White Paper

Advanced Transformer Infrastructure ATI™

Unparalleled Versatility Delivers Unparalleled Value

GRID20/20®
Maximize Grid Reliability

June 2019

Grid Modernization is not a luxury…it is now a necessity!

Why?

Because electricity influences ALL aspects of our lives including economic activity; we are entirely dependent upon a reliable electricity supply, at an affordable price.

The grid is of paramount importance… and it is commonly taken for granted, until an outage occurs.

Substantial grid-edge developments and impacts are now routinely outpacing our distribution grid operator's ability to know where, when, and how much unplanned loading demand is aggregating within our grids.

Simultaneously, Distributed Energy Resources (DER) adoption is rapidly accelerating via clean/renewable energy mandates and public outcry; yet our distribution grid assets were never designed, nor even conceived to handle today's increasing Reverse Energy impacts.

And, the average age of our transformer fleets -- which are now enduring these compounding unplanned loading demands -- is now typically between 25-40 years of age. Yes, most transformers were built and deployed many decades before today's grid-edge developments became a rapidly developing concern. These facts are undeniable, but seldom are they surfaced in the public's eye.

The sobering reality is that the most expansive, most vulnerable and most volatile segment of the entire distribution grid is arguably the span of grid assets located between our well-monitored substations, and our new endpoint (aka, smart) meters. Alarmingly, this same expansive "intra-grid" segment which in the US is comprised of 40+ Million transformers, power poles and power lines remains the LEAST monitored by grid operators. Similarly, Ontario Canada's intra-grids are comprised of over 450,000 transformers, power poles and power lines, that are similarly under-monitored at this time.

So What?

As a result of unplanned grid-edge impacts, and DER, and aging transformer fleets collectively developing, grid Reliability, Resilience, Cybersecurity, Energy Efficiency and grid safety expectations are subsequently being threatened. It is now clear that Advanced Meter Infrastructure (e.g., AMI, smart meters) alone is not reliably able to provide the critical, accurate, timely, unique, granular intra-grid information that is effectively captured and reported by today's emerging Advanced Transformer Infrastructure (ATI)™.

Furthermore, Financial Liability Risk has perhaps never been higher for our vital electricity providers; as the January 2019 bankruptcy filing of Pacific Gas & Electric (US) has illustrated. No longer can utilities confidently rely upon hefty insurance liability policies, Regulator intervention, legislative intervention, and/or their corporate veil to fully insulate and/or protect them from crippling, or devastating lawsuit vulnerability. This unsettling reality creates the potential for some utility providers to experience decreased borrowing power, and/or growing investment trepidation by shareholders in the wake of PG&E's ongoing bankruptcy matter.

While many leadership representatives have been acutely focused on advancing Electric Vehicle adoption and/or rooftop solar deployments to decrease Greenhouse Gas emissions, and/or legalizing marijuana growing at the commercial and residential levels to meet societal demands and to increase tax revenues, the electric distribution grid has quietly become the recipient of unplanned loading impacts that require our immediate attention. The distribution grid represents a critical, fundamental infrastructure that is now over 65 years of age. We are kidding ourselves to believe that distribution grids are impervious to substantial failures given today's ongoing, unplanned grid-edge impacts, combined with never-conceived practices, all occurring upon our aging grid assets.

To this end, Grid Modernization is indeed no longer a luxury. Enhanced grid monitoring and grid future-proofing has now become a basic requirement for ongoing economic stability, personal safety, societal fulfillment, increasing economic development, and our overall growth and advancement.

Advanced Transformer Infrastructure (ATI) presents a viable, cost-effective solution enabling utility operators to proactively reveal and resolve unsavory grid conditions; this now-proven technology emergence signals the next meaningful phase of our necessary grid modernization process.

Unparalleled Versatility

Heretofore, grid operators have been unable to proactively view intra-grid conditions. This reality has resulted in decades of reactive grid management due to insufficient, cost-effective technology. In other words, costly power outages and customer complaints have predominantly driven the industry's historically reactive grid management practices.

Since operators had no access to forewarning-capable technology options, the fact has been that reactive behaviors have resulted in ongoing costly outcomes for ratepayers (e.g., unnecessary outages, premature asset replacements, unplanned truck rolls, and inconvenient social and economic impacts).

But, by now leveraging the substantial intra-grid data and automated alerts value presented to operators by ATI, various meaningful benefits can be delivered for all stakeholders.

