White Paper

Layered Intelligence:
Architecture of a Smarter Grid

Landis+Gyr manage energy better

Is there a best practice for deploying and managing digital devices on the grid?

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by John Radgowski

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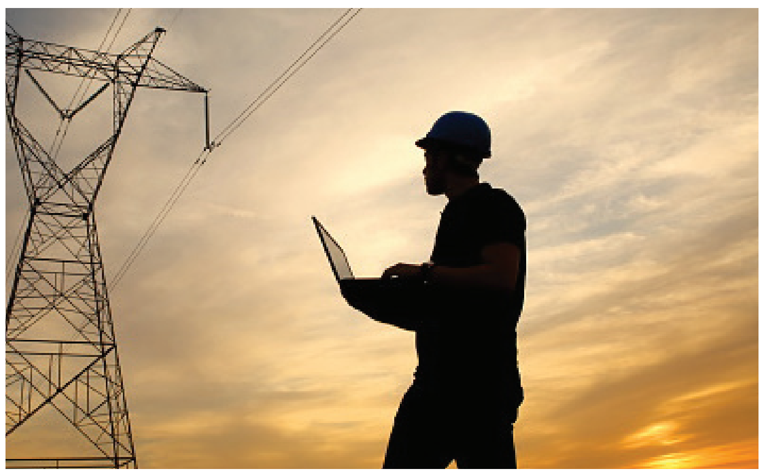
The Optimal Way to Manage Smart Network Devices

Late in 2017, Northeast Group's *U.S. Smart Grid: Market Forecast* found that stateside utilities will likely spend some $110 billion on smart grid infrastructure in the coming decade, and distribution automation is projected to be the largest segment of that market. Researchers predict it will consume 56 percent of those smart grid investments.[1]

While automation itself has inherent value, it has even greater benefit when it's planned around a strategy designed to optimize usefulness for all stakeholders. For utilities, that means the automation strategy should serve consumers, utility owners and regional grid operators. The way to do that is with a strategy that leverages layered intelligence. It's a comprehensive, end-to-end approach to adding distributed computing power to operational technology, grid devices and behind-the-meter resources.



Layered intelligence defined

Layered intelligence is a way of viewing and operating networked grid assets. It combines the best features of edge and central intelligence to provide the right information at the right place and time across the network.

Utility managers are able to identify the distinct layers of grid-connected devices, define their capabilities and roles in grid operation, and implement applications to optimize the operation of each device as well as the entire system.

Hierarchical decision making is a key component of layered intelligence.

There are times when grid-edge devices should speak only to each other. For instance, a meter could communicate peak rate periods to a smart thermostat.

Meanwhile, a community-level device might aggregate data from grid-edge devices like meters, then use that information for specific activities, such as outage restoration.

These community devices also may report to a centralized utility system, which would use the data for things like monitoring and preventative maintenance.

The head-end utility system would also then supply utility managers with reports for regulatory filings and other uses, support informed decision making, manage historic data, facilitate planning and interact with the appropriate wholesale market player.

At each level, devices and software collect only the information they need to see, such as alerts or aggregate data. This gives utilities a more manageable way to accommodate the complexity now growing along with the burgeoning internet of things.

[1] https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/

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> **Smart devices communicate** *and* run applications. They perform tasks **just like computers and smart phones** do.

Why IoT *needs* layered intelligence

While there are times when utilities need centralized control, the internet of things — computing and communications capabilities built into electronic devices — will require power providers to hand off some of that control to community and edge-level devices.

Why? Because there are simply too many devices connecting to the grid to be controlled without a hierarchical approach. Community- and edge-level intelligence comes into play when decisions and reactions need to occur quickly.

According to Statistica, there will be nearly 31 billion connected devices worldwide by 2020.[2] Gartner's prediction is more modest. Their analysts foresee an installed base of 25.1 billion IoT units in 2021.[3]

That's a lot of smart meters, smart thermostats, line sensors and more coming online. These devices create enormous potential for load management and other utility services, but only if utilities can find a way to simplify control. One way is to let the devices control themselves. Another is to put in multiple layers of control, so that grid-edge devices answer to community-level computers rather than swamping utility head-end systems with data and bandwidth needs.

Smart versus connected

Smart devices aren't smart simply because they can communicate with other devices. Their capabilities exceed mere data retrieval and transport. Smart devices are smart because they are capable of running applications and performing tasks the same way a computer or smart phone can act autonomously.

Like smartphones, smart devices can be designed to detect and use a variety of communications protocols. With a smart phone, switching from Wi-Fi to cellular to Bluetooth won't cause the device applications to simply disappear.

