Positive Proof for Distributed Intelligence at the Grid Edge

Lab and Field Testing for Three Use-Case Applications

WHITE PAPER

The utility industry struggles to store and analyze the ocean of data recorded by state-of-the-art distribution devices. Performing some analytics locally—within the devices themselves—promises to unlock new operational value and cost effectiveness, and the first phases of testing needed to prove that theory are now complete. Laboratory investigations showed distributed intelligence (DI) applications far surpassed the capabilities of cloud-based analytics for three common use cases on the distribution grid; and field testing confirmed the results across thousands of customer meters, while also revealing other valuable, real-world applications for the data.

The results mark the beginning of a paradigm shift. By moving analytics into devices at the grid edge, Itron is simplifying how utilities convert data into insights and helping utilities deliver greater benefits through advanced metering infrastructure (AMI). Now, with a DI platform that can deploy data-intensive applications for current and future use cases, utilities will realize continuous growth in ROI over the entire life of an AMI investment. In addition, they will have the technological foundation to enable advanced grid operations and innovative business models in step with the emergence of distributed generation and smart-home solutions.

WHY A DYNAMIC GRID NEEDS DISTRIBUTED INTELLIGENCE

Distributed energy resources (DERs) are fundamentally changing how the grid operates. In the traditional model, utilities have centralized control of generation and power flow to respond to a single variable within the distribution grid—load. But with the proliferation of DERs and the accelerated adoption of electric vehicles (EVs), generation, power flow and load have all become shifting variables. The complexity requires a new model of grid operation that can rapidly assess and respond to local conditions on the distribution grid.

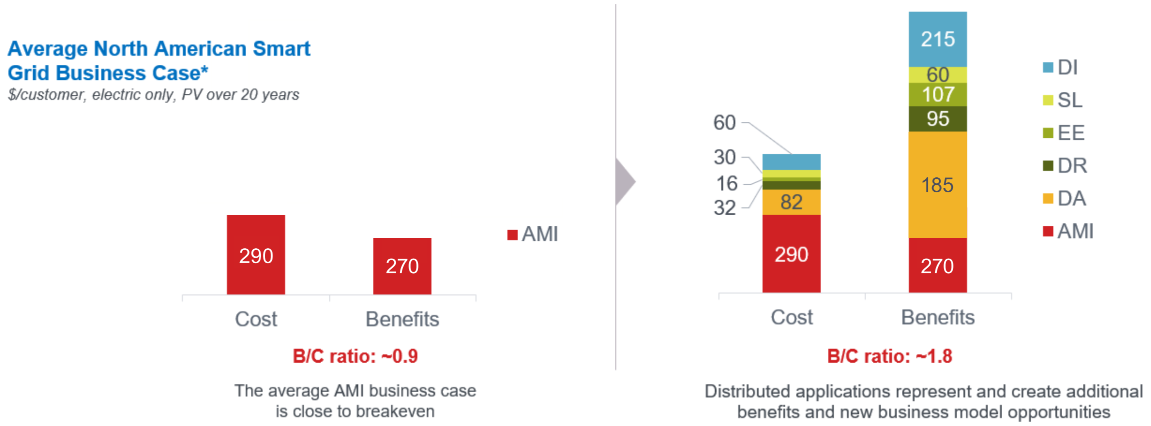
Currently, AMI is capable of providing reasonable visibility (day-later, 15- or 60-minute interval data) into the low voltage (LV) portions of the distribution grid, where the majority of the DER challenges originate. However, to use AMI data to maintain grid stability in real time, the use cases require lower latency and much higher resolution. This means data resolution of one second or greater and exponentially more data—a minimum of 20,000 times more than utilities currently manage from AMI sources. Trying to gain operational value from this amount of data with a centralized system is analogous to having thousands of people throw handfuls of hay onto a stack so that one person can dig through it to find the needle. The better approach is for each person to look for the needle in his or her single handful.

