areas that are not occupied.
- Leverage the advantages of IoT to build holistic, engaging experiences while increasing building efficiency and competitiveness. Alleviate the potential business and technical challenges of creating a piecemeal smart building.
- Opt for flexible payment methods, and don't treat such investments as a capital liability. Channel the savings obtained from building efficiencies to the repayment of these solutions or services, making it an operating expense instead (e.g., energy management contracts).

Sample Vendors

Eutech Engineering; General Electric (GE); Honeywell Forge; Intel; Johnson Controls; Schneider Electric; Siemens; Signify; Spacewell; Terminus

Gartner Recommended Reading

Tech CEO Insight: Align the Smart Building Value Communication With the Shift Toward Well-Being and Sustainability

Creating Sustainable and Innovative Smart Buildings Through Data

How Technology and Data Can Be Used to Develop Smart Building Solutions

Emerging Technologies: The Future of Sensing

Operational Device Management

Analysis By: Lloyd Jones

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Energy and utility companies need to manage sensors, actuators, controllers and gateways deployed in the field, traditionally managed by the operational technology domain. Operational device management (ODM) brings asset, configuration and data management capabilities together to create a comprehensive management platform to mitigate the potential of unmanaged engineering change that could negatively impact operations.

Why This Is Important

Asset-intensive energy organizations sense real-time performance to maintain system stability. They deploy various operational technology (OT), such as sensors, actuators, controllers, gateways and protection devices. Operational devices depend on their connectivity and configuration to measure and control physical processes and assets. Unmanaged change may negatively impact the OT device integrity comprising operational data fabric.

Business Impact

Regulatory audit requirements around OT are tightening in response to avoidable incidents triggered by OT device failures. OT devices are internet protocol (IP)-connected, thus vulnerable to cyberattack and misconfiguration. Yet OT asset management practices need to catch up on primary assets, leaving utilities exposed through unmanaged firmware and configurations. Operational device management capabilities allow OT devices to be maintained and safeguarded across their life cycle.

Drivers

- Legacy operational device management software was confined to basic asset management, excluding configuration and setting optimizations workflow and version management.
- Energy systems are vulnerable to disturbances. OT devices span a wide range of technologies, including phasors, protection, reclosers, tap changers, gateways and radios to detect and control the network to manage disturbances. Traditionally, OT devices were wired, but today they are IP-enabled and software-driven. Consequently, OT devices need to be managed, maintained, calibrated, configured and updated by operational device management capabilities.
- An ODM capability supports multiple device protocols across a wide range of OEM suppliers, and retains appropriate asset management records, including the ability to collect/optimize/update device configurations remotely.
- Operational device management capabilities will reduce operational costs and unexpected failures.
- ODM will support a trusted data fabric and improve the visibility of the power system with accurate, timely measurements that can be used to optimize the power system.

Obstacles

- The majority of OT devices started their asset life cycle in spreadsheets, with the associated data quality and audit risks.
- Some utilities have had limited success with legacy enterprise asset management (EAM) systems for basic asset management such as inventory, inspection and battery management. Still, they are unable to support device configuration, connectivity and data capabilities.
- Some OT devices, such as meters, are well-managed with siloed vertical solutions that are unique to specific device manufacturers, leaving much of the OT device landscape unmanaged.
- A generic data model that abstracts OT devices and their configurations is often unique to a device manufacturer, creating significant complexities for generic OT device management tools.
- Legacy protocols from legacy device manufacturers create a raft of specialized use cases to connect to and configure a specific manufacturer device through a unique physical connector, limiting over-the-air capabilities, and constraining automation, discovery and configuration management use cases.

User Recommendations

- Avoid neglecting OT device management as it will compromise the operational performance of the power system.
- Design the implementation and rollout of an ODM by OT device classes. Protection devices are early obvious candidates that would benefit from the management of multiple configurations matched to various network topologies. But auditability in the case of maloperation can be challenging if the configurations are not accurately version-managed and time-stamped.
- Establish an ODM as a system of record for OT devices, but avoid the architectural temptation to extend the ODM to manage or handle data streams from the OT devices.
- Examine the Internet of Things (IoT) platforms as an alternative to an ODM platform if the provider can support your legacy OT device inventory and required protocols.

Sample Vendors

General Electric (GE); Intelligent Process Solutions (IPS); Oracle; Siemens

Gartner Recommended Reading

Quick Answer: What Are the Digital Checkpoints to Achieve Intelligent Operations?

Market Guide for Digital Platform Conductor Tools

Critical Capabilities for Industrial IoT Platforms

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Wireless EV Charging

Analysis By: Lauren Wheatley, Pedro Pacheco

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Wireless electric vehicle (EV) charging is based on inductive charging that uses the electromagnetic field (EMF) to transfer energy. Induction chargers use an induction coil to create an alternating EMF from a charging base station. An induction coil in the vehicle converts EMF into an electrical current to charge the battery. In addition to stationary charging of parked vehicles, the technology can potentially enable dynamic charging for vehicles as they drive.

Why This Is Important

The technology is based on an application of magnetic induction, which uses a changing magnetic flux to create a current that transfers electricity from an energy source to a battery. The efficient transfer of power for wireless EV charging (on par with conductive charging), both statically and in motion, can facilitate EV adoption by improving charging convenience and potentially addressing drivers' range anxiety.

Business Impact

Wireless EV charging is mostly based on a car parked over a charging mat installed in public or private parking spots. However, applications also include installing long strips of inductive charging plates on roads that charge vehicles as they drive over them to enable dynamic EV charging.

Drivers

Although still an emerging technology with a number of technical issues to resolve (like size and scale) wireless charging offers several advantages for users:

- Despite different user experiences, when compared to conventional internal combustion engine (ICE) refueling, inductive charging makes charging mobile devices and EVs more convenient. Rather than having to connect a power cable, the device can be placed on or close to a charging plate. In the case of dynamic electric vehicle charging (DEVC), the vehicle can drive over a charging path embedded in the road pavement.
- The ability to charge high-value, high-use vehicles like buses and trucks without taking them offline.
- In addition wireless charging is now being prototyped and tested within new vehicle designs.

Obstacles

- Wireless charging is significantly more expensive than cable charging. Economies of scale will reduce the cost gap but may not be enough to drive adoption.
- Static wireless charging doesn't offer much greater convenience over cable charging, since the vehicle must be parked with precision in relation to the charging pad.
- Static wireless charging installation and maintenance on public car parks would be more expensive than cable chargers since the charging pad would have to be installed under the surface.
- Dynamic wireless charging will be very hard to implement at scale — it needs the simultaneous buy-in from a large number of vehicle makers and infrastructure providers.
- Wireless charging is much slower than cable charging, which makes dynamic wireless charging impractical, especially on motorways; either you cover a large distance with wireless charging or the vehicles would have to drive very slowly. This is even more hindering for larger vehicles due to higher power requirements.

User Recommendations

- Deploy strategies to reduce cost as it is a major roadblock for this technology.
- Prioritize overnight charging for fleets for static dynamic charging as it minimizes the situation where users can forget to plug the vehicle at the end of the day.
- Study the combination of static wireless charging with robotic technology in order to serve more vehicles with a lower number of charging pads.
- Focus on dynamic wireless charging only once you see a broad platform of support emerging among automakers and road infrastructure providers.

Sample Vendors

Continental; Electreon; ENRX; Hevo; InductEV; WiTricity

Gartner Recommended Reading

Top Automotive Trends for 2023

Emerging Tech Impact Radar: Electrified Vehicles, 2022

Transactive Energy

Analysis By: Lloyd Jones

Benefit Rating: Transformational

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Definition:

Transactive energy (TE) is a set of techniques to manage the generation, consumption and control of electric power within an electric power system using economic or market-based signals to move energy and account for grid reliability constraints. TE is an economic-value-based network control concept that shares benefits and responsibilities. It is an effective enabling mechanism to exchange information to integrate and orchestrate distributed energy resources (DERs) into local energy markets.

Why This Is Important

Traditional business models for electric utilities and legacy economic constructs are being challenged by the growth and diversity of distributed energy resources. As the network architecture transforms into a decentralized geodesic architecture, utilities are adopting new information-centric business and operating models and leveraging dynamic consumption, congestion and pricing information. TE information constructs apply from local to national networks.

Business Impact

The underlying economic model and control theory for TE markets are not new. Similar methods have been used successfully to operate transmission networks. Utilities that are seeing rising penetration of DERs should start early on understanding TE and its benefits and risks. Operations executives tasked with minimizing network congestion, managing peak loads or integrating responsive loads should work with their system vendors to understand how they are addressing TE requirements.

Drivers

- Transactive energy is being adopted by industry leaders as a path forward. TE is a consequence of energy transition, which is a structural change in energy systems driven by four “D” forces — decarbonization, decentralization, digitalization and democratization. The TE framework is intended to develop new economic constructs that accurately capture the value of energy transactions in a nodal model with locational marginal pricing (LMP).

- The introduction of market economics as an additional control mechanism to manage and optimize short-term energy transactions and long-term investment in the production and delivery asset has proven to be a viable model in wholesale market and transmission operation. A similar construct, applied on the distribution network level, will create a more collaborative environment that will address challenges introduced by the four “D” forces. It will also provide utilities with new business and operating models that may address energy reduction leading to revenue loss as prosumerization reduces net loads.

- Activities on defining a common set of transactive services to be exercised by DERs, via IEEE 1547, under the auspices of working group P825, and include work on IEEE 2030.5 and IEC 61850 standards.

- The development of a TE framework has become a global effort. Examples include the U.S. Department of Energy, GridWise Architecture Council and the EU-SysFlex published in 2021.

Obstacles

- The concept of TE is not new, since it mirrors the identification of flow gates and LMP for open access to transmission resources, however, the application at distribution level is difficult to define, measure and value action mechanisms for grid services.
- TE defines cost of delivery at a certain point as “LMP + D,” capturing both energy costs and distribution grid costs.
- Market redesign and the development of new operational systems, on top of existing infrastructure, are complex and require the active participation of stakeholders.
- The information flows within TE markets must be optimized for high-speed transmission of information about energy supply and demand, quantities, and prices.
- Economic and market contexts vary considerably from country to country (and even from state to state in the U.S.) with fragmented regulations and operational practices.
- TE is a conceptual framework, with vendors getting involved and including market-driven economic constructs in energy dispatch products.

User Recommendations

- Promote education and understanding of transactive energy concepts. Rather than looking for an off-the-shelf TE product, buyers should look for products that are built on and can incorporate a TE framework appropriate for their market.
- Work on developing communications standards for future transactive markets actively.
- Explore the feasibility of transactive-energy-enabling technologies, such as blockchain, DER management systems (DERMS), demand response management systems (DRMS), virtual power plants, and advanced distribution management systems (ADMS), by creating proofs of concept and early innovation initiatives.

Sample Vendors

GE Digital (Opus One Solutions); Integral Analytics; Itron; Octopus Energy Group (Kraken Tech); Open Access Technology International (OATI); Oracle

Gartner Recommended Reading

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Market Guide for Distributed Energy Resource Management Systems

Utility Scenario: Pioneers Are Settling New Digital Frontiers

Industry Vision: Utilities as Platform Providers for the Energy-Sharing Economy

Energy-Sharing Platforms

Analysis By: Lauren Wheatley, Auria Asadsangabi

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

The energy-sharing platform (peer-to-peer [P2P] energy exchange) leverages sharing economy principles to enable P2P energy trades. It is a dual platform — online-to-offline (O2O) — architected to effectively integrate prosumers into energy markets in a controlled way. In addition to providing revenue opportunity to a commercial online platform provider, it provides network owners and operators with visibility into transactions over their infrastructure, and new means to monetize energy assets.

Why This Is Important

Energy-sharing platforms enable integration of prosumer-owned distributed energy resources (DERs) into markets by exposing available capacity directly to customers. Utilities face increased need for flexibility, reliability and resilience, as a result of greater renewables penetration and changing energy security needs. By becoming providers of energy-sharing platforms, utilities can supplement existing revenue and compensate for loss of revenue caused by customers’ self-generation.

Business Impact

Energy-sharing online platforms impact revenue management, customer engagement and consumption analytics. The offline digital distribution platform impacts network operation, requiring a combination of traditional network control functions and economic-based control mechanisms, such as congestion management via distribution marginal prices.

Drivers

- The growing volume of prosumers is driving the market. Energy-sharing platforms turn individual consumers from passive to active managers of their networks. These marketplaces can relieve constraints on the electricity network and offer an alternative to costly grid reinforcements.
- Energy-sharing platforms can provide flexibility services to the main power grid, resulting in improved balancing and congestion management through better operation of DERs.
- The energy-sharing platform is an effective way to integrate prosumers into energy markets in a controlled manner. As a result, consumers will become better acquainted with their energy systems and marketplaces.
- By leveraging economies of connection and digital disruption at the edge of the grid, the energy-sharing platform creates new revenue opportunities for utilities. The energy-sharing platform is a sharing or networked economy (e.g., Airbnb, Uber) that relies on information-processing acumen, rather than ownership of production or delivery assets, to enable distribution, access and sharing of excess capacity in goods and services.
- The energy-sharing economy requires two distinct platforms, also referred to as O2O platforms. The online platform deals with virtual-world transactions by processing information, such as selecting products, placing them in the virtual cart and processing payment. The offline platform deals with delivering actual physical products or services in the real world, and considers availability, distance, traffic congestion and other physical-world constraints.

Obstacles

- Sustainable business models, capital investment and legal provision must be addressed.
- Platform reliability, good customer service and a reliable grid are key to success. Energy management and optimization system (EMOS) solutions will be an integral component.
- While energy-sharing platforms can address DER disruptions on incumbent energy providers, their adoption is hampered by regulatory barriers, such as opening access to grid infrastructure to nonutility participants.
- In the regulated utility sector, local distribution companies and network operators are addressing the disruptive impact of prosumerization on revenue by adding fixed connection charges for consumer self-generating capabilities. This creates an adoption barrier for consumer renewable sources and slows energy utility sector decarbonization.
- Regulating frequency and flow of electricity across the network requires investment in grid edge information technology/operating technology (IT/OT) infrastructure.

User Recommendations

- Work with business leaders to explore the implications of energy-sharing platforms in markets with growing levels of prosumer penetration.
- Ensure the provision of assets and capabilities for an energy-sharing platform business, such as app development platforms for consumer-/prosumer-facing apps, microtransaction billing and settlement systems, APIs for integration with digital distribution platforms, and analytical capabilities for discovery, bidding, negotiation and matching.
- Ensure the platform is designed to generate revenue by orchestrating prosumer integration into energy markets, to monetize use of energy assets at the grid edge, to create more visibility into transactions over utility-operated assets, and to address flexibility needs introduced by intermittent renewable sources.
- Decide whether to provide both parts of the platform, or to partner with sharing economy platforms from other sectors. Weigh implementation timelines in light of solution functionality and maturity.