The following examples represent a portion of the growing list of opportunities that are now created by effectively capturing intra-grid data via ATI, and then converting it into actionable information.

Versatile Applications

1. Power Outages Avoidance (i.e., reduced costly outages occurrences)
2. Accelerated Power Restoration (i.e., automated alert messages issued to operators)
3. Transformer Overloading Identification & Premature Transformer Failure Avoidance
4. Safe Adoption of Distributed Energy Resources (DER) (i.e., primarily residential)
5. Safe Adoption of Electric Vehicle (EV) Charging Stations (i.e., commercial and residential)
6. Safe Adoption of Legalized Marijuana Growing (i.e., commercial and residential)
7. Improved Distribution Asset Mapping Accuracy (i.e., updating antiquated asset information)
8. Cryptocurrency Mining Identification (i.e., residential)
9. Power Theft Identification (i.e., ongoing pre-meter taps, new pre-meter taps, etc)
10. Transformer Longevity Determination (i.e., maximizing Capital investment value for ratepayers)
11. Asset & Battery Storage Placement Planning Insights (i.e., strategically maximize DER value)
12. Greenhouse Gas (GHG) Emissions Reduction Enhancement (i.e., Energy Efficiency gains, safe EV adoption, decreased carbon fuel generation, etc)
13. Reliably Empowering Artificial Intelligence for Operations/Planning/Budgeting Purposes
14. Reduced Fire Risks and Liability Risks for the Benefit of All Stakeholders
15. Automated Intra-grid Alerts (i.e., 'hands-free' proactive grid monitoring = watchdog feature)

16. SCADA-like Functionality (https://grid2020.com/private_files/GRID2020_UC_SCADA.pdf)

The Power of Data

How does any one platform facilitate so much diverse value?

Regarding Advanced Transformer Infrastructure, the answer is two-fold:

1. ATI accurately captures real data, at the transformer. This unique, timely, granular, comprehensive information is reliably attainable from ATI.
2. ATI reveals actual intra-grid conditions that operators can trust to be real. This unique information, enhanced by Automated Alerts and exception reporting, focuses operators on existing and emerging issues that are otherwise typically unnoticed until after a costly problem or failure has materialized.

The following data points captured by intra-grid sensors drive the unparalleled value of ATI:

Energy	**Power Factor**
Delivered Total Active Energy [KWh]	**Phase Angle**
Received Total Active Energy [KWh]	**RMS Voltage**
Delivered Total Apparent Energy [KVAh]	*Instantaneous [V]*
Received Total Apparent Energy [KVAh]	*Maximum per interval [V]*
Delivered Interval Active Energy [KWh]	*Minimum per interval [V]*
Received Interval Active Energy [KWh]	*Average per interval [V]*
Delivered Interval Apparent Energy [KVAh]	*Voltage Imbalance [%] (PDTM only)*
Received Interval Apparent Energy [KVAh]	**RMS Current**
Interval Reactive Energy [KVARh]	*Instantaneous [A]*
Demand	*Maximum per interval [A]*
Delivered Interval Active Demand [KW]	*Minimum per interval [A]*
Received Interval Active Demand [KW]	*Average per interval [A]*
Delivered Interval Apparent Demand [KVA]	**Line Frequency [Hz]**
Received Interval Apparent Demand [KVA]	**Internal Temperature [ºC, ºF]**
Interval Reactive Demand [KVAR]	**Outage Notification**

The distribution intra-grid represents a previously untapped data-rich environment. Heretofore, operators have commonly been relegated to trouble-calls to guide them. But with ATI, operators

can now take unparalleled command of the distribution space. ATI unlocks a wealth of previously unknown information that facilitates a series of utility, economic, conservation, and societal gains.

The unique intra-grid data and related analytics capability created by Advanced Transformer Infrastructure (ATI) is indeed unparalleled. ATI will serve as a necessary complement to AMI; and will provide both AMI and Non-AMI enabled operators with vital Operations, Planning and/or Budgeting upsides.

Given the exceptional versatility and related value presented by ATI, grid operators will possess the capability of presenting convincing Capital Expense/rate-based grid modernization improvement projects to their Regulators. To protect the growing expectations of our grids, ALL stakeholders will need to invest in this vital, next phase of our ongoing grid modernization evolution.

But What is the REAL Problem?

Fact 1 - Every electricity distribution grid is foundationally supported by transformers. The US distribution transformer fleet contains approximately 40+ Million assets; the Ontario Canada fleet consists of an estimated 450+ Thousand assets.