Moving the solution closer to the problem is a design strategy that has succeeded across time in many different fields, and the strategy is now viable for grid operations. As individual distribution transformers experience voltage and bi-directional power flow in the LV grid, edge computing (a.k.a. distributed intelligence or DI) can perform localized analysis, decision-making and automated control within the guardrails of policy engines set and monitored by centralized control.

To learn more about the evolution of distributed intelligence, read Itron's 2020 whitepaper, "Distributed Intelligence: Creating the Future for Utilities."

Stacking Business Case Value

Itron's platform enables increasing benefits by adding applications



Based on publicly available U.S. smart grid business/rate cases and includes Itron internal estimates. AMI – Advanced Metering Infrastructure, DA – Distribution Automation, CVR – Conservation Voltage Reduction, DR – Demand Response, EE – Energy Efficiency (Portal), SL – Streetlights, DI = Distributed Intelligence Apps

THE DI BUSINESS CASE: CONTINUOUS ROI GROWTH

The justification for investing in AMI is well documented and vetted across utilities and regulatory bodies around the globe. Utilities buy an AMI meter that has a standalone justification. But with the ability to run analytics at the grid edge, a DI-enabled meter can do much more. The smart meter applications tested in 2020-2021 address use cases that have long been known to the industry, but had no practical, cost-effective solutions. These applications and others in development (see sidebar) each have standalone ROIs. Yet, the most significant aspect of the business case for a DI platform is that the ROI is not fixed at day one of implementation. Instead, each new application downloaded to the computing platform adds value. Over the life of the investment, the ROI potential of known and unknown future applications is virtually unlimited.

In 2020, long-time Itron customer and testing partner, Tampa Electric Company (TEC) installed 200,000 DI-enabled smart meters. "We get one shot to buy the right hardware to achieve the direction the utility wants to go in over the next 15 to 20 years," TEC's senior director of operations technology and strategy, David Lukcic, said. "With the IoT network platform, we saw we may not take advantage of the DI capabilities on day one, but as the apps and the ecosystem mature over time, we can participate. Plus, in the past we were handcuffed to the direction a technology provider wanted to take us. But the open platform gives us the choice to use Itron's portfolio of apps, or others developed in the app community—or even develop our own. We see that open marketplace as providing greater value and future-proofing for the investment."

THERE'S AN APP FOR THAT

Itron DI-enabled smart meters can download new, independent apps to enable immediate innovations without affecting existing functions performed by the device. Itron is actively collecting laboratory data on more than 300 potential use cases for DI applications. To date, there are nearly two dozen applications on the roadmap for deployment in three categories with **several currently available today:**

Grid Optimization

- Active Transformer Load Management
- Active Transformer Load Monitoring
- DNP3 Client
- **High Impedance Detection**
- **Location Awareness**
- **Meter Bypass Detection**
- Phase Balancing
- Polyphase Targeted Power Quality
- **Residential Neutral Fault Detection**
- Secondary Theft Detection
- Storm Mode
- Under-frequency Load Shedding
- Vegetation Contact Detection

Consumer Transformation

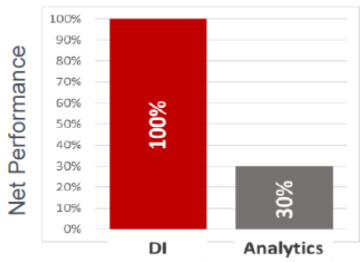
- DI Data Cloud Service
- Smart Payment

DER Integration

- Active Premise Load Shedding
- EV Awareness
- Real-time Markets
- Solar Awareness

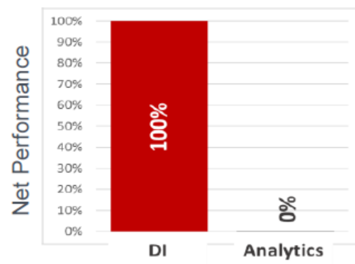
To learn more about these DI applications, see the ***Itron Distributed Intelligence*** *brochure.*