Sample Vendors

Decentralised Energy Exchange (deX); ENTRNCE; LO3 Energy; Piclo; Powerledger; SunContract; TroonDx; UrbanChain

Gartner Recommended Reading

Market Guide for Advanced Distribution Management Systems

Market Guide for Energy Management and Optimization Systems

Quick Answer: How Are Electricity Markets Changing as the Energy Transition Accelerates?

Quick Answer: How Electric Utility CIOs Can Respond to Changing Customer Expectations

Vehicle-to-Grid

Analysis By: Lauren Wheatley

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Vehicle-to-grid (V2G) technology enables energy stored in electric vehicle (EV) batteries to be fed back into the grid. It requires EVs to communicate in real time with electricity providers (both electricity commodity and network services), to control two-way energy exchange between the vehicle and the grid. V2G allows EVs to be treated by utility companies as distributed energy resources to balance loads via inclusion in programs, such as demand response or virtual power plants.

Why This Is Important

The rapid increase and development of e-mobility is likely to advance the V2G technology market with government regulations associated with EV battery cells, onboard chargers, battery designs and thermal propagation expected to offer growth opportunities. Tapping into energy stored in growing numbers of EVs can support the electric grid under various conditions. V2G is still in the early stages but the advantages of this technology are significant.

Business Impact

V2G can impact several utility areas, including commodity management and network operations. Due to challenges with the intermittency of renewable sources the most economical entry is the market for ancillary services, including frequency regulation and flexibility services. Additionally, V2G can provide distribution system support when there is a concentration of parked V2G cars, along with overload elements in the distribution system.

Drivers

- Adoption rates will be driven by regulations, such as the California Energy Commission's Vehicle-Grid Integration Program, which stipulates that there are obligations on utility companies to responsibly integrate EVs into the electricity system.
- Decarbonization of the utility sector generation fleet and consequent decentralization are significantly increasing renewable energy presence in the sector.
- To offset renewable source intermittency, utilities must deploy different forms of storage to address short- and long-term energy imbalance.
- Since, at any time, 90% of the cars are parked, the ability to tap into the energy stored in EV batteries on demand will help address increased volatility and the need for flexibility services during energy transition.
- The (EPRI) estimates that V2G technology can provide $671 million in annual grid benefits, based on 1.65 million V2G-enabled EVs in 2030.

Obstacles

- Major challenges include a lack of infrastructure development and high initial cost of technology integration. In addition, the lack of a viable economic model is the key obstacle for V2G adoption and its slow progression along the Hype Cycle.
- There is apathy from utility companies in enabling V2G.
- The value to the consumer is unclear, utilities need to be willing to provide consumers with a financial incentive that is significant enough to drive adoption.
- Batteries have a finite number of charging cycles. An adequate financial model to compensate owners for the battery degradation resulting from frequent charging and discharging events has not yet been developed.

User Recommendations

- Evaluate V2G as a mechanism to meet storage requirements by using EV batteries when they are parked and underutilized.
- Work with business leaders across several lines of businesses as V2G will impact business models, multiple applications and technology domains.
- Approach fleets of light-duty vehicles, and medium- and heavy-duty trucks for proof-of-concept projects as they are the most likely early adopters of V2G. Fleets can be more easily integrated into the grid than individual consumers and trucks that have larger battery packs will generate greater revenue per vehicle than light-duty vehicles.
- Partner with EV manufacturers, charging operators, fleet owners and other participants in the EV ecosystem to develop strong value propositions and robust business models to accelerate V2G technology maturation.

Sample Vendors

ABB; Hitachi Group; Kaluza; Nissan; Nuvve Holding; Pacific Gas and Electric

Gartner Recommended Reading

Market Guide for Electric Vehicle Charging Solutions

Emerging Tech Impact Radar: Electrified Vehicles, 2022

Emerging Technologies and Trends Impact Radar: Enabling Power and Energy Technologies

Forecast Analysis: Automotive Semiconductors, Worldwide, 2021-2031

Edge AI

Analysis By: Eric Goodness

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Adolescent

Definition:

Edge AI refers to the use of AI techniques embedded in non-IT products, IoT endpoints, gateways and edge servers. It spans use cases for consumer, commercial and industrial applications, such as autonomous vehicles, enhanced capabilities of medical diagnostics and streaming video analytics. While predominantly focused on AI inference, more sophisticated systems may include a local training capability to provide optimization of the AI models at the edge.

Why This Is Important

Many edge computing use cases are latency-sensitive and data-intensive, and require an increasing amount of autonomy for local decision making. This creates a need for AI-based applications in a wide range of edge computing and endpoint solutions. Examples include real-time analysis of edge data for predictive maintenance and industrial control, inferences and decision support where connectivity is unreliable, or video analytics for real-time interpretation of video.

Business Impact

The business benefits of deploying edge AI include:

- Real-time data analysis and decision intelligence
- Improved operational efficiency, such as manufacturing visual inspection systems that identify defects, wasted motion, waiting, and over- or underproduction
- Enhanced customer experience, through feedback from AI embedded within products
- Connectivity cost reduction, with less data traffic between the edge and the cloud
- Persistent functions and solution availability, irrespective of network connectivity
- Reduced storage demand, as only prioritized data is passed on to core systems
- Preserved data privacy at the endpoint

Drivers

Overall, edge AI has benefited from improvements in the capabilities of AI. This includes:

- The maturation of machine learning operationalization (MLOps) and ModelOps tools and processes support ease of use across a broader set of features that span the broader MLOps functions. Initially, many companies came to market with a narrowcast focus on model compression.
- The improved performance of combined ML techniques and an associated increase in data availability (such as time-series data from industrial assets).

Business demand for new and improved outcomes solely achievable from the use of AI at the edge, which include:

- Reducing full-time equivalents with vision-based solutions used for surveillance or inspections.
- Improving manufacturing production quality by automating various processes.
- Optimizing operational processes across industries.
- New approaches to customer experience, such as personalization on mobile devices or changes in retail from edge-based smart check-out points of sale.

Additional drivers include:

- **Increasing number of users upgrading legacy systems and infrastructure in "brownfield" environments.** By using MLOps platforms, AI software can be hosted within an edge computer or a gateway (aggregation point) or embedded within a product with the requisite compute resources. An example of this is AI software deployed (TinyML) deployed to automotive or agricultural equipment to enhance asset monitoring and maintenance.
- **More manufacturers embedding AI in the endpoint as an element of product servitization.** In this architecture, the IoT endpoints, such as in automobiles, home appliances or commercial building infrastructure, are capable of running AI models to interpret data captured by the endpoint and drive some of the endpoints' functions. In this case, the AI is trained and updated on a central system and deployed to the IoT endpoint. Examples of the use of embedded (edge) AI are medical wearables, automated guided vehicles and other robotic products that possess some levels of intelligence and autonomy.

- **Rising demand for R&D in training decentralized AI models at the edge for adaptive AI.** These emerging solutions are driven by explicit needs such as privacy preservation or the requirement for machines and processes to run in disconnected (from the cloud) scenarios. Such models enable faster response to changes in the environment, and provide benefits in use cases such as responding to a rapidly evolving threat landscape in security operations.

Obstacles

- Edge AI is constrained by the application and design limitations of the equipment deployed; this includes form factor, power budget, data volume, decision latency, location and security requirements.
- Systems deploying AI techniques can be nondeterministic. This will impact applicability in certain use cases, especially where safety and security requirements are important.
- The autonomy of edge AI-enabled solutions, built on some ML and deep learning techniques, often presents questions of trust, especially where the inferences are not readily interpretable or explainable. As adaptive AI solutions increase, these issues will increase if initially identical models deployed to equivalent endpoints subsequently begin to evolve diverging behaviors.
- The lack of quality and sufficient data for training is a universal challenge across AI usage.
- Deep learning in neural networks is a compute-intensive task, often requiring the use of high-performance chips with corresponding high-power budgets. This can limit deployment locations, especially where small form factors and lower-power requirements are paramount.

User Recommendations

- Determine whether the use of edge AI provides adequate cost-benefit improvements, or whether traditional centralized data analytics and AI methodologies are adequate and scalable.
- Evaluate when to consider AI at the edge versus a centralized solution. Good candidates for edge AI are applications that have high communications costs, are sensitive to latency, require real-time responses or ingest high volumes of data at the edge.
- Assess the different technologies available to support edge AI and the viability of the vendors offering them. Many potential vendors are startups that may have interesting products but limited support capabilities.
- Use edge gateways and servers as the aggregation and filtering points to perform most of the edge AI and analytics functions. Make an exception for compute-intensive endpoints, where AI-based analytics can be performed on the devices themselves.

Sample Vendors

Akira AI; Edge Impulse; Falkonry; Imagimob; Litmus; MicroAI; Modzy; Octonion Group; Palantir

Gartner Recommended Reading

Building a Digital Future: Emergent AI Trends

Emerging Technologies: Neuromorphic Computing Impacts Artificial Intelligence Solutions

Emerging Technologies: Edge Technologies Offer Strong Area of Opportunity — Adopter Survey Findings

Emerging Tech Impact Radar: Edge AI

Edge Computing

Analysis By: Bob Gill, Philip Dawson

Benefit Rating: Transformational

Market Penetration: More than 50% of target audience

Maturity: Early mainstream

Definition:

Edge computing describes a distributed computing topology in which data storage and processing are placed in optimal locations relative to the location of data creation and use. Edge computing locates data and workloads to optimize for latency, bandwidth, autonomy and regulatory/security considerations. Edge-computing locations extend along a continuum between the absolute edge, where physical sensors and digital systems converge, to the “core,” usually the cloud or a centralized data center.

Why This Is Important

Edge computing has quickly become the decentralized complement to the largely centralized implementation of hyperscale public cloud. Edge computing solves many pressing issues, such as sovereignty, unacceptable latency and bandwidth requirements, given the massive increase in data produced at the edge. The edge-computing topology enables the specifics of Internet of Things (IoT), digital business and managed distributed IT solutions.

Business Impact

Edge computing improves efficiency, cost control, and security and resilience through processing closer to where the data is generated or acted upon, fostering business opportunities and growth (e.g., customer experience and new real-time business interactions). Earliest implementations succeeded in enterprises that rely on operational technology (OT) systems and data outside core IT, such as the retail and industrial sectors.

Drivers

- Growth of hyperscale cloud adoption has exposed the limits of extreme centralization. Latency, bandwidth requirements, the need for autonomy and data sovereignty or location requirements may be optimized by placing workloads and data closer to the edge, rather than centralizing in a hyperscale data center.
- Data growth from interactive applications and systems at the edge often cannot be economically funneled into the cloud.
- Applications supporting customer engagement and analysis favor local processing for speed and autonomy.
- IoT is evolving from simply reporting device status to using edge-located intelligence to act upon such status, bringing the benefits of automation and the creation of immediately responsive closed loop systems.
- Edge computing's inherent decoupling of application front ends and back ends provides a perfect means of fostering innovation and enhanced ways to do business. For example, using technologies such as machine learning and industrial sensors to perform new tasks at locations where business and operational events take place, or at the point of interaction with a retail customer, can drive significant business value.

Obstacles

- The diversity of devices, software controls and application types all amplify complexity issues.
- Widespread edge topology and explicit application and networking architectures for edge computing are not yet common outside vertical applications, such as retail and manufacturing.
- Edge success in industrial IoT applications and enhancing customer experience in retail are well-understood, but many enterprises still have difficulty understanding the benefits, use cases and ROI of edge computing.
- A lack of broadly accepted standards slows development and deployment time, creating lock-in concern for many enterprise users.
- Edge physical infrastructure is mature, but distributed application management and orchestration challenges are still beyond most vendor-supplied component management offerings. The tasks of securing, maintaining and updating the physical infrastructure, software and data require improvement before management and orchestration can mature.

User Recommendations

IT leaders responsible for cloud and edge infrastructure should:

- Create and follow an enterprise edge strategy by focusing first on business benefit and holistic systems, not simply focusing on technical solutions or products.
- Position edge computing as an ongoing, enterprisewide journey toward distributed computing, not simply individual isolated projects.
- Establish a modular, extensible edge architecture through the use of emerging edge frameworks and design sets.
- Accelerate time to benefit and derisk technical decisions through the use of vertically aligned systems integrators and independent software vendors that can implement and manage the full orchestration stack from top to bottom.
- Evaluate “edge-as-a-service” deployment options, which deliver business-outcome-based solutions that adhere to specific SLAs while shifting deployment, complexity and obsolescence risk to the provider.

Gartner Recommended Reading

Market Guide for Edge Computing

5 Top Practices of Successful Edge Computing Implementers

Sliding into the Trough

Distributed Energy Resource Management System

Analysis By: Lloyd Jones

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

A distributed energy resource management system (DERMS) is an emerging set of utility software applications that manage distributed energy resources (DERs), which are connected to the electric distribution grid. DERMS makes DERs more accessible and beneficial for all stakeholders, including consumers/prosumers, aggregators, grid owners and operators, and energy market coordinators, by orchestrating DER across different roles, and group DERs to provide services from energy to flexibility.

Why This Is Important

As energy transition gains momentum, DERs are penetrating all areas of the grid, contributing to the decentralization and democratization of energy provisioning. DER deployment is rising globally and utilities now have an urgent need to integrate and orchestrate DERs to maintain network operations resilience and achieve higher levels of flexibility through the market and dispatch of DERs to balance energy.

Business Impact

DERMS addresses the uncertainties created by high levels of penetration of DERs, such as rooftop solar, by turning DERs into additional control levers to manage distribution network operation and commodity management. It also offers benefits to transmission network operations and flexibility markets. A DERMS will also be relevant to DER aggregators that plan to offer various services to distribution-level energy service markets (as they develop), as well as use it for wholesale market arbitrage.

Drivers

- DERMS, as a software application, addresses the complexity of high levels of DER penetration by turning these resources into useful contributors for energy commodity management, distribution network operation and end-user energy efficiency programs.

- DERMS are most applicable for utilities where renewable generation (in particular, those deployed by consumers or prosumers), energy storage, and electric vehicle adoption are rising rapidly.
- According to the National Renewable Energy Laboratory report, significant operational impacts develop when DER capacity on the systems reaches 15% of the annual peak load (see An Overview of Distributed Energy Resource (DER) Interconnection: Current Practices and Emerging Solutions).
- DERs impact multiple aspects of the utility business and create several possible use cases for DERMS. Examples are mitigating the impact of inertialess renewable sources on frequency control on the operational technology (OT) side, creating the need for flexible markets on the energy commodity management side, using DER as controllable resources to manage grid congestion and acting as a contributing resource to individual consumer energy efficiency.

