Flattening the Grid

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Executive Overview

In the future, running a successful electric utility will require applications that are now being developed. They will run systems that are much more complex, with power flowing in multiple directions. The operation of these future grids will be data driven and will increasingly be controlled by edge devices. To successfully manage a utility in the new, flatter market, a company will have to rely on significantly more, integrated technologies.

When it comes to power generation, delivery, and even consumption, one thing is obvious. Things are changing. The staid utility industry, with clearly divided functions, is getting a structural makeover. Its impervious hierarchy is getting flattened.

Generation is no longer limited to large, centralized plants, owned and operated by utilities. Power flow on the distribution network is becoming much more dynamic. Devices at the 'edge' of the distribution system are making more decisions locally. In short, the grid is becoming more decentralized. This process will accelerate, as time passes.

Change is being driven by a much more diverse landscape of generation sources, both large and small, improved energy storage technologies, new things being electrified (like electric vehicles), and the development of technology that allows for more dynamic load control.

Decentralization is also being driven by the increased adoption of 'green' or sustainable business plans and by the rise in 'prosumer' (a customer that also produces and sells power).

To take advantage of these opportunities, utilities will have to leverage as much value from data as possible. The increase in the amount of data available will be staggering and the data will have to be turned into actionable information in the field, not simply at a centralized location. This will reduce latency and the need for ever increasing bandwidth.

To do this, utilities will have to adopt new technologies and systems that will be able to collect and analyze data from hundreds of thousands of edge devices and then make real-time corrections to meet demand.

Introduction

Currently, a number of systemic forces are working to change the energy industry forever. The most profound result will be the 'flattening of the grid,' which means the traditional hierarchies within utilities will be (and already are being) disrupted.

Three of the most significant are listed below:

<u>The first is the electrification of the transportation infrastructure.</u> This will impact the utility grid in a number of ways, like greater DC (charging) loads, and possibly a new demand peak in the evenings, when people get home from work.

<u>The second, which is already in progress, is the digitalization of commerce.</u> This is driving the need for bigger and bigger data centers.

<u>And, the third is sustainability.</u> There is a worldwide shift toward sustainable resources (green energy) and the grid will have to accommodate dispersed, small, and intermittent generation.

This paper discusses strategies utilities can adopt, so their companies will thrive in the new market.

Flattening the Grid

Successful companies will be built on these four pillars.

The first pillar is automation and control modernization.

Utilities must move away from the current use of fixed-function devices.

Companies relying on these types of devices will not be able to make the type of dynamic adjustments needed to handle fluctuations in demand and distributed generation. Additionally, these fixed function devices, their settings, and interfaces are very manufacturer-specific. Standardized hardware and communication protocols are needed, so utilities can innovate without being bound by a handful of manufacturers.

The second pillar is cyber security modernization.

There will be a large-scale penetration of renewables and other smart devices at the edge of the grid. These devices will work autonomously, so the continuing challenge will be security.

The software running on edge devices must operate safely, blocking the introduction of computer viruses and hacker access. Consider the challenge of monitoring software running on hundreds of thousands of devices. The software must be maintained, updated, and secured and this will require very powerful edge management platforms and solutions.

The third pillar is application deployment process modernization.

Currently when a utility buys a new device, technicians spend a significant amount of time testing, installing, and commissioning the new applications. It would be better if the new device's software could be tested and updated remotely.

Further, the updates should run automatically. New software must also run self-diagnostic functions and 'call-out' for assistance, if problems are detected.

The fourth pillar is increasing grid insights with analytics.

The industry needs to aggregate and normalize all the data at the edge and then unleash the power of analytics and machine learning.

To respond to much more dynamic loads and the challenges of distributed generation, companies need to get more intelligence out of the data. This will be necessary if utilities want to forecast events; take actions to improve and maintain high standards of power quality; avoid outages; distribute energy more efficiently; maximize the value of renewables; and keep costs low.

What are the four pillars of change?