Likewise, that kind of communications flexibility allows things like smart meters to interact with other utility systems and accept firmware or software changes remotely. You can change the nature of a meter or other devices with a simple download.

Here's an example: Arizona Public Service is the first utility in the U.S. to pilot ownership *and* control of residential rooftop solar installations. Each PV system APS controls has a smart inverter connected to the utility's supervisory control and data acquisition (SCADA) system. The goal is to facilitate utility control of the generation resources to provide equipment upgrade deferment, voltage management and more.

[2] https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/
[3] https://www.gartner.com/doc/3840665/forecast-internet-things-endpoints

Layered Intelligence:
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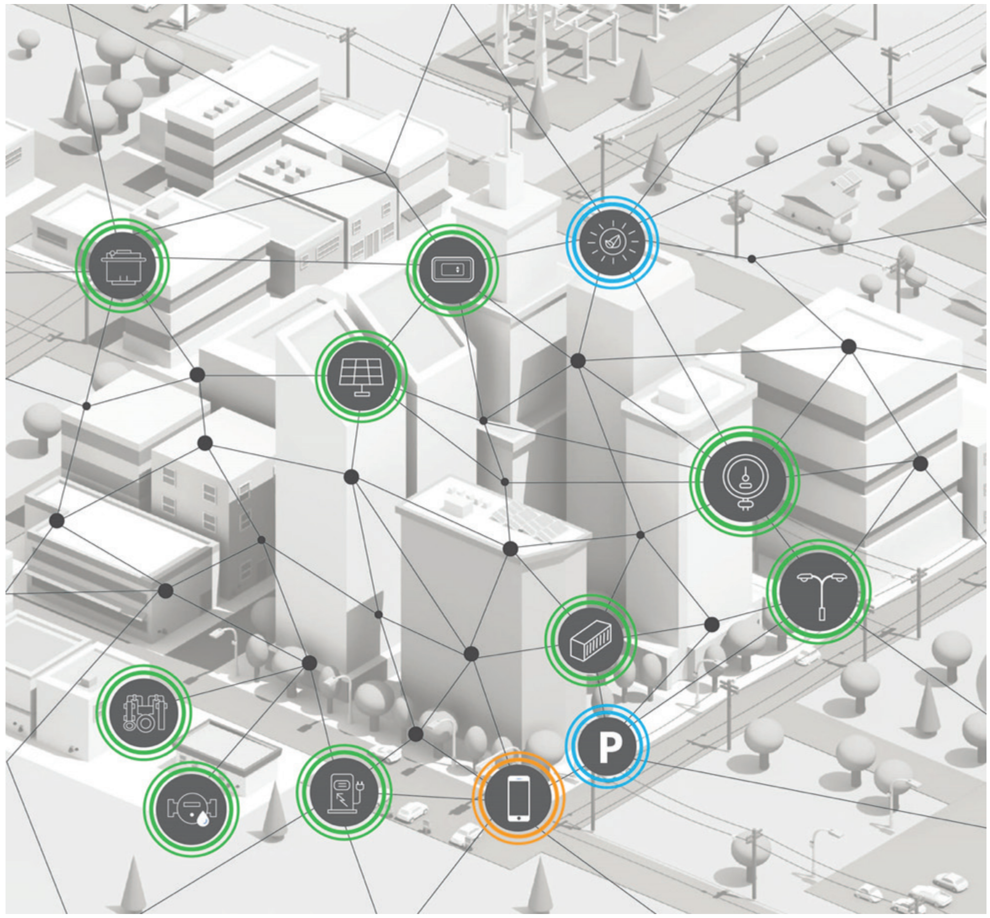
The challenge?

Those inverters communicate via the Modbus protocol, while APS' SCADA system speaks Distributed Network Protocol, or DNP3. A small application residing in the smart invertor handles the translation that allows the inverters to talk to the utility SCADA system.



Benefits of distributed decision making

There is plenty of payback in having intelligence layered throughout utility infrastructure.

For one thing, peer-to-peer communication and control at the grid edge facilitates faster response to rapidly changing conditions.

Cloudy skies can instantly drop the voltage in an area with a high level of solar generation. Even if you have sensors in the area to detect such voltage excursions, without localized intelligence and control, you still need to send a report or alert to a centralized SCADA or DSM system. That's likely to take a couple of seconds, and so will the return command that comes back to the grid edge from the centralized data center.

In contrast, distributed intelligence allows you to put devices and applications close to trouble spots for sub-second response when you need it.

As noted earlier, layered intelligence also allows you to selectively choose what information devices receive and send. For example, Southern California Edison has written dozens of applications to do rapid, high-speed polling of grid-edge devices, such as smart meters serving as sensors.