Obstacles

- DERMS products have emerged with different focus points, such as to manage and analyze DERs' impact on the grid advanced distribution management systems (ADMS), or to manage and integrate DER into local and wholesale energy markets demand response management system (DRMS) or the virtual power plant (VPP).
- Vendors with broad-scope ambitions are forming wider partnerships, further complicating market boundaries and resulting in a lack of common understanding (or outright misunderstanding) about DERMS.
- Misalignment between expectations and reality.
- Too few client case studies and not enough proof of realized ROI.
- Immature DERMS offerings built mostly as an extension of adjacent products, such as ADMS, DRMS/VPP and energy efficiency, using legacy protocols, such as OpenADR.
- A reluctance to embrace newer standards such as IEEE 2030.5 across software, equipment, communications and security.

User Recommendations

DERMS implementation is a significant undertaking. A DERMS initiative is commonly led by the business or operations side, the IT effort required in DERMS deployment is significant.

- Control value delivery and reduce execution risk by building an extensive change management map across operations, customer service, network design, commodity management and control center operations.
- Specify how DERMS should communicate with individual devices at the distribution grid edge, as a universally adopted standard/protocol has not emerged yet. Utilities also need to select data integration models (such as Common Information Model [CIM] or MultiSpeak) to determine how a DERMS can inform other enterprise systems, particularly ADMS, about available operational actions.
- Give clarification to users about the product roadmap and vendor credibility, as vendor products are immature with a narrow focus, leaving adjacent use cases that will be required in the near term unmet.

Sample Vendors

GE Digital (Opus One Solutions); Generac Grid Services (Enbala); mPrest; Schneider Electric (AutoGrid); Siemens; Yokogawa Group (PXiSE)

Gartner Recommended Reading

The Impacts of Exponential Renewable Generation Growth Across the Energy Ecosystem

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Market Guide for Distributed Energy Resource Management Systems

IoT in Utilities

Analysis By: Nicole Foust, Zarko Sumic

Benefit Rating: Transformational

Market Penetration: More than 50% of target audience

Maturity: Early mainstream

Definition:

Internet of Things (IoT) is the network of dedicated physical objects with embedded and edge technology to communicate and sense or interact with their internal states and/or the external environment. IoT is an enabler of digital business and a core building block of digital platforms. Vertical utility IoT examples include advanced metering infrastructure (AMI), and connected operational technology such as supervisory control and data acquisition (SCADA).

Why This Is Important

IoT is an essential component for digital business transformation, intelligent operations, and composable business initiatives. Utility organizations view IoT in favor of a more business-operations-centric approach. Use cases are found in all parts of the utility business. These include advanced metering infrastructure, asset management and work management activities, distributed energy resource management systems (DERMS), and consumer technologies (such as smart thermostats).

Business Impact

IoT helps connect utility operational technology (OT), IT, consumer technology (CT) and engineering technology (ET). Use cases include:

- **Increased engagement:** Experiences of consumers/prosumers that improves loyalty and lifetime value.
- **Resource conservation:** Energy efficiency and pollution reduction.
- **Cost optimization:** Lower inventory spoilage and theft.
- **Optimized operations:** Improved productivity and efficiency, logistics and coordination.
- **Optimized assets:** Asset utilization, health monitoring, reliability and maintenance.

Drivers

- IoT is transformational in utilities as they progress further into the decade of deep redesign. Therefore, we have progressed this technology by one position on this Hype Cycle, driven by continued market investment, activity and use cases.
- In Gartner's 2023 CIO and Technology Executive Agenda: A Utility Industry Perspective, 29% of utility respondents indicate increasing investment in IoT, with enterprises varying widely on their IoT maturity. Larger utilities have ongoing IoT-enabled initiatives for use cases, ranging from incremental benefits (e.g., asset optimization or regulatory reporting) to transformative benefits (e.g., dynamic operations of renewable assets).
- Organizations need a "system of systems" that pulls together the proliferation of IoT platforms, data islands and siloes.
- The falling costs of technology, large number of vendors, and relative ease of deployment for new use cases and experimentation, are factors that are accelerating IoT adoption.
- IoT reference architecture and capabilities are becoming aligned with current vertical industry requirements for remote measurement, monitoring and control. Due to a larger addressable market and R&D funding, price/performance of IoT solutions is improving faster than utility vertical solutions, such as AMI or SCADA. Therefore, we see increased interest from buyers in open IoT solutions that address utility monitoring and control needs.
- The energy transition is impacting the current energy provisioning business model, and driving the need for tighter integration of consumers/prosumers and their assets, such as consumer energy technology, DER and smart appliances in utility markets. This contributes to IoT adoption.
- Consequently, the use of stand-alone IoT such as drones, augmented reality/virtual reality and wearables continues to grow, and general-purpose IoT are becoming established. This creates additional opportunities for utilities.

Obstacles

Utility CIOs and business leads should ensure due diligence in planning for initiatives in common challenge areas, such as:

- Confusing vendor marketing (most vendors leverage IoT in delivering IoT-enabled business solutions).

- IoT implementation and expansion (e.g., end-to-end integration complexity and alignment meet specific business outcomes).
- The need to bridge cultural divides between IT and operations and across business units.
- Legacy investment in OT approaches that may carry technical debt.
- Security concerns and requirements of the IoT solutions, which remain an area of caution to meet security and reliability requirements of legacy SCADA installations.
- The historical emphasis on industry's need for high levels of reliability and safety, along with very large existing investments in legacy operational technologies such as SCADA and AMI, which can conflict with affordability and relative ease of deployment.

User Recommendations

- Discern that IoT is not a single technology or solution. It is a broad-based expansion of related technologies that can be applied to a wide range of use cases and purposes.
- Review IoT uses ranging from the tactical, such as improving a specific business process (e.g., theft detection), or operational procedure (e.g., pipeline inspection), all the way to a strategic enabler of digital utility business.
- Evaluate existing operations for opportunities to leverage IoT, such as drones for infrastructure inspection and wearables for worker safety monitoring.
- Assess IoT initiatives in light of organizations' KPIs and alignment with specific business objectives.
- Incorporate IoT into your industry vision as an enabler of composable business. Educate business stakeholders on the potential of IoT.
- Build a plan and establish champions and superusers to help OT employees adapt their business processes and culture to the large amount of data that IoT will generate.

Sample Vendors

ABB; Accruent; AVEVA; GE Digital; Itron; Landis+Gyr; Oracle; SAP; Siemens; Vodafone Group

Gartner Recommended Reading

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

2022 Sustainability Survey: Energy CIOs Can Help to Retain C&I Enterprises as Customers

Magic Quadrant for Global Industrial IoT Platforms

2022 Strategic Roadmap for Asset Management

2022 Strategic Roadmap for Composable Utility Customer Information Systems

Digital Twin

Analysis By: Alfonso Velosa, Marc Halpern, Scot Kim

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Definition:

A digital twin is a software-enabled proxy that mirrors the state of a thing, such as an asset, person, organization or process to meet business outcomes. There are three types of digital twins: discrete, composite and organizational. Digital twin elements include a model, data, a one-to-one association and monitorability. Digital twins are built into a range of software: analytics, 3D models, CRM and IoT. Data on the state of the thing must be sourced via telemetry or application state changes.

Why This Is Important

Enterprises are using digital twins to create virtual representations of previously opaque or time-lagged things. Digital twins can help meet business outcomes such as process optimization, improved visibility or new business models. Specific examples include improving supply chain decisions via better supply and demand visibility, and reducing downtime by monitoring equipment state. Tech providers are increasing value by building domain-specific templates and integration to data sources.

Business Impact

Enterprises are implementing digital twins to:

- Gain visibility into things such as equipment or customer state that enable people to make better maintenance or marketing decisions.
- Assess, simulate and reduce the complexities of designing and developing innovative products and new service models.
- Improve patient outcomes, employee safety and customer transactions by using digital twins of people.
- Drive new data monetization models and contribute to product-as-a-service business approaches.

Drivers

- Enterprises are accelerating their adoption of digital twins to support a broad variety of business outcomes. These business outcomes include reducing the cost structure through improved monitoring of assets and optimizing equipment and processes by aligning asset digital twins into a range of solutions, such as predictive analytics and field service management. They also include product differentiation by engaging consumers and controlling assets, and integrating data silos into one central visualization.
- Asset-intensive sectors — for example, oil and gas, transportation, manufacturing and buildings — are leading in using digital twins to optimize business processes such as product development, supply chain and operations.
- Leading OEMs are exploring how digital twins can help add long-term annuity streams to their regular revenue.
- Leading-edge enterprises are implementing digital twins to model book-to-bill status, foreign exchange risk and supply chain processes. They do so to optimize costs and improve processes.
- Technology providers — from large cloud vendors to startups — are identifying potential ways to serve and charge customers using digital-twin-enabling product portfolios. In particular, they are developing template libraries to demonstrate domain knowledge and to shorten time to value for enterprise customers.
- Standards organizations such as IEEE, Eclipse, ITU and consortia (including the Digital Twin Consortium) contribute to establishing digital twin standards, architectures, ontologies and improving visibility.

Obstacles

- Few enterprises understand what they are trying to achieve, let alone the metrics for digital-twin-based projects. This lack of vision limits project scope and investment into new business processes that can take advantage of digital twins.
- Few enterprises have the cross-functional fusion teams — across business, finance, operations and IT — that are required to achieve business outcomes powered by digital twins.
- Digital twins present a technical challenge for most enterprises due to the blend of operational and information technologies required to develop and maintain them.
- Pricing remains an art, and most vendors focus on their technology differentiation, even though customer organizations are looking for business value outcomes when purchasing digital twin offerings.
- Standards bodies remain emergent. Most vendors use proprietary formats. There is a lack of standards for a broad range of digital twin technical areas such as data source and model integration and metadata management.

User Recommendations

- Co-create the digital twin strategy with the enterprise business unit to identify opportunities and challenges and establish clear success metrics. Further, the business must select sponsors and super users, create a budget and build a roadmap that starts small and scales up.
- Avoid digital twin projects that lack a business sponsor as this is key to success. Lack of internal sponsorship will waste IT resources.
- Identify IT organization technology, governance and skills gaps and build a plan to resolve them.
- Protect intellectual property by working with procurement to ensure that digital twin data and custom models belong to the enterprise.
- Develop an architectural, security and governance framework to manage large numbers of discrete digital twins, as well as composite and organizational digital twins.
- Select vendors not just for their technology portfolio, but more importantly, for the intellectual property (IP) they have in your vertical market. The IP should be demonstrated in libraries of prebuilt digital twin precursor models.

Sample Vendors

Akselos; Esri; GBTEC Group; Mavim; Nstream; Sight Machine; Toshiba; TwinThread; Vanti; visCo

Gartner Recommended Reading

Quick Answer: What Is a Digital Twin?

Emerging Tech: Tool — Digital Twin Business Value Calculator

Life Cycle Management of Software-Defined Vehicles: Step 3 — Vehicle Digital Twin 2.0

Quick Answer: Privacy Basics for a Digital Twin of a Customer

Emerging Tech: Tech Innovators for Digital Twins — Digital Business Units

Big Data in Utilities

Analysis By: Ethan Cohen

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Big data is high-volume, high-velocity and/or high-variety of information assets demanding cost-effective, innovative forms of structured information processing that enable enhanced insight, decision making and process automation. In the utility context, the ability to acquire, organize, analyze and deliver data across IT, OT, IoT and consumer domains will be a critical requirement for sector digital business transformation.

Why This Is Important

Historically, big data has focused primarily on the volume issues of extremely large datasets generated from technology practices in OT, cloud ecosystems and streaming event sources. We are seeing utilities starting to address data in context and in process. In utilities, as in most asset-centric organizations, OT and machine data are essential to operations. Big data is a precursor to but not a requirement of some utility AI use cases.

Business Impact

Utility and technology business leaders should recognize and act upon:

- The variable nature of big data connections within and across enterprise business units and business processes.
- The smart grid/network data deluge and integrate grid/network modernization initiatives.
- Big data critical domains in advanced analytics and ML analysis, including data preprocessing, model engineering, hyperparameter tuning, feature engineering, data and model management, forecasting, and visualization.

Drivers

- Practices are developing quickly in the energy and utility sector. Big data has emerged from the bottom of the Trough of Disillusionment, as conflicting concepts of what it is and how organizations can benefit from its management and analysis continue.
- Given the megatrend of decentralization and technology consumerization in the utility sector and extension of the grid/network perimeter by inclusion of IoT devices, the number of devices connecting to both the grid/network and data networks is set to grow exponentially.
- Smart metering deployments, with the overwhelming amount of data they provide, usually trigger big data initiatives in customer-facing and network operation activities.
- The increased deployment of renewables and the need to process weather-related data to anticipate its impact on renewable energy output also require adoption of more advanced solutions that combine spatial and temporal weather data with asset performance data.

Obstacles

- Traditional technology-first analytic approaches struggle to extract important relationships between business domains and process entities, leaving useful datasets neglected and underleveraged.
- The need to utilize a variety of data — in particular, transactional data stored in the internal IT systems as well as data obtained from OT systems and by IoT sensors — creates a significant interest in systems that can provide advanced business insight.
- High demand combined with relatively low maturity and lack of internal skills impedes maturation progress and slows down access to and achievement of outcomes and value.

User Recommendations

- Prepare for the increased volume of data generated by physical-asset-embedded sensors, sensing devices monitoring network parameters data generated by edge devices.
- Respond to smart grid/network and commodity market inversion that is producing a different variety of data, such as temporal, spatial, transactional, streaming, structured and unstructured.
- Explore the volume, variety and velocity of data. If volume is increasing as described, variety is expanding or velocity is creating temporal and contextual challenges in data, then you have a big data transformation opportunity that merits investment.

Sample Vendors

Amazon Web Services; Cloudera; Dassault Systèmes; Dell EMC; Hewlett Packard Enterprise (HPE); IBM; SAS; Teradata

API Marketplaces

Analysis By: Andrew Humphreys

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

An API marketplace is a platform to share APIs. Consumers, mainly developers, use API marketplaces to discover APIs and, in some cases, may purchase access to them. They can be either public commercial marketplaces with APIs from multiple providers, public with APIs from a single provider, or private marketplaces for promoting an organization's internal APIs.

Why This Is Important

API marketplaces enable organizations to publicize their APIs. Marketplaces are usually associated with external marketplaces, which share APIs with a community of developers and enable partners to implement solutions using the APIs. However, as most APIs are meant for consumption by teams within an organization, marketplaces are more frequently internal. They make it easier to find APIs internally, helping with wider sharing of capabilities between different business units and product and development teams.