Fact 2 - Most transformer fleets around the globe now average 25-40+ years of age.

Fact 3 - During the last 5-10 years, substantial unplanned grid-edge developments have achieved an accelerated adoption throughout the US, Ontario, and abroad. While many markets have also experienced significant smart meter (i.e., AMI) penetration, these endpoint meters have not been able to reliably or sufficiently support utility operators' handling of the prolific, compounding grid-edge impacts. AMI is merely a piece of our grid modernization process; our grids require more than AMI.

Rooftop Solar

EV Charging Stations

Pre-Meter Power Theft

Cryptocurrency Mining

Fact 4 - Generally speaking, without Advanced Transformer Infrastructure (ATI) assisting them, most electric operators have no idea where, when, or how much unplanned loading burden is

striking our aging transformer fleet infrastructure – now, or in the future. These grid-edge occurrences are already vast, are rapidly escalating; whether individually or collectively, they present imminent transformer overloading risk. As transformers become overloaded, the risk of power outages escalates, and so does the risk of fire, economic impact, loss of property, possible loss of life, and associated liability risks.

Unfortunately, it will take just one failed transformer, occurring at the 'wrong place', and the 'wrong time' to catalyze a fire. With 40+ Million transformers in the US alone (450+ thousand in Ontario), combined with unknown, unplanned loading/overloading impacts, our risk of fire, related damages, and liability is indeed real. Hoping these risks will not occur, or waiting until they do, is NOT a wise plan.

These realities are just getting started as the ongoing adoption of various grid-edge activity is quickly ramping up due to growing public desire, and the need to fulfill ever-increasing clean energy mandates.

Examples of Unplanned Loading Culprits:

1. Electric Vehicle Charging Stations – primarily residential locations
2. Legalized Marijuana Growing – primarily residential locations
3. Cryptocurrency mining – primarily residential locations
4. Pre-Meter Power Theft

Fact 5 - Utility operators typically do have awareness of Distributed Energy Resource (DER) locations within their grid. However, today's distribution grid assets and architecture were never imagined (or designed) to someday handle the impacts now being caused by DER (e.g., rooftop solar, wind).

Commonly, DER deployments will yield excessive localized electricity generation; this results in unplanned Reverse Energy being driven into our grids. Unfortunately, our grid assets were never designed to safely and reliably handle these Reverse Energy impacts.

Fact 6 - Collectively, these aforementioned 'culprits' are now compounding negatively throughout our distribution grids. Without Advanced Transformer Infrastructure (ATI) being deployed, operators will remain substantially unaware of grid-edge burdens; until customer complaints, power outages, economic impacts, associated fire and liability instances demand their attention. This undeniable Reliability Risk, and related Fire/Liability Risk scenario is real, and it is rapidly increasing.

But we now have access to helpful technology through the game-changing benefits provided to electric operators via ATI.

Simply, our growing risk conditions are avoidable via Advanced Transformer Infrastructure (ATI).

Unparalleled Value

Advanced Transformer Infrastructure's benefit merely starts with creating critical intra-grid insight.

To date, few (if any) grid operators are informed by residential customers when and where they are installing Electric Vehicle (EV) charging stations, legalized hydroponic marijuana growing equipment, and/or cryptocurrency mining server pods. In essence, distribution grid operators have no idea where, when, and how much unplanned loading (i.e., transformer overloading and/or overheating) impact is proliferating within their grid as a result of these rapidly expanding grid-edge occurrences. This stark reality creates serious grid safety, fire risk and liability risks for ALL stakeholders.

Of similar concern is the rapid adoption of Distributed Energy Resources (DER). Many clean/renewable energy adoption mandates are now in place in the US (e.g, New York, California, Pennsylvania, Hawaii, D.C, etc), Canada, and others. An estimated 22 US states and the District of Columbia have declared their commitment to honor the United Nations adopted Paris Agreement of December 2015 (whether the US Federal government does/does not embrace the global community's related interest). However, the distribution grid architecture is not prepared, nor designed to fulfill these aggressive expectations.

Admittedly, most of us do not realize what these items actually mean to the state of our grid. Rather, most of us are simply focused on doing 'our thing'; we typically assume the grid will continue to endure.

Question 1:

Why are EV charging stations a grid-related concern?