Bypass Theft Detection



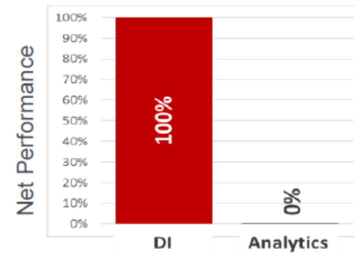
Events Created	10
DI Detected	10
DI False Positives	0
Analytics Detected	10
Analytics False Positives	7

High Impedance Detection



Events Created	5
DI Detected	5
DI False Positives	0
Analytics Detected	0
Analytics False Positives	0

Broken Neutral Detection



Events Created	6
DI Detected	6
DI False Positives	0
Analytics Detected	0
Analytics False Positives	0

Net Performance = (Number Successfully Detected – Number False Positives)/(Number of Events) x 100%

SHOW ME: TESTING THE CASE IN THE LAB

Itron and TEC conducted phase-one testing in early 2020 to compare the cost effectiveness and capabilities of DI against back-office, cloud-based analytics with traditional AMI data. Independent smart-grid consultants at Util-Assist managed the blind testing of data collected from Itron's state-of-the-art DI laboratory (see sidebar). Over the course of a month, Itron engineers manually created occurrences of meter-bypass theft, high impedance and residential neutral fault detection within the one-second data across roughly 60 meters that were performing normal operations for residential demands.

Util-Assist provided load-profile data collected from the lab meters over the course of the month to an established analytics provider. The initial data set included traditional registers and 15-minute interval readings. Despite knowing what they were looking for, and having mature, cloud-based algorithms for detecting the types of use cases created on the meters, the analytics provider was unable to identify any of the occurrences in the limited data set. Util-Assist then provided a second, enhanced data set that included voltage and current readings sampled at 15-minute intervals—a protocol that basic installations can perform with increased backhaul and cloud-data storage costs. From this data set, the analytics provider was able to engage on one of the three use cases.

Throughout the month of testing, the lab meters also ran independent DI applications for each type of use case. The applications' logs showed that the algorithms accurately identified each use-case occurrence in real time and produced no false positives over the course of testing. Table 1 compares the DI results with the results from the centralized, cloud-based analytics.

"TEC wants to expand its use cases to better serve the customer, manage our assets, and provide safe, reliable power," Lukcic said. "For us, this means identifying whether each use case is best deployed from the cloud or the grid edge. For these use cases, the result-based analysis is clearly more favorable with the DI-based apps and indicates the data resolution and attributes available at the grid edge will support new use cases and/or higher certainty than we would have through the cloud alone. That's a major positive for us."

Table 1

Use Case	DI App Results	Cloud Analytics Results
Meter Bypass Detection	100% accurate » 10 occurrences detected » 0 false positives	58% accurate » 10 occurrences detected » 7 additional false positives*
Residential Neutral Fault Detection	100% accurate » 6 occurrences detected » 0 false positives	0% accurate » 0 occurrences detected » 0 false positives**
High Impedance Detection	100% accurate » 6 occurrences detected » 0 false positives	0% accurate » 0 occurrences detected » 0 false positives†

*With additional tuning over time, the cloud-based algorithms would likely produce fewer false positives. A moderate (30-40%) false-positive rate is typical for cloud-based theft algorithms.

**In order to produce accurate results, the cloud-based algorithms would need voltage-to-ground data. The most common meter type in North America (2S) has no voltage-to-ground, only line-to-line voltage.

†The data signature that identifies the use case is lost when meters report only 5- or 15-minute averages of the data. Therefore, back-office analytics tools cannot identify the occurrence.