Business Impact

API marketplaces increase developer visibility and consumer mind share, drive API usage, and, by extension, increase business impact. API consumers can use marketplaces to simplify finding and comparing different APIs when they are looking for specific functionality but have not selected exactly which API to use. There is typically a cost involved with listing in a public API marketplace, but the benefits include exposure to a larger number of API consumers and access to features to enable monetisation.

Drivers

- The number of APIs within an organization is climbing, driving the need for developers to more easily discover which APIs and services are available.
- Composable business, including composable commerce, relies on the use of API marketplaces to share APIs and packaged business capabilities.
- Increased use of low-code platforms, integration platforms, robotic process automation (RPA) and analytics tooling enables more citizen development using APIs that may be sourced from API marketplaces.

Obstacles

- Public API marketplaces that provide a public directory of APIs from multiple providers have had disappointing results, as developers are more likely to go directly to API providers to sign up for APIs. This has resulted in API marketplaces in the Trough of Disillusionment. However, internal API marketplaces have had more success, since they enable developers to share APIs across multiple teams.
- API portals provided as part of API management platforms are typically basic in nature, resulting in significant customization work to create a customer-oriented API marketplace based on such an API portal.
- New open-source platforms, such as Backstage from Spotify, are driving the creation of internal API catalogs as part of larger developer hubs. If your developers are collaborating on solutions around their APIs already, then a simple catalog may be sufficient and a full marketplace is probably overkill.

User Recommendations

API providers:

- Create an internal API marketplace, focused on the needs of software engineers to share APIs across the organization.
- Examine billing terms to understand what the cost of using the marketplace is when considering commercial API marketplaces.
- When considering a commercial API marketplace, examine listing fees and value to your organization before committing.

API consumers:

- Ensure that you use APIs from trusted marketplaces and trusted API providers, examining usage agreements, licensing and billing terms carefully.
- Investigate whether consuming an API directly from the API provider offers better pricing or usage terms than consuming the API via a marketplace.

Sample Vendors

Achieve Internet; Bump; Postman; Pronovix; Readme; Smartbear (Swagger); Spotify (Backstage); Stoplight

Gartner Recommended Reading

Innovation Insight for Internal Developer Portals

Reference Model for API Management Solutions

Home Energy Management

Analysis By: Ethan Cohen

Benefit Rating: Moderate

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Home energy management (HEM) uses automation to optimize residential energy consumption and production using interconnected energy management devices. Hardware items include in-home displays, smart thermostats, switches and appliances, and home-area networks (HANs) for connecting elements and UIs. Software components include OS, analytics and data visualization applications on devices and in the cloud. HEM can connect to utility systems via the internet, stand-alone gateways or smart meters.

Why This Is Important

Utilities are deeply impacted by customer energy production and consumption. However, companies with experience in consumer technology delivery now drive the market evolution for HEM in smart home offerings. Technology companies including Google, Apple and Amazon have launched connected home solutions. Electric vehicle (EV) companies such as Tesla, Nissan and BMW Group are increasing their footprint in the market. Consumer and household electronics manufacturers are also in the market.

Business Impact

HEM is relevant for utility energy efficiency and demand-response programs. Various demand-response projects have identified favorable incremental utility peak load reduction contributions from programmable communicating thermostats connected to utility systems. Results from in-home display trials for demand response and energy efficiency are mixed. HEM can also help differentiate competitive energy retailers. In the future, HEM will be increasingly relevant to home energy production, microgrids, nanogrids, and energy-sharing platforms and EV charging.

Drivers

Digital has created opportunities for utilities and for homeowners to derive new value from the connection of things, information and automation. HEM solutions provide utilities with the opportunity to:

- Understand residential energy needs.
- Optimize the delivery of commodity services.
- Optimize the demand and demand-response quotient from utility energy efficiency programs.
- Optimize utility consumption or dispatch of customer homes' generated or stored electricity.
- Save the utility and the customer money.
- Deliver new home services such as electric-vehicle-to-grid integration and electric vehicle charging.
- Model and analyze customer individual and aggregate behavior in key contexts, including personal, home, mobility and environment.
- Monitor, orchestrate or become an agent for microgrids and emerging energy-sharing and circular economies.

Obstacles

HEM solutions have passed through the Trough of Disillusionment and take five to 10 years to reach plateau because:

- The business and operating models are not clearly defined or refined to match the potential for revenue streams.

- Utilities don't need to own a point of presence or appliance technology to utilize HEM information, so utility interest in pushing HEM to residential customers is limited.
- Smart city initiatives recognize HEM and other home services as an opportunity, but few initiatives provide the funding or the technology along with the compelling use cases, services and benefits for residential homeowners to want to opt in.
- Smart appliances and vehicles provide HEM functionality for some use cases, but not necessarily the complete set or in an aptly packaged and servitized manner. Partial capability and confusing value propositions tend to frustrate consumers and hinder adoption.

User Recommendations

- Focus on interoperability with market-leading devices to enable energy efficiency and demand-response programs. Key standards include IEEE 2030.5-2018, International Electrotechnical Commission (IEC) 61580 and OpenADR Alliance.
- Prepare utility information architecture to support HEM, including providing access to consumption data via web portals and consumer electronics devices. Extend back-end systems via APIs and/or hybrid integration to become a part of vendor and smart city ecosystems.
- Address the long-term growth in energy technology consumerization, including growth in distributed power generation, electric vehicles and home energy management. This will make more advanced HEM capabilities important in some regions.
- View HEM as enabling technology. Energy retailers in contestable energy markets should also evaluate HEM as a means of differentiating their offerings.

Sample Vendors

Amazon; Apple; Centrica; ecobee; Enel X; Google; Honeywell; ONZO; Uplight

Gartner Recommended Reading

Market Guide for Energy Management and Optimization Systems

Climbing the Slope

Meter Data Analytics

Analysis By: Lloyd Jones

Benefit Rating: Moderate

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Meter data analytics (MDA) leverages advanced metering infrastructure (AMI)-generated consumption and event data to provide insights into the operational performance of metering systems and distribution networks (such as hot socket, meter tampering or last gasp). MDA can indicate anomalies in consumption patterns and energy theft, and is increasingly being used to provide insights into network asset loading to help anticipate abnormal events and avoid asset failures.

Why This Is Important

MDA is a technology market that is separate, although adjacent, from meter data management systems (MDMS). Some MDMS vendors have extended their products to provide analytical capabilities such as outage insights if data is streamed. The majority of MDA products are postevent, generating business insights such as consumption, forecasts, feeder balancing and theft insights.

Business Impact

Consumption data is moving from its traditional, siloed use in the “meter to cash” process into an enterprise IT asset data role. MDA can improve network operations (such as distribution network management and asset load management) and commodity management (for example, demand response and load forecasting). MDA offers revenue management, bill alerts, fraud detection, customer service and new consumption-based product offerings in competitive energy markets with nonintrusive load insights.

Drivers

- Many utilities, globally, have deployed smart metering. Consequently, they now have a large amount of consumption data, basic service supply quality measurements (such as voltage level and fluctuation) and event notifications at their disposal.

- Smart metering is a vertical instance of the Internet of Things (IoT) and a key enabler of digital business transformation in the utility sector. Smart metering deployment is the main contributor to utilities' perception of the smart grid data deluge and prompts utilities' interest in big data projects and consequently, meter data analytics deployment.
- AMI deployments increase metering data volume by five orders of magnitude compared to monthly breads. The trend toward shorter measurement intervals can quadruple AMI data volumes. The increased volume of data generated by edge devices (such as smart meters and smart thermostats) challenges data storage capability and requires streaming analytic approaches.
- Vendors are leveraging advanced analytical algorithms based on machine learning and pattern recognition to generate near-time operational insights.
- The continuing push to leverage smart metering data and justify costly investment in AMI has resulted in the fast adoption of advanced analytics in the utility sector.
- Finer granularity and reduced latency consumption data open up the possibility for numerous use cases along utility core business process life cycles (asset, commodity, customer and revenue), and enable the move from historical reporting to predictive and prescriptive business insight.
- As consumption data interval size continues to drop, meter data analytics capability is improving. Examples are providing consumer device "fingerprinting" via nonintrusive load monitoring and identifying particular devices, such as electric vehicles (EVs) or abnormal device operation.

Obstacles

- Smaller utilities, with a limited budget and limited access to internal technical resources, are unable to afford qualified resources and depend on external providers to derive benefits from meter data analytics.
- In many markets, smart metering deployment was driven by regulatory mandates to either facilitate the opening of the competitive retail sector or enable end-user energy efficiency programs; use for broader analytic use cases came as an afterthought. Thus, utilities must define the entire data and analytic strategy, from selecting tools for data ingestion and persistence to sourcing development of the proprietary algorithm.

- Diversity of providers, lack of internal talent, and lack of the shell offering maturity of meter data analytics algorithms make meter data analytics projects expensive and thus slow down adoption.

User Recommendations

- Track new vendors who are entering the MDA space, with promises of lower costs. Look for MDA vendors with prebuilt modules, enterprise vendors with in-memory analytics solutions, analytical platform vendors' offerings (combined with vertical data models) and niche cloud meter analytics providers.
- Evaluate all alternatives against your needs before committing to a solution by including technical performance as well as prepackaged functionality. Carefully consider sourcing options, deployment architecture (cloud or on-premises), time to deploy, vendor's viability and their long-term commitment to the utility sector.
- Ignore the generative AI hype and ensure that the common sense use cases for revenue management and asset insights are deliverable on your data and able to step past your data quality issues. MDA vendors will continue to invest in advanced analytical technologies, such as machine learning and pattern recognition to extract actionable, don't get dazzled.

Sample Vendors

C3 AI; Landis+Gyr; Nokia; Oracle; SAS; Siemens; Xylem Analytics

Gartner Recommended Reading

2023 CIO and Technology Executive Agenda: A Utility Industry Perspective

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Market Guide for Meter Data Management Systems

Consumer Smart Appliances

Analysis By: Sruthi Nair, Zarko Sumic

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Definition:

Smart appliances, such as washers, dryers, cookers and smart thermostats can connect and share information with other machines or systems. Unlike traditional single-purpose appliances, they can send and react to information captured by smartphones and tablets. They connect wirelessly via communication protocols to exchange real-time data for controlling or monitoring applications and can be an integral part of the overall home energy management solution.

Why This Is Important

Growing technological advances combined with an increasing focus on enhancing customer experiences and relationships coupled with increased volatility in energy prices. These have strengthened the foundation for smart home ecosystems, such as Amazon Alexa, Amazon Echo, Apple HomePod and Google Home. It is also important to note that all consumer smart appliances need to adhere to MATTER open source connectivity standards for smart home and IoT devices.

Business Impact

The following utility line-of-business organizations should monitor development in this technology area to leverage it in their programs:

- Customer service departments looking for differentiating service offerings.
- Commodity management looking for active device engagement in energy management programs.
- Network operations departments looking for smart device contribution as a control asset.
- Customer experience teams that plan to enhance and strengthen customer relationships.

Drivers

- Artificial intelligence and virtual personal assistants have become more sophisticated, and the adoption for smart appliances is increasing further.
- Evolving platform capabilities have addressed one of the main obstacles for adoption — lack of integration standards — which is now addressed by the large consumer technology ecosystem. That, combined with an increase in purchasing ability, evolving lifestyles and individual appliances linked to these platforms, has encouraged the move of smart appliances further into the trough and closer toward the early mainstream.
- According to a study, the global smart home appliances market was valued at $36,648.43 million in the year 2021 and is projected to reach $98,319.34 million by the year 2028. The reasons for the same being growing internet penetration, awareness about energy efficiency and conservation and its impact on climate change.
- Cost-effective products from China and India are also drivers for adoption.
- Additionally, utility retailers are incentivizing their consumers to use smart appliances. For example, utilities in the U.S. and U.K. have been providing incentives for usage of smart appliances, such as smart thermostats, energy-efficient refrigerators and air conditioners.

Obstacles

- Challenges around data breach and privacy may create hurdles in adoption of smart home appliances.
- Installation costs are way higher in comparison to conventional appliances.
- Interoperability and integration of software, hardware and communications might be challenges that the appliance vendors might face, as well as integration with other home-energy management systems.
- Production and supply chain of smart home devices because of global semiconductor supply chain challenges.

User Recommendations

- Partner with smart device manufacturers (such as Google Nest smart thermostat) for some segments of their customers as a part of broader demand-response programs, as adoption of this technology is driven by consumers, not utilities.
- Choose vendors that have participated in emerging programmable home ecosystems for better integration and interoperability and have joined the certified partner programs of not one, but many market leaders, such as Amazon, Apple or Google. These programs are strong, and viable options are emerging. Convergence to a common set of standards is likely to occur over time. Until then, there is keen competition between companies to establish proprietary networks in the home to secure market share.
- Focus on achieving benefits through smart consumer appliance integration via consumer technology vendor platforms. Integration will make or break smart home technology.

Sample Vendors

Apple; Constellation; General Electric; Google; Haier Group; LG; Panasonic; Samsung; Whirlpool

Gartner Recommended Reading

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Market Trends: Connected Home Adoption in the U.S. and the U.K.

Market Trends: Removing Buyers’ Friction in the Connected Home With Smarter, Self-Healing Devices

Market Insight: Build a Featured Hardware Portfolio With Ecosystem Partners to Drive Greater Success in the Global Smart Home Market

Customer Gateways

Analysis By: Sruthi Nair

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

Customer gateways are logical interfaces that connect utility systems with consumer systems and devices, such as home energy management (HEM), smart appliances, and domestic generation and storage solutions. These gateways enable digital grid transformation by integrating consumers/prosumers in energy markets through delivering pricing signals, and they support secure, two-way communications to manage and coordinate energy consumption.

Why This Is Important

Customer gateways provide an interface between utility and customer energy management systems. They are critical for connecting customers with energy markets, and are available as stand-alone, internet-connected devices, or are provided by utilities as an integrated component in an advanced metering infrastructure (AMI). These gateways allow consumers to manage energy consumption and assist in decision making.

Business Impact

Load patterns are shifting with the injection of renewables, electric vehicles (EVs) and storage, and volatility in energy prices. Customer gateways affect energy retail and enable technology consumerization. They link utility and consumer tech, smart appliances supporting consumer HEM and transform the energy-provisioning model. They support demand-response and energy-efficiency initiatives, and enable prepayment and dynamic pricing programs.