This lets utility managers sense in real time what's happening in the distribution system. Rather than send all the data back to the utility, SCE wrote applications to sense specific grid conditions and send back alarms when anomalies occur. The apps allow the utility to isolate trouble spots on the distribution system without flooding head-end systems with information.

In addition, layered intelligence facilitates efficient, condition-based protocols. For example, detection of voltage excursions along a feeder can immediately and automatically trigger an alert to possible problems.

Finally, layered intelligence brings a higher level of situational awareness throughout the utility distribution network. That, in turn, can lead to more effective preventative maintenance, lower operational costs, increased reliability and better customer service.

Layered intelligence in practice

So, how does layered intelligence translate into utility activities and processes? You'll find applications on all levels — the localized grid edge, the community level and the distribution network itself.

At the edge

At the very edge of the grid, many of the applications reside in meters and serve customers directly. As an example, look at meter-enabled, prepaid electric service. Salt River Project, a utility in central Arizona with more than one million electric customers, has the largest prepay program in the country. Started in 1993, the utility's prepay program class now has 157,000 customers enrolled and serves 17 percent of the residential customer base.

This past year, SRP updated its program by implementing an app in existing smart meters so that the actual calculations of money paid versus electricity used are done within the meter itself. No data needs to travel back to a utility head-end system, and customers can know exactly where they stand with their pre-paid account in real time by using an in-home display or smart phone.

Many pre-payment programs are done in the cloud and require customers to have internet access. Others require customers to go to a payment center or store-based kiosk. This solution eliminates these requirements and gives customers greater insight into their energy use.

The meters being used were not originally designed to provide this functionality. It's merely an add-on app that supports the program.

Another meter-based app is a demand manager that leverages home-level connectivity and load-control switches to help home owners better manage energy usage.

The application runs on consumers' energy meters, continuously monitoring usage and forecasting future demand, while providing real-time autonomous management of loads such as HVAC, electric water heaters and pool pumps. The project provides customers with an automated tool to reduce energy consumption and lower utility bills by avoiding unnecessary usage during high demand rate periods.

The application also has a load-shifting or shedding effect to help utilities manage peaks passively. The utility is not managing demand of various household loads. It's the app itself that's sending control signals based on a threshold set by the customer.

Load disaggregation is another example of meter-based edge intelligence. Again, it's an add-on app.

Beyond meters, edge intelligence also applies to sensors and allows decisions to be made by the sensors themselves. These decisions are generally made using data from the individual sensor or data from a small number of locally connected sensors. For example, a sensor might detect that a device has a heating issue and automatically send alerts to initiate repairs.

Layered Intelligence:
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In the community

Community intelligence takes advantage of the information and control available from a select group of smart devices.

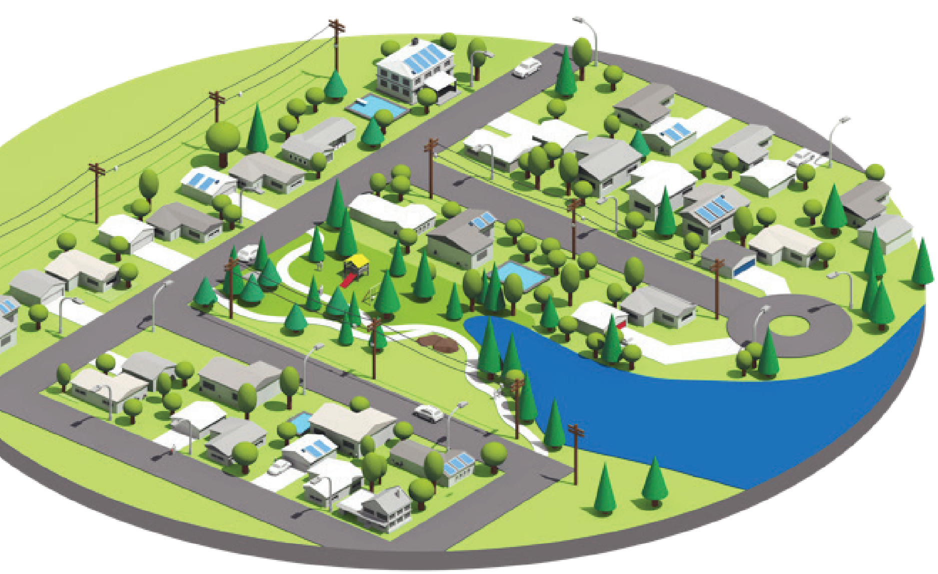
What can you do with it? A few examples include:

- Volt/VAR control on individual feeders and laterals
- Capacitor bank monitoring and control
- Microgrid monitoring to manage loading and surplus energy on campus-level facilities with solar, battery energy storage, diesel generation and other resources

Targeted load control is another example that's gaining popularity as utilities look to manage load for a variety of use cases.