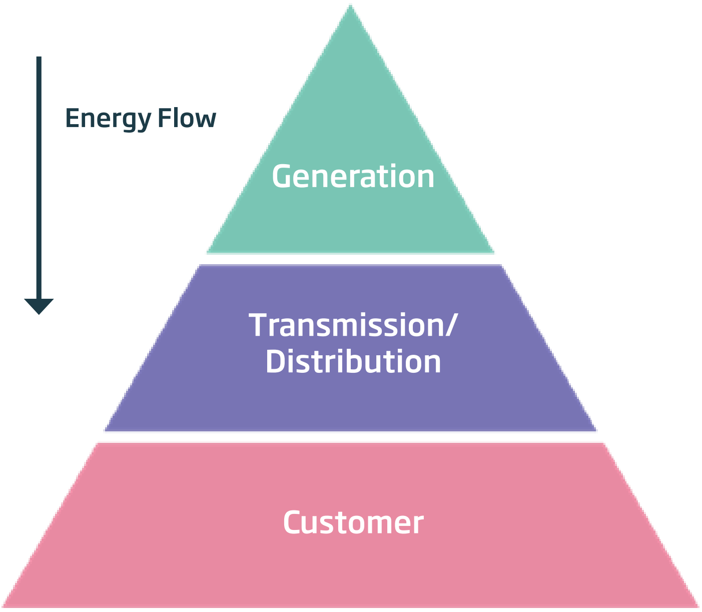
- Automation and Control
- Cyber Security
- Application Deployment
- Analytics

Flattening the Grid

The Old Paradigm Changes

By making these changes, a utility will be able to move away from the old market paradigm: power is generated at big power plants, sent through transmission and then distribution systems to its finally destination -- the customers. This simple industry model is on the way out.

Traditional Industry Structure



With the addition of substantial amounts of distributed generation, power can now flow in multiple directions and direction can change as conditions dictate. One of the forces driving this change is 'intermittency,' including intermittent solar and wind power and charging and discharging of large battery loads, including Electric Vehicles (EV).

Another big change is the evolution of customer to Prosumer. Traditional customers bought power from utilities. In the future, more customers will generate their own power and sell it back to the company.

What are some of the fading paradigms?

- Bulk Power Generation
- One-Way power flow
- Customers only buy power

Flattening the Grid

Driving Change

These changes are being driven, in large part, to the following:

Diversity of power sources

Large fossil-fuel generation is being converted to/ replaced by a plethora of power sources, including inverter-based renewable generation, and smaller Distributed Energy Resources (DERs).

The rise of the Prosumer

Traditional customers are being replaced by non-traditional 'prosumers,' a portmanteau for 'producer' and 'consumer'. Prosumers use the energy they produce and store or they sell that energy to the network.

Prosumers show a much different demand profile than typical customers, during the day.

Improved energy storage technology

Advancements in energy storage technology makes it ever more affordable to increase the size of storage. Newer battery systems also offer more flexibility and can help offset the dynamic changes of intermittent generation.

Electric Vehicle (EV) Adoption

The substantial growth in adoption rates of EV is significantly increasing load on distribution networks. It also presents an opportunity for companies to harness this flexible load in certain use cases.

Corporations adopting sustainability plans

Public opinion and stock markets are rewarding companies with eco-sustainable objectives for growth. In response, organizations are working to reduce their carbon footprint and are investing in efficient, sustainable energy technologies.

The changing utility landscape--from distributed generation to new dynamic loads--will make utility operations significantly more complex.

What is driving change?

- Diversity
- Prosumer
- Energy Storage
- Electric Vehicles
- Sustainability Plans

"In the new paradigm, more stakeholders (including prosumers) will dictate how electricity is generated and consumed."

Flattening the Grid

Growing Complexity

In the new paradigm, the 'edge' of the grid (basically the consumer's side of the power system) will influence greatly how power is consumed and produced. Aggregation of many power generation and storage assets, combined with flexible loads, will help address the challenges that come with the changing energy landscape. There are, of course, existing demand-response (DR) solutions in the market but legacy DR is not going to be enough to respond to dynamic, industry-wide change.

Information from the 'edge' therefore becomes more important and will have to be collected and leveraged. For example, utilities will have to adapt to the supply/demand needs of electric vehicle (EV) charging, energy storage, smart buildings, microgrids, and other participants.

Many utility assets now have microprocessor capabilities, and they are all generating staggering amounts of data. New hardware, devices, platforms, and applications are already able to gather large quantities of information, from more sources, in more detail, with less latency and business models need to be transformed to create new opportunities for the utilities. Data will be at the core.

Similar to the way energy flows are changing, technology has advanced to allow for a more decentralized approach to data analysis, where intelligence at the edge will augment the decisions being made centrally (at the dispatch center).

Thus, the grid is "flattened". Flattening the grid is analogous to flattening a company's organization chart, which typically means reducing the layers of middle management. This reduces the hierarchy of the system and allows more input in decision making from sources far from the top and from sources outside of the usual chain of command.