Drivers

- Customers and their energy technologies, such as distributed energy resources (DERs), EVs and HEM systems, are poised to play central roles as enablers of utility digital business models.
- The vast majority of consumer energy technology is purchased by customers, provisioned by consumer technology megavendors (such as, Google, Apple, Samsung Electronics and Tesla) and installed by third parties.
- By leveraging connected home APIs and/or digital assistants, utilities can address interoperability and integration complexities and concerns. Utilities should consider becoming part of the consumer technology megavendors' ecosystems.
- Options for a customer gateway platform include smart meters, home gateways or cloud-based services provided by third parties, such as consumer technology vendors (e.g., Google Nest) that customers can access via a web browser or an internet-connected device (such as a smartphone or a tablet).

Obstacles

- Technology may soon become obsolete as this capability is delivered by next-generation smart meters.
- The growth of IoT capabilities, increasing device connectivity and alternative means to integrate consumer devices through consumer technology ecosystems, will overtake the adoption of customer gateways.
- Since most consumer energy technologies are provisioned by megavendors and installed by third parties, this will create interoperability challenges for utilities seeking integration of demand response and grid services. For instance, this could include tapping into smart inverters or energy storage batteries for voltage regulation.
- Partnering with OEMs to provide customer gateway services might prove to be a challenge that utilities must prepare for.

User Recommendations

- Provide communication links and control schemas to incorporate customer-installed gateways, HEM systems and smart devices.
- Connect utility-deployed technologies and HEM solutions provided by communication service providers or other consumer technology vendors via gateways.
- Work closely with megavendors to ensure all integration and interoperability challenges are managed.
- Educate the business on the pros and cons of each option, within the context of overall digital grid transformation strategy, before making platform decisions.
- Use customer gateways to communicate price signals to consumers and help them make effective choices about energy consumption, either directly, or through systems programmable by the consumer to take action when price thresholds are met. They can reduce consumption when prices are high and increase it when prices are low.

Sample Vendors

Axiata Group Berhad (Dialog Axiata Group); Barbara; Congruitive; Digi International; HELLA; Powerley; Silicon Labs; SwitchDin

Gartner Recommended Reading

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Market Guide for Electric Vehicle Charging Solutions

Quick Answer: How Electric Utility CIOs Can Respond to Changing Customer Expectations

Microgrids

Analysis By: Ethan Cohen

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Definition:

A microgrid is a self-sufficient group of interconnected electrical loads and distributed energy resources that can operate as a stand-alone power system or be connected to the grid to provide optimization optionality. Microgrids commonly range in size from 100 kilowatts (kW) to 10s of megawatts (MW) and can connect to and disconnect from the grid. Microgrids can operate in both grid-connected and island modes based on technical and economic criteria to optimize energy cost and availability.

Why This Is Important

Microgrid uses include rural electrification, residential or community power networks, commercial, industrial, municipal, hospital and military base power grids. Microgrids leverage traditional and renewable generation sources. Microgrids offer a compelling alternative to traditional energy generation and distribution, using Internet of Things (IoT) to enable integrated control of distributed power generation assets.

Business Impact

Microgrids impact utility generation, distribution and energy retailing domains. They are becoming more important as utilities create new energy ecosystems and expand energy services offerings. Microgrids are also examples of energy technology consumerization, challenging the traditional business model of utility-provisioned energy delivered as a cloud service. By facilitating consumer integration into the energy market, microgrids are contributing to consumer energy management and the energy delivery infrastructure's geodesic transformation.

Drivers

Microgrids offer advantages to utilities and customers by improving energy efficiency, reducing transmission and distribution losses, improving reliability, reducing environmental impact and providing a more cost-efficient electricity infrastructure compared to the traditional electricity distribution grid, as they also:

- Provide local options regarding the choice of electricity generation source and supply, such as distributed renewable energy sources (particularly those that are for energy storage).
- Enable energy customers to self-provision for operational resilience and collaborate or partner with utilities to achieve specific outcomes.

- Support renewable energy and energy efficiency through a viable approach to local grid modernization while incorporating local distributed energy supplies and storage technologies to meet the specific needs of their constituents while networking with the main grid.
- Deliver benefits to utilities by supporting the central grid in handling sensitive loads and the variability of renewables locally and supplying ancillary services to the bulk power system.

Obstacles

- Microgrids do not have the same economies of scale and the coincident load factor of the centralized grid.
- The commercial integration of microgrids into energy markets will require a platform for the energy-sharing, resource-sharing and market-sharing economy.
- Technical constraints inhibit the integration of microgrids into distribution grids, including specific elements like dual-mode switching functionality, reliability, power quality and protection.
- Central electricity network operation impacts for microgrids require new utility systems, such as distributed energy resource management systems and advanced distribution management systems, which can be costly and complex to deploy.
- Microgrids must have mechanisms to regulate voltage and frequency in response to changes in load and system disturbances. This is because all power in microgrids comes from distributed generation resources and controllable loads within the microgrid, which typically requires investment in operational technology (OT) to perform distributed control.

User Recommendations

As microgrids progress into mainstream utility, CIOs should:

- Observe market developments in microgrid use cases, and evaluate what kinds of offerings might be advanced to develop new revenue, enhance resilience and improve energy provisioning.

- Enable the utility to quickly and thoroughly evaluate microgrid development and/or operation by developing minimum viable products for microgrid cases. Despite the significant promise and industry excitement about the concept, relatively few fully commercialized state-of-the-art microgrids have been deployed by utilities in many regions.
- Advance computational capabilities by improving physical models that leverage machine learning and automation.
- Dedicate some investment to a microgrid design authority to improve microgrid operations reliability, security and self-healing capabilities in intelligent grid operation for electricity distribution.

Sample Vendors

Alencon Systems; Ameresco; Generac Power Systems; NRG Energy; PowerSecure; Schneider Electric; Siemens; Veritone; Yokogawa Electric Corporation (PXiSE Energy Solutions)

Gartner Recommended Reading

2023 Utility Trend: Orchestrate Flexible Resources to Maintain Power System Operational Integrity

ADMS

Analysis By: Lloyd Jones

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Advanced distribution management systems (ADMS) are a decision support environment executing against a network model with a common user experience for all roles that monitor, secure, control and optimize the operations of the distribution grid. ADMS functions include state estimation, fault location, isolation and restoration, volt/volt-ampere reactive optimization, outage management, voltage reduction, peak demand management, and impact assessment of distributed energy resources (DERs).

Why This Is Important

Operators of electric distribution networks use ADMS for both regular operations and abnormal (storm recovery) modes of operation. ADMS integrates the decision support for network operators across outage management, power network analysis and network operation needs.In the past, outages were addressed via a separate product outage management system (OMS). OMS is considered to be a legacy application subsumed by ADMS.

Business Impact

ADMS shorten outage restoration and improve availability. ADMS can be leveraged to improve business performance across network operations, customer service and asset management with accurate prediction of restoration times, distribution reliability, and optimization of network configurations. ADMS can analyze rising DERs' impacts and suggest control actions to an adjacent DER management system (DERMS) to control DERs. ADMS may defer new investment in grid assets.

Drivers

- As the global utility sector experiences the energy transition, utilities must modernize their energy delivery networks to resolve current operational challenges, and enable new business and operating models that monetize the use of the digital grid's expanding services. To safely and effectively manage the delivery infrastructure, utilities need a solution that serves as the "brain" and "nerve center" of the digital grid.

- The solution must consolidate and integrate the necessary software into a real-time platform. This platform will orchestrate how all the functional network components and parties from the extended ecosystem (including consumers and DERs) can operate, coexist, and interact in the new democratized energy markets.

- Given these requirements, utilities need a comprehensive enterprise application suite — ADMS that address a wide range of distribution operations scenarios. To meet new requirements, ADMS need to extend across traditionally separated IT and operational technology (OT) domains, as well as support the extension of monitoring and control capabilities with integration of smart devices in the consumer technology (CT) domain.

- ADMS also need to provide a single user experience (single pane of glass) and common network models for monitoring, operation, restoration, analysis, and optimization of the modern energy delivery network. The same integrated environment must support network operators managing the grid under normal operating conditions and support emergency restoration following a storm.

Obstacles

- The ADMS market continues to be a mix of commercial off-the-shelf (COTS) and customized, project-specific implementations. This is a reflection that most ADMS vendors have OT backgrounds and have slowly adopted best practices to support composable orchestratable modular architectures.
- Vendor offerings are maturing, but some project setbacks can still be expected. ADMS project deployments are challenged by requirements for high-quality network models (typically sourced from GISs). Integration requirements across many systems (including customer information systems, meter data management systems, supervisory control and data acquisition [SCADA], and DERMS) make delivery challenging.
- Many buyers in regions with large secondary networks expect ADMS to provide a full model and the same standard set of algorithms on secondary networks. Vendors do not offer that, and instead offer limited functionality with limited insight in secondary network operation.

User Recommendations

- Acknowledge that ADMS can be adapted to different objectives and use cases. Selecting the best ADMS vendor is an important decision. It is a critical factor for achieving success in the targeted use cases. ADMS are complex production environments that are data-intensive, and implementations can take two to three years or longer. Vendor choices are not easily reversed.
- Evaluate implementation challenges upfront and take steps to mitigate project risks. Although a range of comprehensive ADMS products are now available across global markets, most implementations still involve some custom development; buyers should plan accordingly.
- Acknowledge and be aware of limited options for ADMS implementation and dependence on product vendors, which introduces added risk.

Sample Vendors

Emerson Electric (Open Systems International [OSI]); ETAP; General Electric; Indra (Minsait ACS); Oracle; Schneider Electric; Siemens; Survalent

Gartner Recommended Reading

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Market Guide for Advanced Distribution Management Systems

Market Guide for Distributed Energy Resource Management Systems

The Energy Transition Question: Do We Need the Grid?

Customer Energy Storage

Analysis By: Ethan Cohen

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Customer energy storage technology, including battery, flywheel or hydrogen, supports site-specific power reliability and enables behind-the-meter energy management. It also complements grid-scale energy storage when it is grid-connected. On-site storage is often used with on-site renewable resources and power control systems to mitigate electricity intermittency, increase on-site renewable generation value, and complement the value of customer electric vehicles and building battery storage.

Why This Is Important

Meeting the challenge of integrating customer-owned renewable generation and storage into the electricity delivery network and addressing the opportunity to add new capability to the utility while providing benefits to energy customers is a vital part of the energy transition for electric utilities and increasingly important to water utilities and other organizations that participate in circular economies.

Business Impact

Used jointly with on-site generation, customer energy storage is a key component of a distributed energy resources strategy, which transforms the utility delivery infrastructure from a centrally controlled radial network to a locally controlled geodesic network. It delivers physical, operating and economic efficiency and opportunity to the utilities, energy customers and others. For energy consumers of all sizes, customer energy storage can play an essential role in energy management and sustainability.

Drivers

Customer energy storage is emerging from the Trough of Disillusionment and will mature quickly — reaching the plateau in two to five years — because many consumers will move swiftly to obtain lower cost, improved service and the economic benefits from sustainability reputation and renewable energy credits.

In modernizing the electricity grid and building new capabilities, utilities have incentive to not only respond to customer-deployed energy storage but also invest strategically to ensure storage can deliver stackable benefits that provide the utility with operational and economic performance improvement.

Customer deployment of on-site energy storage:

- Enables consumers to participate more actively in energy markets — particularly when combined with on-site renewable sources to optimize energy efficiency.
- Provides the customer with valuable energy storage applications, including time-of-use energy cost management, demand charge management, electric service reliability and electric service power quality.

Utilities can add to and complement these consumer applications to:

- Improve operational performance in managing electric energy timeshift, electric supply capacity, area regulation, voltage support and transmission congestion relief.
- Create new consumer services.
- Economically integrate nonutility renewable energy sources.
- Reduce greenhouse gas emissions via thermal production offset.
- Develop circular economic relationships with other utilities, particularly water utilities at the energy-water nexus.

Obstacles

- Selecting the right technologies to deploy and applications to implement
- Developing the right business case and gaining confidence in investing based on the complementary and combined benefits of storage applications, because the individual economic benefit of individual applications may be negative or marginal
- Measuring and accounting for the impact of heretofore slow-paced vehicle-to-grid development
- Reconnoitering the pace of new energy market development or lack of the same
- Getting clear guidance from regulators about the mandates and policies regarding utility engagement with, connection to and orchestration of nonutility, consumer- or third-party-owned storage

User Recommendations

As customer energy storage progresses into the mainstream utility, CIOs should:

- Evaluate the effect more widely deploying nano, residential, and small to midsize commercial energy storage technology as part of the energy technology consumerization trend.
- Explore innovative technical and business opportunities resulting from the combination of energy storage, control systems and IoT in storage applications from bulk power to transmission, distribution and renewable integration.
- Leverage lessons learned from digital technology and IT consumerization to ease the disruptive effects of energy technology consumerization, as well as foster the inclusion of consumer-owned energy technology into utility energy markets and ecosystems.

Sample Vendors

Mercedes-Benz; NEC; Niterra North America; Nissan; Schneider Electric; Stem; Tesla

Gartner Recommended Reading

2022 Sustainability Survey: Energy CIOs Can Help to Retain C&I Enterprises as Customers

EV Charging Infrastructure

Analysis By: Lauren Wheatley

Benefit Rating: Moderate

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

The EV charging infrastructure, or electric vehicle supply equipment (EVSE), is a component of the overall supply system for the recharging of EVs and plug-in hybrid EVs. Different means of providing electricity to charge EV batteries exist, including slow residential AC charging and fast commercial DC charging. Ownership models include private, publicly owned, municipal or commercial charging points, including those owned by EV manufacturers, fleet owners and individuals.

Why This Is Important

Current momentum in EV sales can only be sustained if the majority of the population have access to convenient and affordable charging infrastructure, both publicly available and private chargers at residences and workplaces, among other destinations. EV charging infrastructure has implications for utility companies, depending on the role they want to have in the electrification of transportation; there is significant benefit for those owning, managing and operating EV charging infrastructure.

Business Impact

The major areas of utility impact will be delivery (charging infrastructure life cycle management) and retail. Owners of the distribution network will have to ensure their infrastructure can handle additional load introduced by EV charging. The impact of EV charging on distribution networks can be mitigated with charging control to avoid periods of peak demand. Ownership of the EV charging infrastructure provides network operation benefits, in addition to increased electricity sales.