Because most EV charging stations create a significant unplanned load burden on the related transformers. EV charging stations are documented to cause the equivalent of 1 to 2.5 additional homes worth of unplanned loading on the upstream transformer. Adding an EV charging station into the neighborhood is like adding 1 - 2.5 homes "overnight"; and expecting the 25-40+ year old transformer to routinely and reliably service that demand without incident. If two EV charging stations are installed in the same neighborhood, then we have just added up to 2 – 5 homes worth of unplanned load burden onto the same aged transformer; which was never imagined to handle such loading when the utility personnel installed it, decades earlier. This is how overloading occurs, and spawns the risk of transformer failure, power outage, fire, and related damages. Each EV presents a different loading demand, but all EV's present a substantial unplanned loading impact upon our aging transformer fleet assets. The following two articles help to further express this reality:

https://www.clippercreek.com/charging-times-chart/,
https://www.lek.com/insights/ei/preparing-grid-uptake-electric-vehicles

Question 2:

Why is legalized residential marijuana growing a grid-related concern?

The electricity needed to hydroponically grow four pot plants is nearly equal to that needed to operate 29 refrigerators, the Northwest Power and Conservation Council estimates. This implies that for every residential grower who simply produce four (4) hydroponic plants, the associated transformer will immediately be exposed to the equivalent power demand of 29 additional refrigerators. If two residential growers connected to the same transformer occurs, the upstream transformer is now serving an unplanned load burden of 58 refrigerators. Keeping in mind that

most transformers were installed decades ago, and with little to no expectation of this type of grid-edge loading burden ever emerging. See the following article:

https://www.govtech.com/dc/articles/Marijuana-Home-Growers-Effect-on-Colorado-Power-Grid-Proves-Substantial.html

Question 3:

Why are DER adoption efforts and Clean/Renewable Energy mandates creating a concerning issue for our distribution grids?

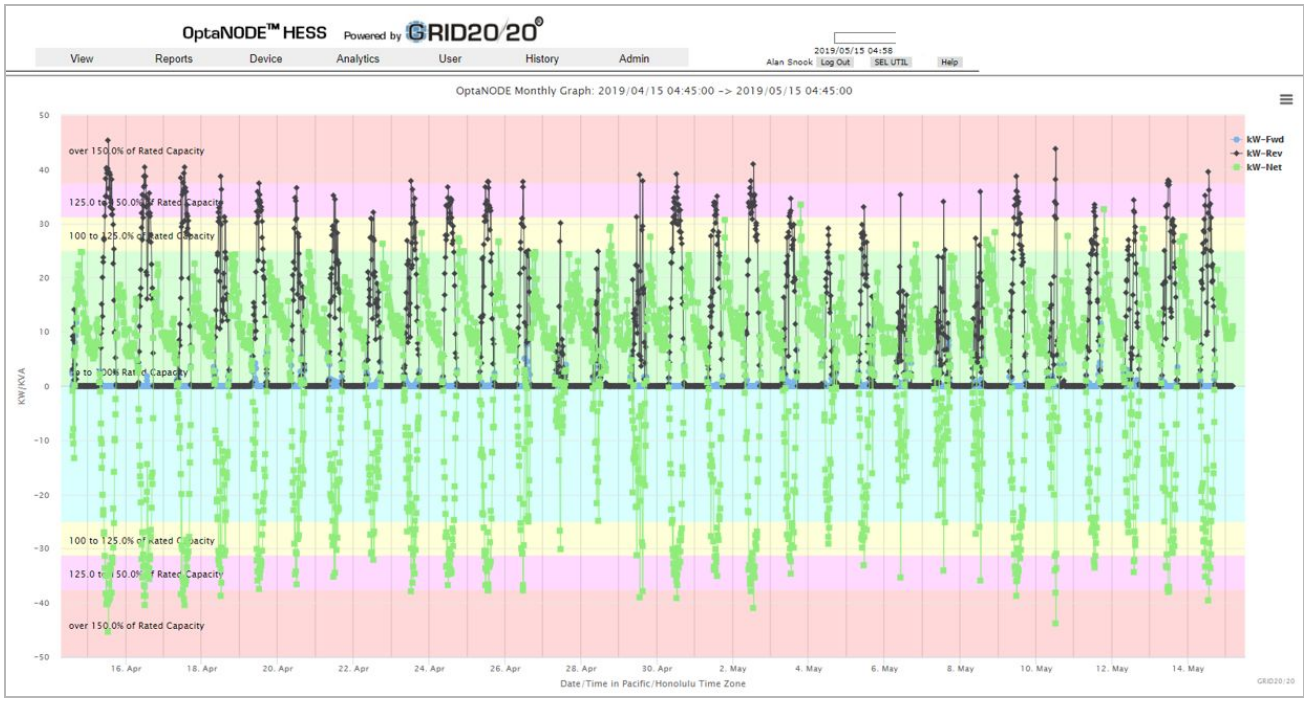
Because the distribution grids supporting most domestic and international societies are comprised of transformer fleets that were never imagined, nor ever designed to receive Reverse Energy. DER typically results in excess (Reverse) energy being driven into the grid, through transformers, from the DER source (e.g, rooftop solar on residential homes).