Adding to complexity

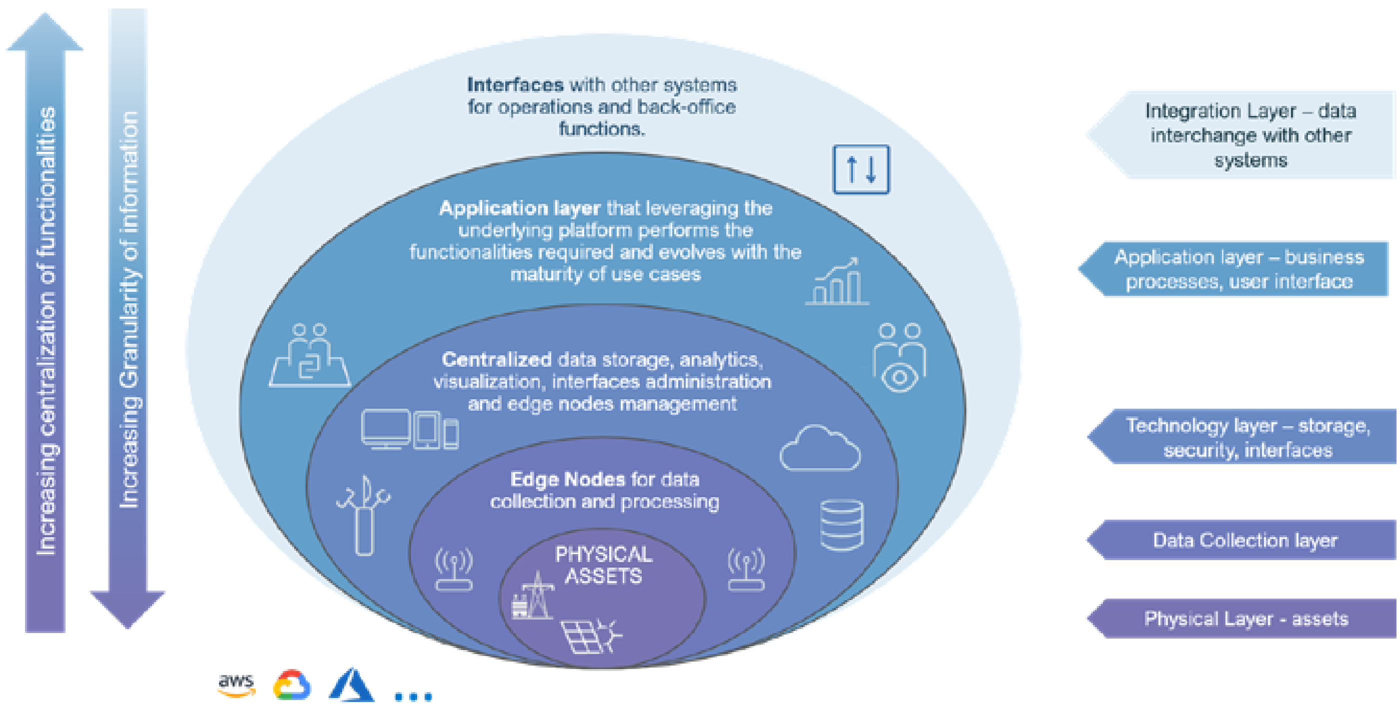
- **Prosumer**
- **Edge Data**
- **Decentralized Control**
- **New Supply/Demand Option**

The world creates 2.5 quintillion bytes of data every single day – yet only a fraction of it is utilized.

Tools for Change

Just like today, future electric companies will need to collect data, use it to dispatch resources, and then pay power providers. However, significantly more players will be involved in meeting demand (generators and curtailment partners), so keeping track of compensation owed will be more difficult.

Onesait Utilities is a suite of Minsait ACS products that can meet those needs. The platform incorporates prosumers and renewable energy by combining IT and OT technologies. It works with various types of technical data and will put that data to use in different domains. **Onesait Utilities'** architecture is designed for the new paradigm and has successfully been in use for several years.



Onesait Utilities Applications:

- Asset Performance Management (APM)
- Customers (CIS)
- Metering (MDM)
- Operational Intelligence
- Prosumer

Tools for Change

Architecture

Physical

Onesait Utilities can be represented by nesting layers. At the center are the physical assets--everything that is connected to the grid. This includes small items (e.g. individual solar panels and small storage batteries), large devices, (e.g. substation transformers and capacitor banks), and facilities (e.g. the substation itself).