Drivers

- EV charging infrastructure needs to increase more than twelvefold by 2030 to support the growth of electric cars projected in the International Energy Agency's Global EV Outlook 2022, adding 22 million charging points per year. This will require a cumulative installed charger capacity of over 1.9 terrawatts, and have a significant impact on electricity supply and demand.
- Charging infrastructure is not yet ubiquitous. In the U.S., together the Inflation Reduction Act and the Infrastructure Investment and Jobs Act have earmarked nearly $11 billion for the establishment of a network of EV chargers. Many European countries still fall short of the Directive 2014/94/EU of the European Parliament and of the Council recommendations, while automotive companies are creating joint ventures, e.g., Daimler Truck, TRATON GROUP and Volvo Group, to install high power charging points near highways and logistics hubs.
- EVSE infrastructure continues to rapidly evolve, with some countries installing large-scale interconnected EV charging stations along main transport routes. Key considerations for developing charging networks include digitalization, interoperability and planning roadmaps.
- In markets where there is strong public and policymaker support for EV, the network operator may explore EV charging as an extension of energy delivery infrastructure, with a traditional investment recovery model. In other markets, utility organizations use this as an unregulated business opportunity. The ability to gather consumption patterns will help utilities mitigate the impact on the distribution grid and may result in additional future revenue growth as electricity displaces gasoline as the preferred transportation fuel.
- The electrification of heavy freight trucks is underway and long-term planning for megacharger infrastructure (1 MW or more) is required.
- The Open Charge Point Protocol (OCPP) allows EV chargers to expand their digital functionality, allowing advanced interoperability between charger and OS.

Obstacles

- Recharging EVs places a high load on the electrical grid when they are not scheduled for periods of reduced load or reduced electricity costs.
- Market fragmentation and lack of a common unifying platform slows maturation and adoption of EV charging infrastructure.
- EV charging technology evolves at a slower pace than EV technology due to longer product life cycles, limited R&D investments and because EV charger replacement rate is slow in relation to cars.
- Regulation is often an obstacle to the adoption of smart charging technology. For instance, Germany and some U.S. states have mandated the adoption of card payment terminals at public chargers, which indirectly discourages charge point operators from adopting “plug and charge,” the most convenient technology.

User Recommendations

- Invest in electric charging infrastructure if you operate in markets where there is a significant government sponsorship for EV adoption. In those markets, utilities (mostly distribution network operators) can recover the investment in EV charging through regulated distribution tariffs where investments enable new business models that deliver convenience and price competitiveness to end customers.
- Leverage EV charging infrastructure to get better insight and some control over EV charging implications on existing distribution grid and improve asset utilization.
- Ensure your EV infrastructure strategy aligns with your jurisdiction’s regulatory treatment of EV infrastructure investment. The regulatory structure has strong implications for the ownership structure and organizational arrangements of charging infrastructure.

Sample Vendors

ABB; Blink Charging; ChargePoint; EVBox; EVgo; General Electric; Schneider Electric; Siemens; Tesla

Gartner Recommended Reading

Market Guide for Electric Vehicle Charging Solutions

Emerging Tech Impact Radar: Electrified Vehicles, 2022

IT/OT Integration

Analysis By: Kristian Steenstrup

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Information technology/operational technology (IT/OT) integration is the end state sought by organizations (most commonly, asset-intensive organizations), where IT and OT are treated as a seamless entity with cohesive authority and responsibility. In this state, there is an integrated process and information flow. Integration includes infrastructure, software, processes and potential resources.

Why This Is Important

The IT content of OT has grown exponentially and their integration allows for unprecedented efficiency gains. Yet, for most organizations, IT and OT are managed by separate groups with different approaches to managing technology. Integration can be initiated by IT departments. However, operational business units may also seek integration when trying to solve other challenges, such as dealing with cybersecurity, rising support costs, safety concerns, disaster recovery or software administration.

Business Impact

Opportunities and benefits from transparency, and an integrated value chain based on data, come from integrating the systems. As IT and OT platforms and technologies converge through increasing the use of IT architecture within OT, a successful digital business manages both IT and OT together. There is a shared responsibility, even though direct reporting lines may not shift. Data can be shared, and process flows become continuous and coherent, with minimal interruptions.

Drivers

- With IT/OT integration for asset-intensive digital businesses, organizations will be much more capable of managing, securing and exploiting data, information, and processes.
- IT/OT integration results in integrated systems, processes and teams of people, as technology domains with different areas of authority and responsibility come together.
- A common driver is for better reliability and maintenance strategies through more direct access to condition, and the use of on-premises data and SaaS solutions for plants and equipment.
- Integrated operational intelligence will provide better production management, quality control and responses to events in the supply chain, and more efficient production processes. The result will be a more agile and responsive organization.
- Digital twins, digital threads, product as a service and equipment as a service require remote Internet of Things (IoT) and OT data collection, and hence integration of IT and OT domains.
- The data from OT systems will be the fuel for better decision making in areas such as operations (adjusting and responding to production events), energy consumption, environmental sustainability, material consumption, and product quality, safety and reliability.
- A single data ownership and governance can be set up, resulting in clear end-to-end accountability for data owners.

Obstacles

- A lack of common governance structures due to a siloed approach to managing technology in the past has to be overcome.
- Without incentives, this will not change because historically, IT and OT had little contact and have different reporting lines.
- Completely integrated approaches to IT and OT are difficult to achieve because of the deeply rooted tradition in many businesses, where engineers and operations staff have been the “exclusive owners and operators” of OT.
- Many companies have disparate standards of technology in IT and OT, and even different standards for documenting the technologies, making initial planning difficult.
- A common data model spanning IT and OT rarely exists.
- Risk appetite across IT and OT, which is currently diverse, may have to be aligned.
- With the increased number of attacks in OT that have originated in IT, most stakeholders in OT will be cautious about “opening the door to ransomware” when integrating IT and OT.

User Recommendations

- Evaluate the IT/OT integration challenges and benefits in your specific company, and individual business units within the company.
- Achieve consensus across groups and with senior management, and create an alignment activity first to manage governance and standards. Sustainable integration needs well-planned IT/OT alignment.
- Add a more integrated approach to technology progressively. This integration should extend at least to data exchange and platform maintenance, with particular attention paid to communications, cybersecurity, and enterprise architecture. In some companies, that commonality will lead to an organization no longer delineated between IT and OT.
- Balance increased complexity and risk on the one hand, versus the potential benefits from better production management and more efficient production processes.
- Initiate IT/OT alignment discussions to arrive at common standards for platforms, security and architecture.

Sample Vendors

Accenture; Cisco; Eurotech; NTT DATA; PTC; Rockwell Automation

Gartner Recommended Reading

Quick Answer: What Are IT/OT Alignment and IT/OT Integration?

Manufacturing Insight: How to Position Hybrid IT/OT Offerings

How IT Standards Can Be Applied to OT

Survey Analysis: IT/OT Alignment and Integration

When Does a CIO Need to Be Involved in OT?

Distributed Generation

Analysis By: Lloyd Jones

Benefit Rating: Transformational

Market Penetration: More than 50% of target audience

Maturity: Mature mainstream

Definition:

Distributed generation (DG) is an energy supply method that situates generation at or near where it's used. DG may include a mini-hydro, diesel, biofuel, wind, solar or fuel cell, and may be customer-owned. DG is a subset of distributed energy resources (DERs) and includes on-site storage. Wider adoption transforms centrally managed, radial delivery networks to more complex networks requiring advanced hybrid engineering control and economic-incentive-based distribution network operating modes.

Why This Is Important

Utilities may deploy DG as part of a strategy to manage the timing of network upgrades. DG may be used temporarily or permanently to alleviate congestion and assure energy availability. Energy-intensive customers in industrial sectors seeking to secure energy availability have invested in DG. Commercial and groups of residential customers are investing in DG. DG adoption challenges legacy utility business models, raising questions about how the grid will be operated and monetized.

Business Impact

DG deployment has transformational impacts on utilities. DG gives energy customers more choices, and may increase the installed base of environmentally and economically sustainable generation — reducing greenhouse gasses — and may encourage improved energy efficiency. However, DG creates significant challenges to grid operations, even while improving energy resilience. DER in general, and DG in particular, are the main drivers of the energy transition.

Drivers

- According to the Bloomberg New Energy Outlook 2021 report, the cost of solar declined by 85% from 2010 to 2021 — close to low-triple-digit price performance improvement in less than a decade. However, costs are expected to rise in 2022 for the first time in 10 years due to supply chain and commodity price rises.
- The price performance improvement is the main driver behind rapid DG (renewable) adoption by consumers. Exponential technology advances at the grid edge are making it simpler, easier and less expensive for businesses and consumers to begin self-generation. They are also making it easier for consumers to actively manage their interaction with energy markets by controlling when to buy, store or sell energy back to the grid.
- Regulatory mandates, such as FERC 2222 of 2021, mandate equal treatment of smaller-scale DG on the wholesale markets.
- Jurisdictions that actively pursue renewable energy by supporting feed-in tariffs and net metering arrangements are more conducive to DG deployment. For example, California expects that one-fourth of new-generation resources will come on the customer's side of the meter (mostly rooftop solar). The International Energy Agency World Energy Outlook forecasts that incremental solar photovoltaic deployments will account for more than 70 GW of the combined future capacity additions through 2040 — the largest share of total additional capacity by type.
- Engine innovation is accelerating, with smaller, quieter units coming to market, including modular and linear engines that are multifueled.

Obstacles

- Integrating DG into electric distribution networks is a significant challenge requiring electric delivery operations knowledge, and expertise in software and hardware design.
- Integrating DG into utility business operations requires utilities to serve a more-dynamic, decentralized grid and respond to diverse prosumer and business partner ecosystems.
- Most utilities have had little incentive from regulators to pursue DG. Few utilities have an organizational structure ready to coordinate and facilitate a vast array of third parties with interests in DG expansion.
- DG interconnection standards are maturing in particular, following the release of the IEEE 2030.5 standard; however, regulatory oversight is still a patchwork of interconnection rules. Issues with sitting and permit costs still limit adoption.
- National grid codes need to be updated to support interconnection applications.

User Recommendations

- Watch out for transmission and distribution asset deferral benefits, but have backup plans if the DG technology has an unplanned outage.
- Propose incentives to regulators that would help them support cost-effective nonwire alternatives to traditional utility wire infrastructure upgrades while adhering to their service mandate.
- Review the information management and communication effects of DG growth, such as the need to expand communications networks and historian systems. Because a significant percentage of DG will be deployed by customers in the form of renewable generation, it will also enable consumer participation in carbon dioxide abatement.
- Treat DG as a part of overall DER strategy. That will require investment in distributed energy resources management systems or modification of advanced distribution management systems to address the needs of DG orchestration.

Sample Vendors

Ballard Power Systems; Bloom Energy; Capstone Green Energy; Caterpillar Energy Solutions; ITM Power; Plug Power; Rolls-Royce; Tesla; Wärtsilä

Gartner Recommended Reading

The Energy Transition Question: Do We Need the Grid?

Energy CIOs: Get Ready to Operate Under Multiple Energy Provisioning Business Models

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Market Guide for Distributed Energy Resource Management Systems

Phasor Measurement Units

Analysis By: Lloyd Jones

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Phasor measurement units (PMUs) are measurement devices installed at critical points on the grid. PMUs sample voltage and current waveforms, hundreds of times per second using a GPS time stamp to convert measurements into time-stamped magnitude and phase angles known as a synchrophasor. Synchrophasor analysis helps transmission and distribution operators drive power transfer capacity toward the dynamic stability limit, manage congestion and anticipate and avoid voltage collapse and blackouts.

Why This Is Important

PMU adoption has accelerated worldwide as transmission and distribution operators confirm its real-time measurement benefits, namely improving grid observability and reducing state estimate workloads. PMUs help operators manage frequency, allowing more renewable capacity onto the grid. With wide-scale adoption of PMUs across transmission achieved, we are seeing accelerated adoption at distribution as PMUs become embedded in protection devices.

Business Impact

PMUs are deployed by system operators (SO) to improve grid security and reliability. Improved energy transfer and better integration of renewable resources are the primary benefits driving PMU and wide-area measurement systems (WAMS). PMUs enhance situational awareness of congestion and grid oscillations. WAMS have embedded AI and event stream handling capabilities use PMUs to rapidly identify root causes from several phasor measures per second, to suggest possible actions to operators and traders.

Drivers

- The energy transition accelerates with low inertia, intermittent renewable resources added to the grid, frequency control will become a lot more complex. PMUs are appropriate for transmission and distribution grid owners and operators that want to pursue improved grid security and reliability.
- Utilities with high percentages of renewable generation will find PMUs useful for managing dynamic stability.
- Utilities with high prosumer distributed energy (DER) penetration should explore the use of micro-PMUs (uPMUs) to improve grid controllability and observability, and to manage DER outputs on networks with limited inertia, which experience frequency and voltage excursions.
- The use of PMUs is an essential part of wide-area measurement systems (WAMS), along with phasor data concentrators (PDCs), backhaul communication networks, centralized data collection systems and associated analytics are being used by operators in both control and post disturbance analysis applications.
- uPMUs are the application of PMU technology in the distribution grid where the uPMUs operate in the microsecond range. uPMUs are used to manage voltage and frequency transients triggered by the rising penetration of prosumer owned DERs. uPMUs are gaining acceptance at the distribution level, with both measurement and protection applications. Use of uPMUs in distribution networks can allow deeper levels of penetration of renewable energy as uPMUs implement closed-loop control for zero-inertia power systems.
- A high percentage of digital relays deployed in recent years already have phasor measurement capability embedded, so utilities should be alert to potential applications in operations automation.
- Phasor and inertia data is valuable for energy traders in the flexibility and balancing markets.
- Phasor measurements are useful for measuring and validating resource responses in the frequency control ancillary services market, and can provide useful data points for settlements.

Obstacles

- PMUs generate copious temporal data, requiring big data tools and environments for data persistence and advanced algorithms to process streaming datasets using machine language (ML). These capabilities are absent in legacy energy management systems (EMSs).

- WAMS expansion is limited by low-latency communication network availability. Utilities are gaining confidence to build out networks, but costs still impede adoption, followed by cybersecurity concerns.

- IEC TR 61850-90-5 is a critical technical standard to wider PMU adoption, addressing the delivery of high-speed data collected by synchronized phasor measurement devices over wide-area communication networks. It describes data latency requirements for wide-area monitoring, protection and control applications, and assures cybersecurity protection for this data.

- IEEE C37.118.1 deals with phasor estimation, while c37.118-2 sets out the messaging format, but with no restrictions on the choice of communication medium or transport protocol.

User Recommendations

- Expand PMU measurement networks to drive the energy transition. SO must work with regional and national operators to coordinate PMU rollouts and openly share data and insights.

- Align IT and OT requirements and standards to support the rollout of high-speed wide-area communication networks. Typically, PMU and WAMS deployment costs are shared across operations coordinators such as independent system operators, regional transmission organizations, power pools or government-coordinating entities.

- Interrogate suppliers roadmaps to ensure your system vendors (including energy management, SCADA], AMDS, DERMS) are incorporating phasor analysis into their roadmap, and will deliver explainable AI and ML capabilities to make sense of this valuable data stream.