To this date, no one seems to empirically understand the various grid and safely impacts of DER driving Reverse Energy into the distribution grid. Thus, no one truly knows:

A. what happens to transformers that are routinely or occasionally receiving Reverse Energy;
B. what happens when the designed capacity of a transformer is periodically or routinely exceeded in reverse due to DER impacts;
C. what happens to related circuit feeder voltages when DER delivers Reverse Energy into the grid.

All of these unknowns (and others we have not yet discovered/realized) equate to Grid Safety, Grid Reliability, and Grid Resilience Risks. Whether we have or have not yet seen increased transformer failures resulting from DER, common sense must prevail. Imagine operating any device in the reverse direction for which it was designed -- doing this each day……for hours at a time -- and expecting that the device will simply withstand the never-imagined ‘abuse’ without incident or outright failure.

In essence, we are now exercising this precise mentality by expecting our distribution transformers to reliably and safely continue operation, while being expected to withstand a reverse energy condition they were never conceived to handle. Due to ATI, we no longer need to gamble with this serious risk.



NOTE: This graph illustrates how DER can create Reverse Energy Overloading on the upstream transformer. In this case, the transformer is receiving enough Reverse Energy daily, forcing it to operate between 125% - 150% of its rated design as established by the transformer manufacturer. How long can this transformer, and thousands or millions like it, sustain this abuse until failure is experienced?

As the 2017 Napa Valley fire (US), and the 2018 November Camp Fire (US) clearly illustrated, electricity grid asset failures have the ability to create catastrophic loss. Furthermore, as the 2018 Camp Fire disaster ultimately revealed, the corporate veil of utility operators can now be legally pierced via lawsuits claiming negligence, punitive damages, etc. As the January 2019 bankruptcy filing of Pacific Gas & Electric (PG&E) illustrated, loss claims and lawsuit damages can financially overwhelm and even topple the largest utility operators; a new era in Liability Risk Management has just begun. https://www.cnn.com/2019/01/29/business/pge-bankruptcy-fires/index.html

Summary

Collectively, via today's ongoing grid-edge advancements, the unknown occurrences (i.e., where, when, how much) of these grid-edge impacts, the unknown DER impacts, all collectively striking our aging transformer fleets, there is a new challenge facing distribution grid management. Our

historic reactive grid management process is now antiquated; waiting for imminent grid issues and power outages to occur is no longer necessary.

Using time-proven, cost-effective innovative IoT technology comprising the Advanced Transformer Infrastructure (ATI) solution, utility operators now have the necessary technology available to help identify, monitor, and proactively remedy these serious emerging grid issues. The use of ATI's unique intra-grid information will substantially benefit the Operations, Planning, and Budgeting departments of our valued electricity providers. Thus making our grids more reliable, resilient, efficient, and safe.

ATI solves real problems, and simultaneously creates a new era in proactive grid management.

The introduction of ATI signals the next phase of our ongoing, much-needed Grid Modernization initiatives. Given the substantial, aggregated distribution grid impacts associated with compounding grid-edge developments (aka, advancements), utility operators will now require intra-grid 'vision', as is uniquely and accurately achieved by the Advanced Transformer Infrastructure (ATI) solution.

Making the Capital Expense Commitment

By leveraging the industry's fastest-to-install, most accurate, and most wide-ranging cost-effective **OptaNODE®** intra-grid sensors, today's transformer fleets can be rapidly converted into a useful form of "smart transformers". Of great importance, the OptaNODE intra-grid sensors do not require power outages for installation, and they can be swiftly installed without any end-use customer involvement.