THIS IS NOT A COMPUTER SIMULATION

Itron's advanced DI lab is a 1/500th scale representation of a complete distribution feeder assembled in the company's Raleigh, North Carolina office. Because computer modeling is insufficient for developing DI applications, the lab is comprised of actual distribution equipment and full-voltage meters, all with differently modeled loads representing the array of major appliances and light bulbs found in homes and businesses.

The lab is fully remote controlled, allowing teams from around the globe to run three-shift operations and collaborate on testing. To date, the lab has simulated more than 300 use cases, and engineers continue to expand the related data sets needed to develop algorithms that can accurately identify use-case occurrences from background noise in the home and elsewhere on the feeder.

The lab generates use-case datasets not only for Itron's DI application developers, but also for third-party developers. With several years' worth of data to share, Itron is enabling rapid DI innovation in the industry while helping to keep the cost of entry down for technology partners.

PRESERVING THE UTILITY'S PLACE IN THE REVENUE STREAM

Keeping up with the rapid evolution of the distribution grid is the challenge of the day. But even as utilities work to integrate DERs into stable operations, the capabilities of DERs change the nature of traditional revenue streams. In order to provide reliable grid services to customers, distribution utilities will need to develop new revenue models to be fairly compensated in a world of local energy transactions that take place on the utility grid. Roughly 15 years ago, a similar situation occurred in the transmission grid. Instead of one utility owning generation, transmission and distribution, deregulation led to numerous companies owning discrete portions of the power grid. Without generation capacity to sell, or end consumers to sell to, owners of the transmission grid reverted to charging fees for the transfer of power across their infrastructure.

As DERs enable consumers to become prosumers—a blend of producer and consumer, dynamically trading their generated or stored power at the grid edge—owners of the distribution grid will need to develop transfer-fee models of their own to maintain revenue levels. In doing so, they can avoid the situation that hobbled regulated companies in the telecom industry. These companies—like electric utilities—were responsible for maintaining sprawling infrastructures, but their revenues disintegrated as customers abandoned land-line phone service for new cellular, cable and fiber alternatives.

Itron's DI platform, which is enabled by an intelligent, multi-application network with multiple communications options, and edge computing and analysis capabilities, provides real-time situational awareness and localized control of the grid to evolve operations and enhance the end customer experience. Today's DI applications enable utilities to enhance grid resiliency, increase DER adoption and improve consumer engagement. Itron's DI platform and Enterprise Application Center are designed with standard support for third-party application development to enable direct customer access to usage data from the meter via standard Wi-Fi. With open standards, the platform makes edge-computing and communication capabilities available for utilities or third parties to develop solutions that manage new transactions among DERs or other products and services in the emerging smart-home market, providing the end customer with easy access to their energy information. Early smart-home solutions for monitoring and controlling energy consumption required specialized hardware that limited adoption. But with the embedded capabilities of Itron's DI platform, cloud data access will allow ubiquitous technologies like Wi-Fi to close the gap between customers, their energy data and the smart-home solutions of the future.

SHOW ME: TESTING THE CASE IN THE FIELD AT SCALE

Phase-two field testing of the same DI applications took place in the TEC service territory during the first half of 2021. The purpose of the field testing was twofold:

» Demonstrate that sophisticated analytic algorithms running locally on revenue meters can successfully detect problem-conditions in a complex, real-world distribution network with a high level of accuracy.

» Demonstrate that DI applications can be remotely deployed and managed at large scale on meters in a production environment without negatively impacting the AMI system's core meter-to-cash operations.

The field testing achieved both goals. The three DI applications were successfully installed "over the air" to 200,000 meters already deployed at customer locations. After a few days establishing baseline performance metrics, the applications began detecting and reporting high-impedance and meter-bypass events. A joint team from TEC and Itron then performed field inspections on a sample of 15 meters that returned DI alarms, verifying visible error conditions greater than 86% of the time (the DI application for residential neutral fault detection returned no alarms).