Data Collection

The next layer connects the physical world to the digital world, and it is where data is collected and processed. IoT gateways, that use Intel chipset technology, run the **Onesait Things Edge** software. This assures interoperability with grid devices; data collection at the finest granularity; low latency of processing and execution; and control and notification capabilities. New software components can be deployed to process data, to execute commands, to update workflows. Every deployed piece of software is monitored from a central engine, to make sure no unauthorized operations occur.

Technology Layer

This is the centralized component of the platform where data is stored but it is also where all the services and software components of the platform are contained. It is where interfaces are configured and managed and where the platform is administered. Applications can access this layer and use different tools to convert the data into visual displays, perform workflows, apply controls, and perform analytics.

The importance of the technology layer increases as the number of deployed edge nodes increases. When a company has hundreds of thousands of edge nodes deployed, being able to manage them all efficiently and effectively becomes paramount.

Another function of this layer is cyber security, thus making sure that only authorized software is running on the edge devices.

Application Layer

The application layer is where the organization performs business rules, analyzes information, learns, and applies learning. Use cases are shaped into new business rules and new functionalities are finally automated. Algorithms are fine-tuned and can be transferred to the edge nodes to run autonomously.

Integration Layer

This layer pervades the whole platform and manages the interfaces among the components, as well as the interfaces for third-party systems outside the platform. **Onesait Utilities** uses standards to integrate with external systems, so it is as openly accessible as possible.

Analyze.
Learn.
Improve.

Tools for Change

Aspects of Complexity

Some of the most important capabilities of **Onesait Utilities** are discussed below.

Asset Characterization and Connectivity

> **Complexities**
>
> - **Asset Characteristics**
> - **Connectivity**
> - **Analytics**
> - **Compensation**

To operate effectively, a utility needs specific information about each available asset. (How fast can load be shed? Where can it be shed? How much load can be shed?)

This might include information needed for voltage reduction; energy curtailment in a smart building through the building's automation system; or to adjust household thermostats and/or water heater elements. All these devices may have different interfaces and operating parameters, therefore managing demand also requires intimate knowledge of how all assets are connected and what communication protocols (among the many standard protocols and the proprietary ones) they are using.

Not only does a utility need to connect to the assets, but also to cloud applications operated by demand aggregators. For example, there might be a third-party company managing a large numbers of connected water heaters or a cloud application that can send set-points to remotely operated thermostats.

Analytics. Analytics plays a critical role when making scheduling and dispatching decisions. It is also the engine that forecasts demand and continuously monitors power delivery during a flexible demand event.

During the event, the utility must be able to analyze data from network nodes and detect and respond to any nascent problems.

For example, a fast moving storm may cover all the solar panels in a city, decreasing power output by 30 or 50%. The most effective utilities will be able to accurately forecast load, minute by minute, and determine how much can be covered by distributed generation. In this way, utilities can avoid paying for very expensive 'spot' power to meet unexpected peak demand.

While energy storage and demand curtailment are both good ways to control variable generation and to shave peak loads, they can be expensive. So the cost of building battery farms and paying compensation to peak shaving customers must be considered.

Reward. Utilities must compensate those who participate in demand response events. Compensation can come in various forms, such as a flat-rate discount on a monthly bill or a token for every time the customer has participated. There are even more sophisticated approaches that take into consideration the characteristics of every connected asset. In this latter case, the level of compensation may depend on the source's participation in the event, how much help they provided, how reliable the source is, how fast it responded, etc.

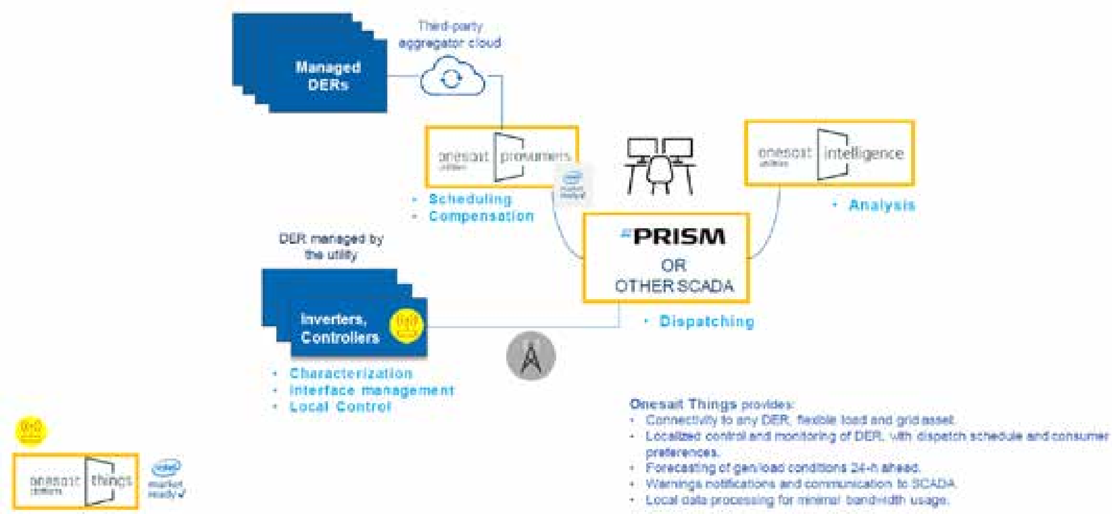
All these criteria are meant to increase customer participation and to incentivize customers to adopt technologies that support distributed generation and flexible demand.