Colorado Springs Utilities, for instance, deployed 1,900 smart thermostats and software applications to enable load shedding on specific feeder circuits where capacity constraints could impact transformers and other distribution equipment.

During peak power events, community-level intelligence uses load information to determine the number of customer thermostats to control. If a customer opts out of a control period, the software automatically adjusts to find replacement load curtailment to ensure load-shedding requirements are met. Unlike most demand-side management initiatives which target peak power costs, this program is meant to mitigate system constraints and control infrastructure expense.



What's driving the utility internet of things?

Distributed energy resources (DER)

Navigant Research and Public Utilities Fortnightly forecasts capacity from DER like rooftop solar and storage to grow as much as five times faster than traditional, centralized generation over the next 10 years.

Electric vehicles

Bloomberg Energy Finance sees EV power consumption increasing to 33 TWh annually by 2025. Managed charging — the process whereby utilities turn the charger on or off — has the potential to help utilities lower peak loads.

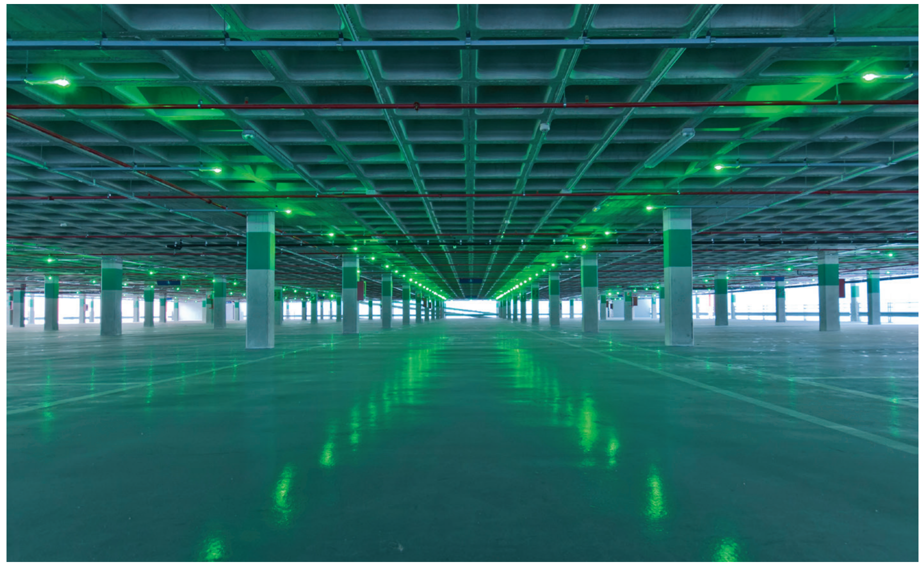
EV overload

Without managed charging, utilities are looking at more peaks and more problems. Studies conducted by the Sacramento Municipal Utility District show that this utility may need to upgrade as much as 12,000 transformers — 17 percent of the utility's transformer assets — due to EV-related overloading.

Aging infrastructure

The American Society of Civil Engineers 2017 Infrastructure Report Card notes that most U.S. T&D lines date back to the 1950s and 1960s and they've reached their 50-year life expectancy. Meanwhile, most U.S. high-voltage transmission lines are at full capacity. Many utilities are opting for increased situational awareness of aging assets to defer outright asset replacement.

Community-level intelligence is essential for smart city applications, such as smart parking and traffic management.



This application could be considered community intelligence because on the community level, you may be looking at the infrastructure associated with a substation or a feeder coming from a substation. Or, it could also be a smaller geographic area that is part of a smart city, such as a neighborhood or an area around a sporting complex.

Another example of community-level intelligence includes fault location isolation and system restoration (FLISR). While it can also be done at the system level, some of the decision-making processes can be performed out along the feeder or in the substation. With FLISR solutions — Volt/VAR, too — you're making decisions based upon information from more than one sensor; however, these sensors are all located in the same geographic area.

Community-level intelligence is essential for smart city applications, such as smart parking and traffic management. In the case of smart parking, a group of parking sensors that are in the same geographic area send data to a community level system. This system then keeps track of open parking spaces and sends information on the availability of parking in a geographic area up to a system level parking-management software.