TEC issued work orders or customer notifications for 13 of the 15 premises. For the two premises with no visual evidence of problems, the team determined it was likely that the app detected a poor connection or a deteriorating conductor early in its failure cycle, before it reached the point of visible damage. To confirm, TEC will replace the service drop and connections at one of the two premises and observe any changes in the high-impedance application. Table 2 captures the DI results from the field trial.

Table 2

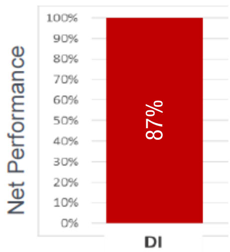
Use Case	DI App Results	Field Inspection Results
Meter Bypass Detection	3 alerts	3 confirmations*
Residential Neutral Fault Detection	0 alerts	N/A
High Impedance Detection	12 alerts	10 confirmations 2 inconclusive**

*Unbeknownst to field inspectors, service savers, which create theft-like conditions, had been installed by TEC at each site to bypass bad underground service cables.

**The apps likely detected early-stage failure, before damage was visible.

TEC initially deployed three DI apps via networked communications to 200,000 customer meters.

Combined DI Applications

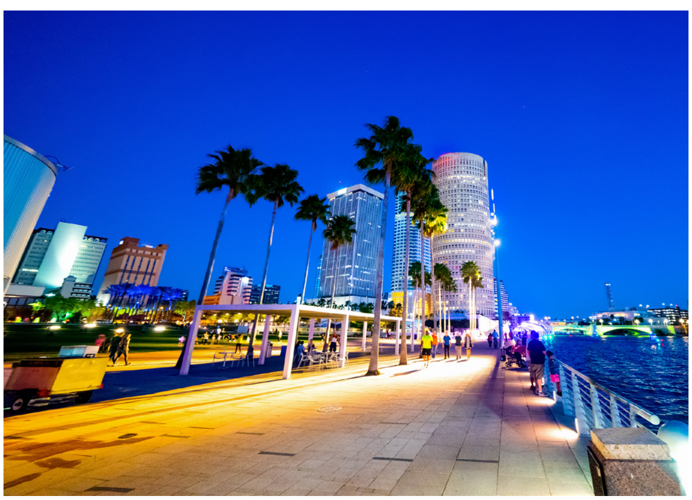


DI Alerts Inspected	15
Field Conditions Confirmed	13
Inconclusive Field Conditions	2

Net Performance = (Confirmed Alerts/Number of Inspected Alerts) x 100%

"Our predictions on DI are proving to be accurate and grounded with each step in the evaluation. We gained valuable, real-time data for revenue protection and customer safety that we didn't have before," Lukcic said. "Not all use cases are a fit for DI, but when they are, the value far exceeds back-office results. With the lab and field trial to ground the value of this technology, we intend to start including DI apps in our regulatory filings like any other analytic software or product that addresses challenges for our customers."

As part of the full population rollout, TEC now has over 800,000 DI-enabled smart meters installed with ~720,000 of them running the grid-edge applications, comprising ~2.2 million applications overall. Monitoring of the field trial will continue into 2022 to quantify effectiveness and continue to assess the total cost of ownership (TCO) and benefit to the as-is and projected business processes.



ADDITIONAL INSIGHTS

In addition to the measured results, the field testing revealed several other valuable insights. The first was the rapid pace of innovation with DI applications. After the initial applications were installed and functioning, TEC's operations engineers asked if it would be possible to receive voltage analysis as well. Within a matter of weeks, Itron updated the set of applications to include the additional capability. "The speed of development is much quicker than traditional methods," Lukcic said, adding that with proof of concept in hand the utility now had to develop a prioritized plan for operationalizing the abundance of new insights for regulatory filings, load profiling, customer experience, distribution planning and/or troubleshooting by operations engineers.

