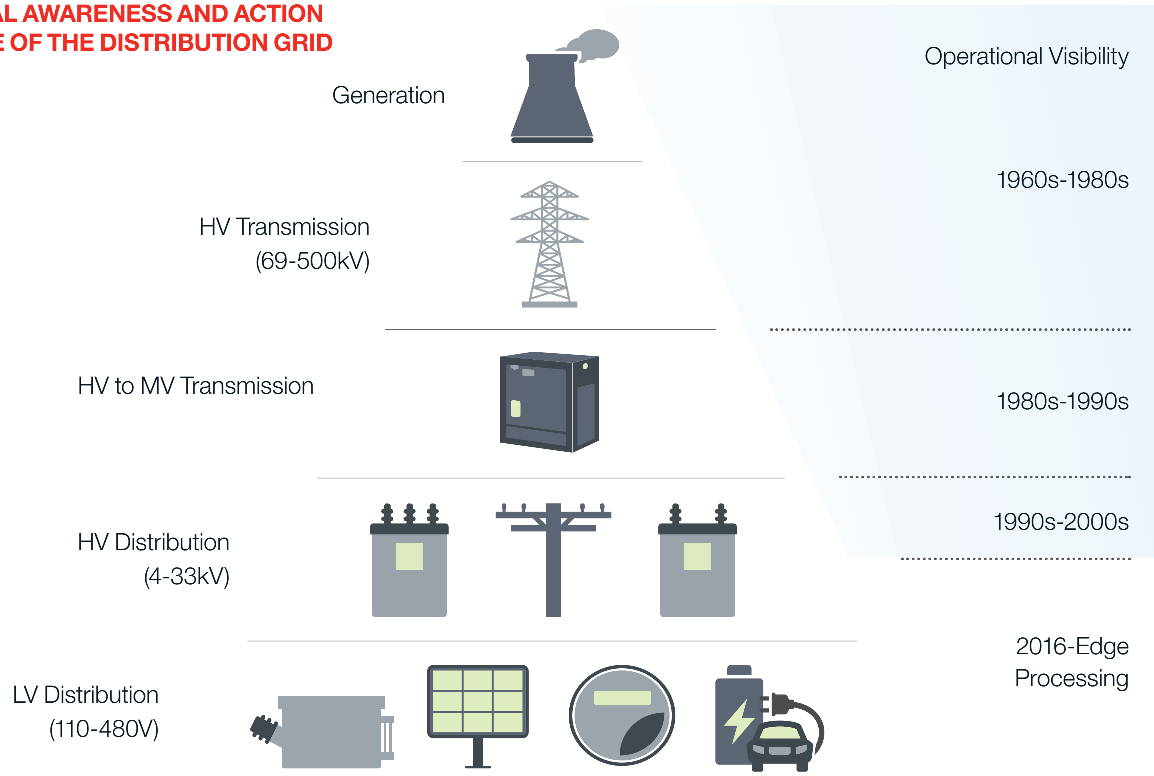
The Active Grid

A Case for Edge Intelligence on the Lower Voltage Network

by Tim Driscoll

WHITE PAPER

OPERATIONAL AWARENESS AND ACTION TO THE EDGE OF THE DISTRIBUTION GRID



A DISTRIBUTED GRID REQUIRES DISTRIBUTED INTELLIGENCE

It is a common misconception that the operation of distribution grids supporting significant amounts of distributed generation and storage capacity will just be a larger-scale version of the centralized supervisory control and data acquisition (SCADA) models used today to operate utility generation and transmission networks. SCADA systems consist of advanced sensors in the field that relay data in near real time to a centralized control system where operational decisions are made and then commands are relayed back to the devices in the field.

However, there is a significant difference between the traditional centralized generation and transmission network model and the next-generation distribution grid that thwarts a simple extension of the SCADA model into the distribution grid. In the traditional utility model, load or demand is variable, while generation and power flow are parameters centrally controlled by the utility (or system operator) through a relatively small number of points to respond to variations in load.

A DIFFERENT OPERATIONAL MODEL

In the distribution grid of the 21st century, where distributed energy resources (DERs) will be widespread if not ubiquitous, none of the three variables—load, generation and power flow—will be controlled by the utility or system operator. As a result, the distribution grid must respond to changing conditions in real time, not through a centralized command and control model like SCADA to meet demand, maintain grid stability and protect assets.