- Explore deployment of uPMUs (if you have rapid prosumer DER growth rates) to improve the observability and controllability, and to manage DER outputs on networks with limited inertia, which experience frequency and voltage excursions.

Sample Vendors

General Electric; Hitachi; Macrodyne Technologies; Yokogawa (PXiSE); Quanta Services; Schweitzer Engineering Laboratories; Siemens

Gartner Recommended Reading

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Market Guide for Distributed Energy Resource Management Systems

DRMS

Analysis By: Ethan Cohen

Benefit Rating: Moderate

Market Penetration: 20% to 50% of target audience

Maturity: Obsolete

Definition:

Demand-response management systems are applications for managing utility electricity demand-response programs. Capabilities include enrolling customers and their load resources, and planning, executing, measuring and generating settlement payment amounts for DR events. DRMS can address some aspects of distributed energy resource orchestration and integration, particularly at lower DER penetration levels, and can individually meet requirements of energy retailers with commodity-based offerings.

Why This Is Important

Demand response (DR) is an important resource that can be used to maintain demand and supply balance for electricity grid operations and wholesale markets. As demand goes up, less efficient and often higher-carbon-emitting electricity generators are utilized. Demand-response management systems (DRMS) are obsolete and have been supplanted by distributed energy resources management systems (DERMS).

Business Impact

DRMS optimize the peak shaving impact of investments in electricity generation and delivery for integrated utilities. In unbundled markets, these systems help distribution utilities optimize local congestion challenges, and flexibility use cases. Utility operations that can benefit from DRMS include retail, supply and resource adequacy planning. Some advanced distribution management systems (ADMS) can integrate with DRMS to make DR an effective operational measure for targeted distribution network optimization.

Drivers

The desire for keeping utility network reliability high and total costs low drives DR and DRMS. DRMS provide utilities with the opportunity to:

- Meet requirements to develop and manage utility DR programs.
- Get the most out of large-scale advanced metering infrastructure (AMI) deployments and increase economic DR.
- Address regulatory direction for the adoption of DR and increasingly automated demand response (ADR).
- Combine DR and DRMS with consumer energy storage and energy management services.
- Support vehicle-to-grid integration.
- Use DR and demand management to defer some grid upgrades by reducing load at a substation or circuit level.

Obstacles

- DRMS is on the Slope of Enlightenment and has now become obsolete because its value as a system-based capability is diminishing.
- DRMS is becoming subsumed by DERMS before plateau.
- New technologies such as advanced distribution management systems (ADMS) and DERMS are maturing to address a broader range of distribution network management needs.

User Recommendations

- Evaluate whether DRMS are still needed to support company strategy, to fulfill a specific, clear need, or if a focus on ADMS or DERMS is more appropriate to the ambition, business model and operating model of the utility.
- Address the long-term growth in energy technology consumerization, including growth in distributed power generation, electric vehicles and home energy management. This will make more advanced DR capabilities important in some regions.
- Evaluate and consider the OpenADR 2.0 standard to connect directly with load resources for faster and more reliable demand reductions.

Sample Vendors

ABB; AutoGrid; Enel X; GE; Itron; Resource Innovations (Nexant); Schneider Electric; Siemens

Entering the Plateau

Substation IEDs

Analysis By: Lloyd Jones

Benefit Rating: High

Market Penetration: More than 50% of target audience

Maturity: Mature mainstream

Definition:

Substation intelligent electronic devices (IEDs) are used to automate parts of the power system. IEDs monitor local processes, may execute local control and communicate with SCADA systems as well as emerging cloud Internet of Things (IoT) data collection platforms. IEDs can automate distribution circuits and substations. Examples of IEDs include digital protection relays, substation breaker controls, distribution line reclosers, capacitor controls and general-purpose IoT edge gateways.

Why This Is Important

Utilities have steadily adopted digital systems to automate substations, but progress has been slow because of the large base of legacy assets and protocols. The overall percentage of fully automated substations is still below 30% but is set to accelerate to accommodate electric vehicles and distributed energy resources at the MV/LV border. Utilities use the term IED to describe a range of automation devices that align to IEC 61850 to provide control, monitoring and protection of key assets.

Business Impact

IED technology is applied by electric utility engineering and operations organizations that manage substations across the generation, transmission and distribution sectors. As the energy transition accelerates, system parameters such as inertia will need to be actively managed. IED devices that leverage phasor measurements will be deployed as units on the transmission and distribution systems or as a part of substation automation systems.

Drivers

- The energy transition is introducing new loads, such as electric vehicles and battery charging as well as distributed generation at the edge of the grid. This makes feeder and substation load profiles more volatile, subject to rapid swings in energy demand and rapidly shifting energy flows. Utilities are investing in sensors to measure and IEDs collect this proliferation of data.
- Utilities will move toward intelligent operations where local events are sensed and managed locally. IEDs will play a more prominent role in substation control, detecting local events and measures, and making local control decisions coordinated from substations across feeders but within a delegated operational decision envelope as permissioned by SCADA.
- Information from IEDs could still be routed to SCADA systems (data such as operational data, critical for real-time decision making). Data is also routed via data ingestion platforms for staging to engineering applications (as nonoperational data, valuable to planning, engineering and maintenance roles). IoT sensors that support IEC 61850 are an obvious overlap.
- IEDs deployed within substations use high-bandwidth Ethernet connections over fiber optics, typically with embedded Microsoft Windows operating systems. IP network devices are hardened for electromagnetic immunity and multiple protocol support.
- As the substation automation matures, control and data acquisition buses within substations will become increasingly common.
- Vendors have focused recently on improved remote-device management, better diagnostics, stronger cybersecurity and improved redundancy.
- IEDs create critical site gateways for operational device management.

Obstacles

- Note the emerging overlap of IEDs with the IoT market space, which creates a potential technology pivot to a more generic technology space, with the possibility of lower long-term costs.
- IEDs were an early and vertical version of an IoT device, and in the near-term general-purpose IoT will impact and complement IED, before IoT devices replace IEDs in the medium to longer term.

User Recommendations

- Engineering and operations teams: Leverage IEDs to support the analytics needed to optimize transmission and distribution grids. IEDs can provide a steady flow of equipment operation information, supporting operational decisions, condition-based maintenance and asset performance management applications.
- Utility CIOs: Address the need to support the life cycle of IEDs. This should include configuration management, backup and recovery, patch management, security measures, and upgrade planning as well as the more common location and asset management.
- Standards engineers: Track working groups within the Institute of Electrical and Electronics Engineers (IEEE), such as standard P1815 (formerly Distributed Network Protocol [DNP3]) has been mapped to the International Electrotechnical Commission (IEC) 61850 object models to improve device interoperability.
- Consider the potential for disruption of IED by IIoT technologies with cloud to edge capabilities.

Sample Vendors

Eaton; Hitachi Energy; Indra (Minsait ACS); S&C Electric; Schneider Electric; Siemens

Gartner Recommended Reading

How Utility CIOs Can Deliver Business Value With Digital Twins

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Adv. Distribution Protection Restoration Devices

Analysis By: Lloyd Jones

Benefit Rating: Moderate

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

ADPR devices leverage real-time information on nearby operating conditions to protect distribution assets. Advanced devices use embedded microprocessors to adjust relay parameters to reflect dynamic conditions on the electric distribution network, such as reversed energy flow, switched network segments or rapidly changing weather conditions. Advanced devices adapt to real-time network conditions and modify operating parameters and protection algorithms.

Why This Is Important

Prosumerization of the grid edge with distributed energy resources including solar, storage and microgrids requires changes to grid operations and protection to ensure the consistent delivery of adequate power quality to all customers. As traditional radial-fed distribution circuits (feeders) are reconfigured for self-healing operations, protection systems must become capable of managing multiple fault scenarios and incremental switching steps in an automated way.

Business Impact

ADPR devices are deployed by two types of utility organizations:

- Customer service organizations need ADPR devices to support distributed energy resources and improve customer experience.
- Electric distribution utilities to protect the network. Business functions impacted by ADPR specification, design and placement include asset management, planning, engineering, operations and communications engineers to ensure resilience.

Drivers

- The adoption of distributed generation, microgrids, energy storage systems, solar photovoltaic systems and electric vehicles (either by utilities or by customers) will require more sophisticated protection systems. Customer adoption of DER technologies at the grid edge are forcing bidirectional power flow by injecting energy at the edge of the grid. The volatility of the feeder load profile is increasing. Intermittency causes rapid swings in powerflow disturb the network's technical performance and stress electromechanical equipment.

- Intermittency introduces harmonic and dynamic behaviors that are forcing utilities to reconsider how they achieve operational integrity of the grid. Networks are experiencing operating modes that were not known when the networks were designed and built.

- Smart (processor-equipped) distribution protection and restoration devices can sense and communicate over peer-to-peer wireless networks or fiber-optic networks. Note that Internet of Things (IoT) sensors can be added in parallel to traditional OT sensors to supply data feeds to smart protection. Smart protection and restoration devices operate autonomously or in concert with substation automation systems to reliably protect distribution grid assets. These devices include communications gear, control units, circuit switching devices and associated software for configuration, simulation, testing and in-field event playback. Circuit monitoring and protection devices include IP network addressability, self-powering capability and chip-based digital signal processing to reduce latency. These capabilities have become embedded within traditional equipment form factors for ease of deployment by line crews.

- Distribution engineering departments will use refurbishment programs to update legacy passive protection schemes to active ADPR devices that address the increased operational complexity.

Obstacles

- Legacy protection equipment in substations and on feeders need to be refurbished to support intelligent operations.
- ADPR devices have both simple protection functions and composite functions based on peering and contextual topology insight, for adaptive control. These capabilities are maturing and could be augmented by substation monitoring or consumed into Intelligent Operations approaches.
- New frameworks and architectures will develop at the edge of the grid as IoT platform technologies will provide alternative channels to access customer owned energy devices and resources. IT professionals should check the capabilities of IoT vendors as well as traditional OT vendors when making architectural decisions about future field device deployment.

User Recommendations

- Track industry working groups and consider participation in groups such as International Electrotechnical Commission (IEC) 61850 for substation integration and Institute of Electrical and Electronics Engineers (IEEE) 1547 for interconnection standards.
- Integrate tightly the advanced distribution protection with advanced distribution management systems (ADMSs) via FLISR functionality or stand-alone outage management systems (OMSs) as part of an integrated grid strategy.
- Deploy extended ADPR devices on feeders to detect abnormal operating conditions and new states to detect an event. Respond to an event by using preconfigured switching response for the detected state/event.
- Track the work of the Open Field Message Bus (OpenFMB), sponsored by the Smart Grid Interoperability Panel's (SGIP's) energy IoT initiative. This is a framework for the interaction of distributed intelligent nodes of field devices at the grid edge, based on a scalable peer-to-peer, publish-subscribe architecture.

Sample Vendors

Eaton; General Electric; Hitachi Energy; Schweitzer Engineering Laboratories (SEL); Siemens; S&C Electric Company

Gartner Recommended Reading

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Market Guide for Distributed Energy Resource Management Systems

Market Guide for Advanced Distribution Management Systems

CIM Integration Standards

Analysis By: Lloyd Jones

Benefit Rating: Moderate

Market Penetration: More than 50% of target audience

Maturity: Mature mainstream

Definition:

The Common Information Model (CIM) is an International Electrotechnical Commission (IEC) standard (primarily contained in standards 61968 for distribution, 61970 for transmission and 62325 for markets). These standards express utility domain objects in the Unified Modeling Language (UML). Utility architects use information modeling tools with the CIM as a canonical data model to standardize conventions and accelerate delivery. These methods are often referred to as “model-driven integration.”

Why This Is Important

Utility application portfolios are constantly evolving as new business needs arise and legacy applications are retired. Successful integration of new applications into existing environments or the extension of business processes to new energy system participants, or outsourcing arrangements requires close attention to business vocabulary. Domain-specific applications invariably describe the same utility “object” in different ways. Vendors have embraced CIM across the business landscape.

Business Impact

CIM reduces the integration effort for utility IT projects. CIM profiles are a subset of the CIM with classes and attributes for a business context to accelerate projects and drive automated message payload design directly from design tools. Cross-functional processes (operations, outage and asset management) and collaborative business transactions (data and model exchange, energy trading, distributed energy resource (DER), customer service) will benefit from CIM-based integration.

Drivers

- CIM is a formal IEC standard IEC 61968 covering electrical distribution systems. The standard sets out information models for a wide range of objects with the aim of improving interoperability through standardization, accelerating software development and improving compliance testing.
- Formal governance of CIM is via the IEC Technical committee 57, working group 14. Other CIM related activities take place within the CIM Users Group and other corresponding standards' coordination efforts such as Electric Power Research Institute or the Smart Electric Power Alliance.
- CIM has been adopted as a core of the EU-SysFlex 2021 that sets out data exchange standards and protocols.
- Utility and vendor adoption of CIM 17 is steadily increasing across the utility value chain, including use cases across operations, advanced metering infrastructure (AMI), work management, asset management, advanced distribution management (ADMS) and more recently distributed energy resources (DER). This includes customer enrollment and operations with distributed energy management systems (DERMS).
- Vendor participation in global interoperability testing continues to increase. CIM compliance is being evidenced across internal product architectures as vendors move to a modular plug-and-play ecosystem. This trend supports the rise of grid architectures where control of the network will be exercised at multiple levels by multiple parties.
- Adoption of CIM in North America has been on a slow but steady rise for years; however, utilities in other nations and continents have shown faster adoption rates. Grid authorities in China, Russia and Europe are mandating the use of CIM, and interest is growing in Australia and South America.
- CIM is being implemented by multiutility organizations to support gas and water with CIM extensions.

Obstacles

- Almost all utilities undertaking model-driven integration for the first time require the assistance of specialized integration consultants to equip their staff with appropriate tools and understanding.
- European markets are currently driving most transmission model exchange extensions and methods, to support flexibility markets by leveraging CIM. This is not yet consistent across all global markets.
- Note all CIM changes are ratified globally before adoption, which does create some lag between emerging use cases and implementation in the CIM.
- Larger utilities tend to extend CIM within their own semantic models, designing their own web services and message payloads to serve emerging use cases. This investment can accelerate benefits in AI work as it imposes data standardization across application objects. However, custom extensions do slowly find their way back into the version-controlled formal model often with some subtle changes. This imposes a maintenance effort on legacy extensions.