Use Case #1

Use Case: Flexible Demand

The **Onesait Utilities** platform features multiple modules, working together to provide exceptional response to normal operations and to unexpected, flexible demand events.

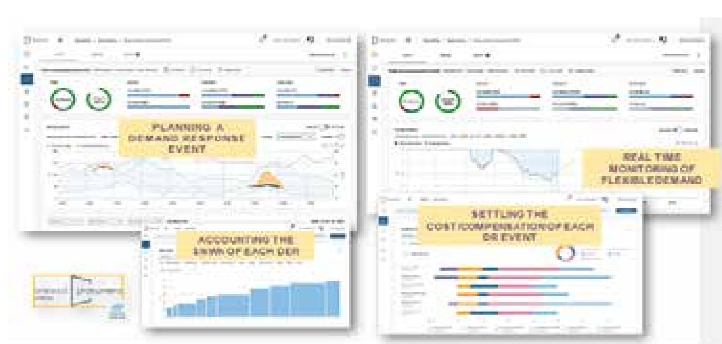
Scheduling and compensation are handled by **Onesait Prosumers** (an Intel market-ready solution). The module connects and manages the characteristics of all connected devices and those of demand aggregators through open communication protocols and cloud-to-cloud interfaces.



Onesait Things Edge is the physical layer, mentioned earlier in this document, and when connected to DERs provides localized control and monitoring. It communicates with SCADA but can execute control schedules and take actions locally, thus requiring limited exchange of information and data with any centralized control. This minimizes bandwidth requirements and reduces latency.

Analysis is performed by **Onesait Intelligence**, which examines technical data and supervises the dynamic performance of an event. **Onesait Intelligence** interfaces with utility SCADA to monitor the performance of the network. It runs the necessary analytics to forecast system load and localized peak loads at the substation and/or feeder level. **Onesait Intelligence** also interfaces with **Onesait Things Edge** to perform the analysis and forecasting for multiple generation sources.

> *"With edge computing, there is no need for the edge device to receive commands from a centralized system. This minimizes bandwidth requirements."*