In other words, the distribution grid must become a sentient, intelligent network, capable of responding quickly and locally to real-time conditions as they occur, based on a centrally controlled set of operating parameters. This functionality and its capabilities will be crucial for utilities as they manage the technical and business challenges that lay ahead.

Patterns and trends will continue to be monitored by centralized systems that will provide control parameters to coordinate local devices and resources. But the local devices will also analyze, make decisions and act on those decisions at the edge. This operational scenario is much more analogous to utility relay and protection systems used today than to SCADA systems, and it requires edge intelligence to analyze, make decisions and take action—just as relays and protection systems do today. In many cases, this edge processing will be distributed intelligence, where groups of devices at the edge communicate and work together in real time.

Because generation and storage will be distributed across all points of the distribution grid, from substations to customer homes, and because financial transactions and generation/load decisions will occur at all those points, intelligence and processing power will need to be ubiquitous at all layers of the distribution grid. This will include distribution substation equipment; medium voltage protection, management and monitoring equipment; and lower voltage grid devices, such as sensors and meters at the very edge of the distribution network.

LIMITED GRID VISIBILITY

In the late 1980s, utilities had virtually no visibility into the distribution grid. Generation and transmission were fully instrumented and controlled through SCADA. But even most distribution substations—which transform power from high voltage transmission lines to the medium voltage circuits that run along the streets— were completely invisible. Common practice at that time was to identify distribution substation outages by noting significant drops in transmission load on the SCADA-monitored transmission lines.

By the late 1980s and into the 1990s SCADA had been extended to most, but not all, of the distribution substations, so there was awareness of the power flow going into the distribution circuits, but still no visibility beyond that point. Then over the following 20 years up to present, some monitoring and notification was extended into the medium voltage distribution network, through use of recloser and capacitor controls and fault recorders, as well as into the low voltage network, through use of smart meters with some limited monitoring and alarm capability. Yet even today, utilities remain largely blind, on a real-time basis, to conditions within the distribution network and have minimal ability to manage rapidly changing conditions at the edge of the network.

THE AGE OF PROSUMERS

Now that consumers own generation on an increasingly large scale and regulatory initiatives are beginning to allow distributed generators to sell power directly to consumers across the distribution grid, the traditional volumetric utility business model is imperiled. Utilities are at risk of being left with regulatory edicts to maintain distribution infrastructure without the necessary level of funding to do so. In addition, the emerging transactive energy marketplace at the grid's edge will involve many financial transactions that will fall outside of the utilities traditional business and financial processes.

If utilities are to survive and thrive amid these disruptive and competitive challenges, they will need to turn these challenges into business opportunities and leverage their "energy incumbency" and relationships with customers to be the key player in an increasingly distributed and transactive grid. This is another reason why distributed edge intelligence is crucial for utilities.

Edge intelligence-enabled meters, sensors and other devices on the distribution network can communicate and manage these transactions and power flows in real time, keeping the utility relevant and in control of their distribution system and the financial transactions that ensue. As the incumbents, utilities will be the logical choice to perform this function, but only if they are ready to provide the services when required. If they're not ready, other technology vendors such as Google, Nest and the cellular providers will happily step up and fulfill that role.

Implementation of edge processing capability, and the business agility it provides to manage these transactions is their best defense against that outcome.

SAMPLE DISTRIBUTED INTELLIGENCE APPLICATIONS

THE SHIFTING DATA PARADIGM

Distributed intelligence—as in the distribution of analysis, decisions and action away from a central control point—is not a new concept. From smart phones running mobile apps to supply chain management solutions to multiplayer online gaming, distributed intelligence and computing has proven a consistently effective approach to managing large, complex, data-intensive systems and organizations. The Internet of Things (IoT) is accelerating this trend. So why is edge processing such a hot topic at utilities today? There are three main drivers:

» Data volumes
» Latency and resilience
» Technical capabilities

Data Volumes

The rate of data creation has consistently outpaced growth in network capacity and data storage by orders of magnitude over the past decade or more, in both the general IT industry and in the utility industry. Often statistics are cited about how more data has been created in the last year or two than in all of human history.