User Recommendations

- Adopt CIM to rationalize integration effort across enterprise applications and to reduce costs of integration. Be prepared for a multiyear, disciplined IT focus to implement an enterprise semantic model and associated tools. This can be a significant challenge for smaller utilities.
- Analyze recent additions to the CIM model, including advanced dynamics modeling for renewable asset types and more sophisticated unbalanced network modeling. Recent and future developments include analytics support, weather information, energy storage and asset health.
- Explore the use of MultiSpeak as it can be a more direct solution for smaller utilities in the North American market focused on distribution only and leveraging web services. (National Institute of Standards and Technology [NIST] Smart Grid Conceptual Model has selected MultiSpeak funded by National Rural Electric Cooperative Association [NRECA] targeting distribution only use cases.)

Gartner Recommended Reading

Market Guide for Distributed Energy Resource Management Systems

Market Guide for Utility Customer Information Systems

Meter Data Management Systems

Analysis By: Lloyd Jones

Benefit Rating: High

Market Penetration: More than 50% of target audience

Maturity: Mature mainstream

Definition:

Meter data management systems (MDMS) are the IT components of the advanced metering infrastructure (AMI) responsible for cleansing, calculating and providing data persistence for the commodity consumption data. MDMS is also responsible for disseminating metered consumption data for internal/external use. MDMS can contain a subset of meter asset information, premises, topology or customer information. However, the key data being tracked is metered commodity consumption and meter-related events.

Why This Is Important

Utilities have used meter data primarily as an input to the monthly billing and settlement process. The energy transition needs better edge visibility — driving a requirement for higher-resolution data. A modern MDMS can disseminate consumption information to internal and external users or to applications with more granular data. MDMS-hosted meter consumption data supports billing, load profiling, forecasting, asset loading, network operation and a variety of analytic use cases.

Business Impact

All subsectors of the utility industry are interested in MDMS because companies in each segment provide a metered commodity at the customer's premises and manage the metered consumption data. However, MDMS requirements are shaped by needs in the electric power utility segment. Affected areas include energy commodity management, load forecasting, distribution asset utilization, network operation, revenue management and customer service.

Drivers

- A shift is still underway from a meter data refresh rate from once a month to daily reads of 15-minute interval consumption data. Utilities are now getting insight into energy consumption closer to the “real time” of many business processes.
- In the past decade, the proliferation of smart metering created vertical solutions for remote meter data acquisition as well as MDMS as a platform for operational algorithms.
- Digital transformation of utilities is driving the need for multipurpose metering data repositories that can meet requirements outside of metering data’s traditional use in a “meter to cash” (revenue management) process.
- There is an emerging set of new requirements to support the energy transition that is impacting metering technology as well as processes and organizational structures.
- These new requirements will elevate metering from simply a component of the revenue-processing life cycle to an enterprise function supporting multiple uses of consumption data in other domains. These include asset management (optimal network configuration and loss minimization), commodity management (load profiling and forecasting) and CRM (customer segmentation based on static load profiles and response to variable pricing signals).
- MDMS is approaching the Plateau of Productivity. This is a phase when successful implementations are common and are followed by case studies that can attest to benefits realization. Additionally, more mature service offerings for product delivery are being developed (in many cases by external partners), which, consequently, reduces the risk of implementation failure.

Obstacles

- The MDMS market has matured and is moving from a “greenfield” market to a replacement market, with an increased number of utilities considering the replacement of legacy client/server on-premises versions.
- Buyers have a better understanding of their needs and have realistic benefit expectations, improving alignment and value realization.
- The legacy smart metering and MDMS markets are an example of a vertical Internet of Things (IoT) market that is being disrupted by technological developments in the horizontal IoT general-purpose market.
- The utility industry has not yet fully embraced the general-purpose IoT, and instead favors niche vertical solutions with deep domain expertise.
- Architecturally MDMS is aligned with current IoT reference architectures. Consequently, MDMS vendors are expanding their offerings to become a generic IoT platform, while general-purpose IoT platform vendors are encroaching on the utility MDMS market.

User Recommendations

- Focus on key capabilities such as the validation estimation and error correction (VEE) library. Scalability is driven by higher sampling rates and demand for consumption analytics, along with the ability to ingest data from field devices other than revenue meters.
- Move beyond meter-to-cash by using metering data to support business improvement initiatives in the commodity management area and to optimize distribution asset utilization.
- Exercise caution in MDMS requirements expansion, especially where real-time data processing is required as some vendors have failed to move to serverless architectures.
- Examine other big data solutions, such as in-memory data analytics, to avoid overloading MDMS with processing tasks that could impede core transactional requirements such as meter-to-cash obligations.
- Expect meters to evolve to become edge compute devices hosting measurement, data gateways and applications. This will drive new expectations for a new generation of MDMS.

Sample Vendors

Honeywell International; Itron; Landis+Gyr; Oracle; SAP; Siemens

Gartner Recommended Reading

Market Guide for Meter Data Management Systems

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Energy Storage for Grid Operation

Analysis By: Nicole Foust

Benefit Rating: Transformational

Market Penetration: More than 50% of target audience

Maturity: Mature mainstream

Definition:

Energy storage for grid operation improves transmission performance by compensating for anomalies and disturbances, and relieves transmission congestion or adjusts for low-voltage conditions during peak periods. It also defers upgrades and incremental investment in transmission and distribution, and reduces peak generation or transmission capacity with deferrable loads. This form of energy storage for grid operations is distinct from energy storage for balancing renewable energy intermittency.

Why This Is Important

Energy storage for grid operations continues to gain momentum globally as costs decrease, regulatory acceptance and requirements grow, use-case success examples increase, and new providers enter the market.

Business Impact

Transmission planning engineers and substation engineers should evaluate energy storage options, communications engineers should evaluate how to service the latency and reliability needs for communication, and protection engineers should define requirements for protection and control. Enterprise architects must help address how transmission and distribution (T&D) applications will interact with storage control systems, and provide guidance on message payloads and cybersecurity requirements.

Drivers

- The electric power infrastructure is transforming from a system of power interconnections to a very complex, diverse, interconnected, interdependent and adaptive system. Increasingly, utilities are developing capabilities to support automation opportunities.
- Requirements for grid-system storage range from hundreds of kWs to 300 MW/1,200 MWh. As a result, grid-operations storage is central in this transformation, impacting both transmission and distribution systems design.
- The deployment of intermittent generation has implications in energy systems' resilience. In addition, although price and energy sources are market forces, energy availability is the issue for customers and providers. A prominent use case is driven by the rising and falling of the overall load and flexibility requirements in the grid throughout the day. The variability creates issues for some segments of the market, resulting in availability and price volatility driving the need to be managed through energy storage.
- There is a need to sustain and better manage the increasing growth of renewable energy and capabilities for balancing supply and demand dynamics.
- Many regulatory agencies require utilities to develop distribution resource plans that parallel and expand past integrated resource planning efforts, and that explore the benefits and costs of grid-operations storage relative to both transmission and distribution.
- Some vendors, such as Tesla, have made progress in deployment of, and realized benefits from, battery farms with the South Australian government and regulators mandating investment.
- A growing number of regulatory jurisdictions require utility investment in energy storage for grid support because the industry still seeks ways to adequately motivate and reward investors and developers.
- As this sector matures, energy storage projects will gain the same bankability as grid-scale solar resources and contribute to effective integration of renewables.

Obstacles

- Battery technology is rapidly evolving. Technologies include flow cells such as vanadium-based redox batteries (VRBs) and zinc bromide batteries, sodium-sulfur batteries, lithium-ion batteries, advanced lead-acid batteries, compressed air and liquid systems, and high-power flywheels.
- Requirements for grid-connected storage are in flux due to market and regulatory pivots.
- Grid-operations energy storage must have a subsecond response time, be highly reliable and capable of operating when batteries are not completely charged, and support rapid discharge.
- Storage for relieving congestion and for deferring upgrades needs to be capable of long discharge cycles.
- Grid-scale storage devices also represent a new asset category with different operational and asset maintenance parameters to manage.
- Grid storage for transmission and distribution capacity deferral must still compete with traditional infrastructure build-out and other strategies, such as demand response and conservation voltage reduction. Other challenges include fire safety, reliability and long-term performance degradation.

User Recommendations

- Evaluate potential benefits and payback periods by using engineering and financial models to gauge performance requirements of specific applications when deploying storage for grid support.
- Focus on the integration requirements between storage systems and existing power infrastructure. Utility IT and operational technology (OT) leaders should pursue approaches that leverage industry standards for open interoperability to support testing of different storage technologies. (One example is the IEEE P2032.2 Guide for the Interoperability of Energy Storage Systems Integrated With the Electric Power Infrastructure.)
- Bolster system operators' visibility into storage device operations from within energy management and distribution management systems to evaluate the availability of storage resources for operational challenges.
- Monitor environmental and health and safety considerations, as some types of battery storage are susceptible to overheating and combustion.

Sample Vendors

ABB; DNV; Habitat Energy; S&C Electric; Saft; Siemens Energy; Tesla

Gartner Recommended Reading

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

2023 CIO and Technology Executive Agenda: A Utility Industry Perspective

Market Guide for Advanced Distribution Management Systems

Market Guide for Distributed Energy Resource Management Systems

How to Deal With Digital Dragons When They Emerge in the Utility Sector

Appendixes

See the previous Hype Cycle: Hype Cycle for Digital Grid Transformation Technologies, 2022

Hype Cycle Phases, Benefit Ratings and Maturity Levels

Table 2: Hype Cycle Phases

(Enlarged table in Appendix)

Phase ↓	Definition ↓
Innovation Trigger	A breakthrough, public demonstration, product launch or other event generates significant media and industry interest.
Peak of Inflated Expectations	During this phase of overenthusiasm and unrealistic projections, a flurry of well-publicized activity by technology leaders results in some successes, but more failures, as the innovation is pushed to its limits. The only enterprises making money are conference organizers and content publishers.
Trough of Disillusionment	Because the innovation does not live up to its overinflated expectations, it rapidly becomes unfashionable. Media interest wanes, except for a few cautionary tales.
Slope of Enlightenment	Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the innovation's applicability, risks and benefits. Commercial off-the-shelf methodologies and tools ease the development process.
Plateau of Productivity	The real-world benefits of the innovation are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generations. Growing numbers of organizations feel comfortable with the reduced level of risk; the rapid growth phase of adoption begins. Approximately 20% of the technology's target audience has adopted or is adopting the technology as it enters this phase.
Years to Mainstream Adoption	The time required for the innovation to reach the Plateau of Productivity.

Source: Gartner (August 2023)

Table 3: Benefit Ratings

Benefit Rating	*Definition*
Transformational	Enables new ways of doing business across industries that will result in major shifts in industry dynamics
High	Enables new ways of performing horizontal or vertical processes that will result in significantly increased revenue or cost savings for an enterprise
Moderate	Provides incremental improvements to established processes that will result in increased revenue or cost savings for an enterprise
Low	Slightly improves processes (for example, improved user experience) that will be difficult to translate into increased revenue or cost savings

Source: Gartner (August 2023)

Table 4: Maturity Levels

(Enlarged table in Appendix)

Maturity Levels ↓	*Status* ↓	*Products/Vendors* ↓
Embryonic	In labs	None
Emerging	Commercialization by vendors Pilots and deployments by industry leaders	First generation High price Much customization
Adolescent	Maturing technology capabilities and process understanding Uptake beyond early adopters	Second generation Less customization
Early mainstream	Proven technology Vendors, technology and adoption rapidly evolving	Third generation More out-of-box methodologies
Mature mainstream	Robust technology Not much evolution in vendors or technology	Several dominant vendors
Legacy	Not appropriate for new developments Cost of migration constrains replacement	Maintenance revenue focus
Obsolete	Rarely used	Used/resale market only

Source: Gartner (August 2023)

Document Revision History

Hype Cycle for Digital Grid Transformation Technologies, 2022 - 14 July 2022

Hype Cycle for Digital Grid Transformation Technologies, 2021 - 29 July 2021

Hype Cycle for Digital Grid Transformation Technologies, 2020 - 12 August 2020

Hype Cycle for Digital Grid Transformation Technologies, 2019 - 30 July 2019

Hype Cycle for Digital Grid Transformation Technologies, 2018 - 2 August 2018

Hype Cycle for Smart Grid Technologies, 2017 - 31 July 2017

Hype Cycle for Smart Grid Technologies, 2016 - 18 July 2016

Hype Cycle for Smart Grid Technologies, 2015 - 13 July 2015

Hype Cycle for Smart Grid Technologies, 2014 - 24 July 2014

Hype Cycle for Smart Grid Technologies, 2013 - 30 July 2013

Hype Cycle for Smart Grid Technologies, 2012 - 27 July 2012

Hype Cycle for Smart Grid Technologies, 2011 - 25 July 2011

Hype Cycle for Smart Grid Technologies, 2010 - 23 July 2010

Hype Cycle for Smart Grid Technologies, 2009 - 16 July 2009

Hype Cycle for Intelligent Grid Technologies, 2008 - 26 June 2008

Recommended by the Authors

Some documents may not be available as part of your current Gartner subscription.

Understanding Gartner's Hype Cycles

Tool: Create Your Own Hype Cycle With Gartner's Hype Cycle Builder

Research Roundup: Top 10 Trends Shaping the Utility Sector in 2023

Predicts 2023: Adapting to the Energy Transition

Market Guide for Distributed Energy Resource Management Systems

Market Guide for Advanced Distribution Management Systems

Energy CIOs: Get Ready to Operate Under Multiple Energy Provisioning Business Models

Table 1: Priority Matrix for Digital Grid Transformation Technologies, 2023

Benefit	*Years to Mainstream Adoption*			
↓	***Less Than 2 Years*** ↓	***2 - 5 Years*** ↓	***5 - 10 Years*** ↓	***More Than 10 Years*** ↓
Transformational	Distributed Generation Energy Storage for Grid Operation	Decision Intelligence Digital Twin Edge Computing IoT in Utilities	Generative Design AI Grid Twin Intelligent Industrial Assets Smart and Sustainable Building	Transactive Energy
High	Edge AI Meter Data Management Systems Substation IEDs	ADMS Big Data in Utilities CPS Security Customer Energy Storage IT/OT Integration Phasor Measurement Units	Distributed Energy Resource Management System Energy-Sharing Platforms Microgrids Software-Defined Assets Vehicle-to-Grid Virtual Power Plants	
Moderate	CIM Integration Standards	Adv. Distribution Protection Restoration Devices API Marketplaces Consumer Smart Appliances Customer Gateways EV Charging Infrastructure Meter Data Analytics	Home Energy Management Operational Device Management	Advanced Wide-Area Transmission Operations Wireless EV Charging

Benefit	*Years to Mainstream Adoption*			
↓	**Less Than 2 Years** ↓	**2 - 5 Years** ↓	**5 - 10 Years** ↓	**More Than 10 Years** ↓
Low				

Source: Gartner (August 2023)

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Phase	*Definition*

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