"We learned a lot about our system that we intuitively knew, but to have hard data was very exciting," Lukcic said. The voltage analysis, for example, showed exactly how much voltage drop occurs at premises further down a feeder line and the amount of voltage bump caused by a capacitor bank on the line. Similarly, by tracking voltage anomalies, the utility can proactively tweak its grid-management tactics to ensure customers do no go above or below regulated voltage parameters.

TEC found it could now confirm or dispute the models it used for grid planning and begin shifting to a planned asset management approach on the low-voltage grid. In particular, engineers used the high impedance detection application to observe actual impedance at individual transformers and determine whether or not they were sized appropriately. The application also returned hard data on the "phantom" load factor caused by the adoption of LED lightbulbs and more energy-efficient appliances.

"Now we can take a look at our modeling and see what those planning tools tell us relative to what we're actually seeing in the field, and how we want to adjust them," Lukcic said. The impedance application also revealed where incorrect meter types had been installed at a handful of locations across the service territory.

TEC is working with Itron to install a second bundle of applications in 2022 that includes location awareness, as well as reviewing the business case for the identification of electric vehicles and photovoltaic solar installations. The utility intends to include the new applications in its grid modernization plan for funding discussions with the regulatory commission. Beyond 2022, TEC aims to use DI to integrate the low-voltage distribution grid into its automated distribution management system (ADMS) via virtual transformers. By building upon this intelligent foundation to enable low-voltage grid control, all applications and services that TEC implements moving forward provide more intelligence to unlock more possibilities.

THE HERE AND NOW

With the third generation of DI meters in production and delivering benefits in the field, the next phase in the evolution of the distribution grid is here. This foundation provides continuous insights, analytics and control to redefine what's possible with low-voltage grid management. The first applications will provide substantial benefits for grid optimization, operational efficiency, DER integration and improved customer service. Future applications will be developed in response to market needs and incentives that are currently unknown. Purchasing meters without DI capabilities at this point would block a utility from effectively participating in the rapid evolution of the distribution grid.

Itron is working to give utilities the unlimited potential of AMI + analytics in a manner that focuses on outcomes, while reducing the burdens of increased data management. With the right insights, in the right places, you can monitor, control and evolve your distribution grid to maintain grid reliability, resiliency and efficiency.

THE UTILITY PERSPECTIVE

Tampa Electric Company is a midsized investor-owned utility (IOU) generating nearly 5,000 megawatts (MW) of electricity for more than 800,000 customers across a 2,000-square-mile service area. With the implementation of Customer Resource Management (CRM) in 2016, the organization saw value in the automation of processes and consolidation of data. AMI was the next logical step, and the organization decided to develop it in parallel with other initiatives to achieve a transformational vision for new customer experiences and operational programs. This included an Advanced Distribution Management System (ADMS), work management upgrades, smart city IoT projects, volt/var optimization and DI.

"We recognized there's a lot of value in linking these projects, because there are many common skillsets," said David Lukcic. "We wanted to leverage the data in concert and determine up front the best tools to use and the best places in the organization to perform these functions."

Already a long-time customer, TEC's choice to work with Itron came down to established relationships, competitive price points, existing DI applications and Itron's commitment to building an open platform for flexible innovation and true technology partnerships. "Ultimately, the competitive selection process gave us the confidence to continue working with Itron," according to Lukcic.

TEC wanted to tackle DI right out of the gate, believing that it could give high visibility into the rapidly evolving customer space, while also enabling a proactive operational stance that could drastically reduce the never-ending work of chasing symptoms on the grid and reactively responding to customer complaints. However, the project team didn't build DI into the initial rate case, because they wanted to test individual applications to truly quantify costs and benefits.

"DI is a really exciting concept, and intuitively we knew the value was there. But when it comes down to it, you have to be able to answer fundamental questions for regulators and shareholders," Lukcic said. "Now, the testing and field results allow us to report back that as we layer in new apps, we can have business cases and positive returns that were not part of the original business case, proving that TEC has made the right investment decision."

Itron

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