Ten years ago, typical residential electric meters produced one value per month for customer billing. Over the past decade, meters have progressed through hourly data, then 15- or five-minute load profile data, to now, where some distributed meter applications utilize 40+ values per second on every residential meter. This represents approximately 100-million-fold data growth compared to just 10 years ago.

What about network capacities? A decade ago, typical Local Area Networks (LANs) operated at 10Mbps. Today, typical LANs operate at 10 to 100 Gbps. That represents an increase in network speed of three to four orders of magnitude, while meter data growth over the same time period has been eight orders of magnitude.

While all major AMI vendors that transport meter data claim different speeds and have different methods of measuring effective bandwidth, the same rule is true: growth in network speeds for all major AMI vendors over the past decade has been about three-to-four orders of magnitude, according to their own measuring methods.

Continued improvements in network speed and performance still fall well short of growth in meter and energy data production. Similarly, typical storage drive capacities a decade ago were in the range of 100GB while today they are in the range of about 10TB and these drives perform is 10 to 100 times faster. Again, these improvements are several orders of magnitude less than the explosion in data.

Making the problem worse, meter vendors are expected to release standard residential metering devices producing data in the 4kHz range and above in the next two to three years, which represents another three orders of magnitude growth in data. Clearly, network and storage capabilities are not keeping pace with data creation. The result of these trends is obvious: if data is not processed and filtered at the edge, data simply goes to waste, and applications that use that information are not possible.

Latency and Resilience

Many operational applications for the Active Grid will require voltage corrections, power flow adjustments and other control measures to occur in near real time, across a very large number of devices, all with slightly different current operating conditions. These outcomes are simply not attainable using models that rely on data transfer and command to and from a central command system to many millions of devices in the field. Latencies in data transfer and large-scale decision processes are simply too high. In addition, a fully centralized model across millions of devices (for example every meter, protection device, voltage correction device and distributed generator) also introduces operational risk.

It is not economically practical across so many devices, distributed across an entire utility service territory, to provide multiple, contingent network paths, thereby making connectivity dropouts between devices and central command inevitable. If devices do not have the ability make decisions locally and operate autonomously when needed and in small local groups, there will be instabilities introduced due to the loss of the ability for those devices to monitor and act across the distribution network.

The only practical solution to this dilemma is to distribute intelligence and processing to the edge devices so they don't suffer from unmanageable latencies and can continue to act autonomously during interruptions in central connectivity.

Technical Capability

It is only in the last two to three years that the cost of technology and communication networks capable of supporting true distributed edge processing across the electricity distribution network (meters, reclosers, capacitor controls, fault recorders and so on) has come down to the point where it is cost effective to deploy widespread edge processing solutions with net positive ROI with definable business value. This is the other reason computing at the edge is a hot topic today. Previously it was only an academic discussion; now it's cost effective and practical, even compared to the cost of current generation AMI and utility networks.

PUTTING DISTRIBUTED INTELLIGENCE TO WORK

With this shift in technical capability becoming both cost effective and practical, there are now real, demonstrable benefits to leveraging distributed intelligence within the electricity distribution network.

Operational Efficiencies

Although much of the discussion of edge processing centers around requirements for the distribution grid of the future, the practical availability of edge processing now enables many current-state operational efficiencies and safety improvements. In many cases, these applications are only possible because of access to higher frequency data streams in the meters that across any AMI network. In other cases, applications utilize this data and/or peer-to-peer information sharing to provide vast improvements in effectiveness over current-state use case models.

Examples of applications that drive measured improvements in grid efficiency include:

» *Location Awareness:* Intelligent meters and devices can determine their own topological location (phase, transformer, feeder) on the distribution network with very high accuracy. Existing utility records are not very accurate. Location awareness improves the efficiency of many utility operations, including outage response and several of the other edge processing applications. This application is also critical to many Active Grid applications, since the grid cannot be operated effectively if the connectivity topology is unknown or is not accurate.