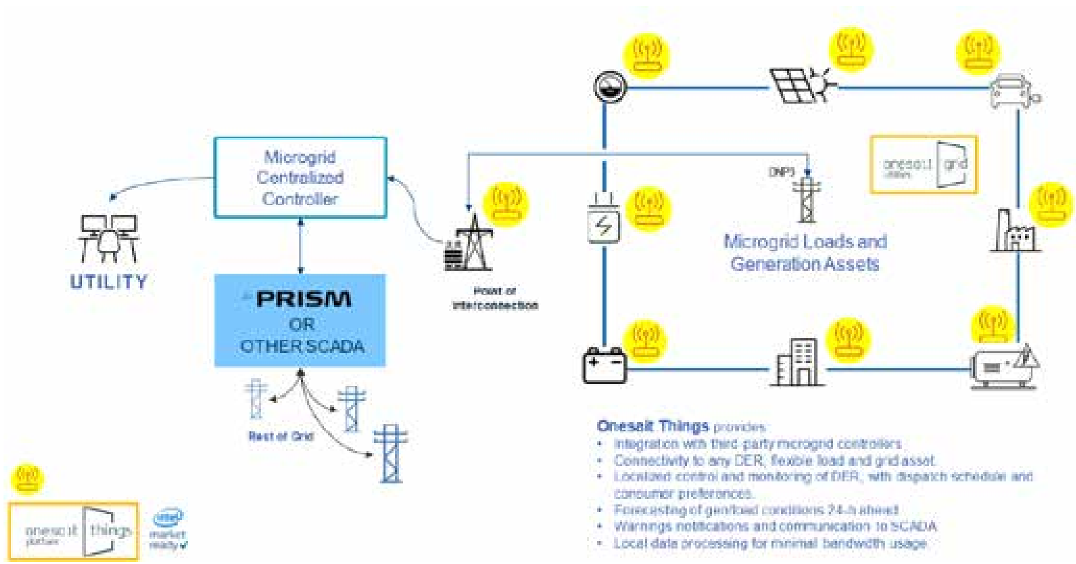


Use Case #2

Use Case: Microgrid Control

In Australia, **Onesait Things Edge** and **Onesait Utilities Grid** are optimizing the operation of a large microgrid with a 3.5 MW peak demand. This is a private, embedded network that includes 25 buildings of various types--including one very big, net-zero, smart building. The microgrid also has electric vehicle charging stations and a total of 1.5 MW of solar generation. The 1.2 MW-hour storage battery is the largest, behind-the-meter, energy storage system in Australia.

The Australian government supported this very large project through its Renewable Energy Agency (ARENA).



Onesait Things Edge and **Onesait Utilities Grid** effectively run the microgrid. From the outer grid's perspective, the microgrid looks like a single resource that sometimes acts like a load and sometimes like a generator. (The microgrid is registered as a 'grid service,' which allows it to sell energy back to the national grid.)

Onesait Things Edge connects every asset to the Onesait platforms by means of Intel-based Internet of Things (IoT) gateways. At the center of the Microgrid is **PRISM**, the Minsait SCADA system, which controls the microgrid and its connection to the utility grid.

"From the national grid's perspective, the microgrid looks like a single resource that sometimes acts like a load and sometimes like a generator."

Use Case #3

Use Case: Asset Monitoring

Beyond simple monitoring, **Onesait Asset Performance Management (APM)** allows utilities to evaluate the health index of their physical assets and their probability of failure. Data can be analyzed for a single asset as well as for the whole fleet of similar assets and up until the summarized status of an entire network.

Real-time data can be automatically compared to historic data, providing a snapshot of equipment health. This information, especially valuable for Commercial and Industrial customers with large equipment, can be used in the traditional way (to plan the demand and response of the utility) but can also be used to provide valuable feedback to customers on energy usage and energy performance analysis.

Predictive monitoring, based on asset data, can analyze the behavior of assets in real-time and monitor the evolution of problems. **Onesait Things Edge** connected directly to the assets and their sensors, can perform this analysis of performance spotting deviations from expected results that may hide underlying causes.

The Future & Flat Grid

Flattening the grid, or in other words, breaking up the traditional hierarchy that sees generation on one side of the value chain and a very predictable load at the other end, requires a more distributed control and a much more dynamic setting of network operation parameters.

Events that were traditionally only experienced in transmission, such as loss of generation requiring a sudden ramp-up of back-up generation, can now be experienced on distribution systems, as well. This is creating new challenges for the industry and not just in normal operations, but in novel ways, like the grid overloading from both directions.

Excess generation on the distribution side, can overload the grid with reverse power flow. On the other hand, when distributed PV generation drops by 20 or 30 or 50% in a matter of minutes, the grid must quickly pick up the load. It is a worldwide problem: base load has not changed from the traditional resources because renewable generation can fluctuate.

To prosper in the more dynamic and more complex industry, utilities need to redesign and rethink the traditional industrial architecture. Generation will no longer be isolated in a silo at one end of the value chain. The function of the substations will change and so must their designs, which will move from multi-rack hardware systems to software-based architectures.

The existing analog function of power conversion and physical protection will still be in place, but the controls performed today by peer-to-peer communication will be virtualized and run on a new computing infrastructure, for example, IEC 61850 B Class C-2 certified servers or NC16 with long life. Intel is committing to provide the CPUs for this market for the next 15 years.

As much as possible, protection, control, and automation will be virtual, which will lead to a very scalable infrastructure. When a utility digitizes their system, feeder by feeder, they perceive their network in terms of a grid of semi-autonomous microgrids.

Intel is committed to supporting the industry, both utilities and manufacturers, to design reference architecture for the future substations, and to test it in the field, so the needed applications can be created.

Fattening the grid, means breaking up the traditional hierarchy that sees generation on one side of the value chain and a very predictable load at the other end.

When a utility digitalizes their system, feeder by feeder, they see their network in terms of a grid of semi-autonomous microgrids.

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