Likewise, with smart traffic management, a collection of traffic sensor data can be sent up to a community level for processing and decision making to do things like reroute traffic after large sporting events. Or, traffic sensors could help cities make roads safer. Imagine road-temperature sensors feeding a community-level processor that determines if road signs should be changed to indicate unsafe conditions and caution drivers of potential dangers.

Across the system

System intelligence has historically been the most familiar means of monitoring and controlling grid assets. At this level, interaction occurs between a large number of devices spread out across a wide geographic area. Decision making focuses on how to run the grid or, in the case of smart cities, how to run the community.

For example, if you're rerouting power from one substation to another based upon outages or overloading, you need system-level intelligence because this task requires visibility to both substations. Systems such as an ADMS will use sensor data from both substations and along both feeders to make these types of decisions.

Managing the entire distribution system, including community and edge devices, is done from both a real-time view and historic data, requiring interfaces with all relevant networks and applications.

Layered Intelligence:
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Many smart meters deliver voltage measurements in real-time from select number of meters and sensors.

One such application is advanced outage analytics that leverages data from line sensors and other devices to predict outage location and the customers affected. Once power restoration begins, such analytics can pinpoint which parts of the system are back online and which aren't.

Analytics like these help direct crews to the spots where the greatest numbers of customers are affected by the outage, plus they help system operators make switching decisions. Likewise, outage analytics can take things like historic momentary outages and predict where issues exist to facilitate preventative maintenance.

Asset loading analytics also support system-level intelligence. Here, you take historic, time-based consumption data from meters, correlate it with transformer sizing and loading limits, and determine which transformers may suffer a shortened life due to continuous overloading. The analytics help utilities prioritize replacements based on financial data.

Yet another system-level application is voltage monitoring. Many smart meters deliver voltage measurements in real-time from select number of meters and sensors. Bringing this information together in a central location, visualized on a map, makes analysis easier. You can see if a capacitor bank or regulator has issues when all the meters under those devices show high or low voltage. Operators can use this information in making maintenance and control decisions.

In fact, in each of these layers of intelligence, you augment decision making for utility personnel and the customers they serve. On the utility side, you boost the accuracy of decisions and planning because now these actions are based on solid data. On the customer side, layered intelligence improves the delivery of electric service itself. It's more reliable, easier to manage and it may even cost less.

What's more, layered intelligence isn't a diversion from traditional utility operating methods. It's really an extension of them.

The Hierarchy of Decision-Making

SYSTEM LEVEL: SCADA, DMS, DERMS, VPP AND ANALYTICS SOFTWARE		
Interacts with …	• Community-level devices • Grid-edge devices • Behind-the-meter devices	• Wholesale markets • Historic utility data and analytics systems
Responsible for …	• Overall reliability • Resource adequacy • Volt/VAR and frequency regulation	• Reserve capacity • T&D constraint mitigation
Managed by …	• Utility data and command center	
COMMUNITY LEVEL: DATA COLLECTORS, LINE CONTROLS		
Interacts with …	• Grid-edge devices • Community-level devices • Behind-the-meter devices	• System-level software • Specialized software, i.e., outage management
Responsible for …	• Distribution-level reliability • Volt/VAR optimization • Distribution system devices such as capacitor bank controls, sectionalizers, etc.	• Aggregation of distributed energy resources — data collection and control • Smart city applications
Managed by …	• Head-end systems	
EDGE LAYER: METERS, LINE SENSORS, LINE DEVICE CONTROLS		
Interacts with …	• Community layer collectors • Head-end systems	• Behind-the-meter devices
Responsible for …	• Self-directed automation	• Peer-to-peer automation
Managed by …	• Built-into-device, autonomous applications	• Community- and system-layer commands

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Conclusion: A Simple Way to Manage Complex Systems

If you look at utility infrastructure, it is already organized as a layered infrastructure: starting with the complete distribution system, then substations that are taking power from the transmission system, and feeders that are going out to customers and, even within them, the laterals and service transformers. The entire organization of the electric system is hierarchical because this is a natural way to manage complex systems.

Distribution systems will become increasingly complex as the internet of things proliferates and more smart devices interact with utility networks. A layered approach to architecture and planning is proven successful at managing complexity to unleash the full potential of the smart grid.

This strategy not only makes the most sense for grid modernization, it is becoming easier for utilities to implement. Intelligent nodes now integrate with nearly every sensor and distribution device necessary for edge and community intelligence. Protocol flexibility and translation capabilities are standard practice, while data at the system level is more interoperable and manageable than ever before. As a result, the automation promised by IoT is accessible and attainable for every utility.

Need help planning your grid architecture and growth strategy? Contact a Landis+Gyr consultant at **futureready@landisgyr.com**