» *Safety and Reliability Applications:* These applications detect safety and reliability issues—most of which are currently undetectable today—thereby reducing technical losses, interruption in service frequencies and durations, and safety risks and equipment damage. They include:

- High impedance connection detection
- Broken neutral fault detection at form 2S services
- Loss of phase detection at delta-wye transformers
- Loss of neutral detection on three-phase transformers
- Downed conductors

» *Outage and Restoration Detection:* Using distributed intelligence, distributed statistical methods, and parallel processing and communications, this application can much more rapidly identify the scope and location of power outages and verify the success of restoration efforts, including rapid identification of nested outage conditions.

» *Theft Detection:* Highly-accurate detection of theft based on current flows on the low voltage secondary, at the customer service entrance and through various meter bypass methods are enabled with distributed intelligence.

Distribution Network Stability and Operation

These Active Grid applications provide real-time monitoring and management within the distribution grid to maintain grid stability. These capabilities will become much more important with the introduction of widespread distributed generation and storage, as well as with the introduction of step load changes, such as the widespread adoption of electric vehicles. Most of these applications rely on a combination of edge processing and peer-to-peer communications among smart meters and grid devices.

Examples include:

» *Active Transformer Demand Management:* Real-time control of load and distributed generation behind a transformer to meet energy demand within rated transformer capacity.

» *Active Demand Response:* Real-time control of load and distributed generation to predictably achieve demand reduction targets. Also includes local computation of demand response performance at each metering point to provide consumers with real-time feedback and time-aggregated results to back office control systems.

» *Intelligent Voltage Monitoring:* Meters share information and self-select bellwether meters in real time to report accurate voltage profiles across feeders to both voltage control devices and centralized voltage management applications. Metering devices communicate directly with voltage control devices in the field using native distribution automation (DA) protocols such as DNP3.

» *Active Transformer Voltage Management:* Real-time control of loads and generators behind a transformer, so that each transformer can act as a virtual 'voltage regulator' within control set points.

» *Real-Time Markets:* Meters and distributed generation communicate in real time to broker local energy transactions (buy/sell) between consumers and generators within the distribution grid. Meters maintain settlement data and deliver that to financial systems for processing and billing.

Customer Service

Many of the previously described applications also impact customer service (better outage response, better reliability, real-time performance feedback during demand response events), but there are also distributed intelligence applications aimed directly at delivering new, value-added services to customers.

Examples include:

Load Disaggregation: Real-time decomposition of total load into individual appliance usages with no special equipment required behind the meter. Performing this at the meter through download of an application—which uses high-frequency data available on the meter—is much simpler and more cost effective than the installation of dedicated monitoring equipment in the customer's home. It also provides significantly faster and more accurate results than applications running in the back office that attempt to disaggregate whole premise loads using much lower resolution, historic load profile data. Load disaggregation can be applied to multiple customer services including:

- Customer education
- High-bill complaint resolution
- Targeted active load control and demand/energy management
- Energy efficiency program effectiveness evaluation
- Identification of poorly running consumer appliances that require maintenance, such as A/C units
- Customer service programs like expected activity (kids are home, elderly are OK) and unexpected activity (possible break in)

CONCLUSION

In the face of mounting technical and business challenges associated with distributed generation and other disruptive technologies, utilities must rethink their strategies and operational approaches to assure the stability of the grid and the success of their business.

A distributed grid requires distributed intelligence to operate it. Technology advancements—such as distributed intelligence, machine-to-machine communication and IoT convergence—are redefining what's possible in grid operations, customer service and business development.

At Itron, we believe that by strategically implementing edge intelligence into their distribution networks, utilities will not only assure the reliability, efficiency and safety of the grid, they will also stake out an enviable competitive position as they march down the path to the transactive energy marketplace of the future.

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Tim Driscoll is director of information management outcomes, responsible for data management, analytics, and distributed intelligence applications and strategy at Itron, a company dedicated to enabling utilities and cities to safely, securely and reliably deliver critical infrastructure services to communities in more than 100 countries. Tim has been in the utility industry for 30 years and has been with Itron for the past 19 years, with roles in marketing, solution architecture, sales, product line management and consulting. Prior to joining Itron, Tim worked at Nova Scotia Power for 10 years in the areas of distribution engineering and load research & forecasting. Tim has a bachelor's degree in Mathematics and a bachelor's degree in Electrical Engineering, both from Dalhousie University in Canada, and is a registered professional engineer.

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