For the purposes of ensuring/improving Grid Reliability, improving Grid Resilience, ensuring safe adoption of DER, striving to reduce Greenhouse Gas (GHG) emissions, and pursuing Energy Efficiency, Advanced Transformer Infrastructure (ATI) will meaningfully address the industry's rapidly-evolving needs.

Returns on Investment associated with Advanced Transformer Infrastructure are typically rewarding for all stakeholders. ATI will enable most electric operators to present convincing Capital Expense rate-based grid modernization improvement projects to their Regulators. Deployment of ATI will simultaneously facilitate meaningful financial, conservation, productivity, and safety gains for all parties.

ATI - Various Benefits:

For the last 6-10 decades, electric operators were tasked with "keeping the lights on". Now, electric distribution operators are under constant pressure; to improve Reliability, fulfill clean/renewable energy mandates, control Operations expenses, improve grid Resilience, manage DER integration, prevent Cybersecurity threats, achieve Energy Efficiency, safely adopt EV charging stations, fulfill Regulator expectations, etc… all while somehow maintaining revenues/fiscal stability.

By providing operators with novel intra-grid vision, a series of presently unknown instances and unsavory conditions will be identified/revealed. As a result, operators will have a proactive (no longer reactive as has historically been the case) awareness of multiple presently-unknown conditions.

Examples (not an exhaustive list):

A. Forward and Reverse Energy influenced loading/overloading/overheating of transformers,
B. above/below ANSI standard voltages fluctuations,
C. identification of unplanned loading due to residential EV charging station locations,
D. identification of unplanned loading due to residential marijuana growing,
E. identification of unplanned loading due to cryptocurrency mining,
F. transformer temperature/heat mapping indicators,
G. transformer-centric outage notifications to facilitate accelerated restoration,
H. miscellaneous unplanned loading/overloading (e.g., power theft, authorized unmetered uses, etc),
I. actual quantification of Reverse Energy (kWh) entering the grid at the transformer level,
J. recognition of ideal battery storage locations given actual Reverse Energy (kWh) entering at the transformer level, etc…

Through never-before-achieved intra-grid awareness, operators will receive the ability to foresee emerging grid conditions (versus waiting for and responding to trouble calls), and will benefit from taking subsequent pro-action where/when appropriate. ATI will further benefit operators via:

A. fewer trouble calls (i.e., reduce costly unplanned truck rolls),
B. improved SAID/SAIFI performance,
C. increased metered revenues (fewer outages, identified metering errors, etc)
D. decreased Liability Risk (reduced catastrophic/disasters risk related to asset failures/fires)
E. improved planning capability given proactive insights of grid conditions/developments
F. improved Capital Expense budgeting via increased grid visibility/predictive needs capability

G. safe DER adoption (addresses Clean/Renewable Energy initiatives while reducing Liability Risk)
H. enhanced Distribution Automation (easily integrate intra-grid sensor data into SCADA, OMS, etc
I. reduced fire and wildfire risk (i.e., proactively revealing overloaded and over-heated high-risk transformers, automated alerts being delivered to operators via SMS text and/or email)
J. improved operating efficiencies

ATI - Sample Deliverables:

By strategically deploying cost-effective, highly accurate, fast-to-install intra-grid sensors, operators will:

A. Identify unknown/unplanned transformer loading occurrences (provide intra-grid visibility),
B. Capture/monitor/resolve unplanned transformer overloading/over-heating occurrences,
C. Quantify actual Reverse Energy (kWh) entering the grid at the transformer level due to DER,
D. Evaluate loading/overloading/voltage impacts associated with DER and unplanned grid-edge activity,
E. Empirically determine intra-grid sensor cost-value/deployment density and business case justification,
F. Empirically estimate GHG reduction (via DER offset) and Carbon Emission Reduction credit value,
G. Improve Grid Reliability, and Grid Safety (safe adoption of DER and unplanned grid-edge installations),
H. Facilitate improved Grid Planning capability and Capital Expense Budgeting,
I. Determine SAIDI and SAIFI improvement opportunity (proactive grid monitoring, automated alerts)

Advanced Transformer Infrastructure (ATI)™ will clearly demonstrate the multiple value propositions and savings created by leveraging data uniquely revealed by intra-grid sensors. Proactive use of ATI's unparalleled data for analytics purposes, and the ability to deliver rapid Automated Alert Notifications will establish a new paradigm for operators. This pioneering technology will deliver a 'hands-free' grid monitoring watchdog solution and will accelerate the development of Artificial Intelligence platforms.

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