PREDICTIVE GRID QUARTERLY REPORT

Building a Predictive Grid for the Motor City
Executive Overview
In June of 2014, Tollgrade partnered with DTE Energy to work together on a Clinton Global Initiative (CGI) Commitment to Action for a comprehensive grid modernization project in the Detroit metropolitan area. The goals of the commitment were two-fold:

1. Prove out the concept of a “Predictive Grid” across DTE Energy’s service territory. To achieve such a grid, DTE Energy deployed Tollgrade LightHouse Smart Grid Sensors, a technology capable of monitoring the distribution network to find the tell-tale signs of faults and asset health problems before outages occur.

2. Publish the results in a series of eight Predictive Grid Quarterly (PGQ) Reports over the next two years. These reports aim to provide a new industry benchmark to show how U.S. utilities can better detect and respond proactively to power outages by monitoring their distribution grid with Smart Grid Sensors. The data will reveal new methods in the battle to prevent outages that we expect will become larger industry-wide adopted standards. Sharing the results of the CGI project at DTE Energy and other Tollgrade Sensor deployments nationwide, we hope to identify patterns in the sensor data that could help utilities adopt a proactive posture toward preventing outages.

The commitment entitled, “Building a Predictive Grid for the Motor City,” was featured on stage during the closing plenary session moderated by President Bill Clinton at the CGI America meeting in Denver, Colorado (watch the video).

Why this Project Matters to Detroit and the Nation
The distribution piece of our electric grid is the unsung hero of the grid and our economy. According to EEI, 90% of outages happen on the U.S.’s distribution grid network. But, predicting and responding to outages on this part of the network is very difficult because of its size. For example, in the U.S., the distribution network is the largest part of our electric grid spanning 6.6 million miles – that’s like going to the moon 13 times and back. Due to the sheer size of the distribution grid, historically there has been very little real-time data to help utilities proactively detect and respond to outages.

Predicting outages can make a significant economic impact. The Detroit metropolitan area, for example is the backbone of the nation’s automobile industry which employs over 700,000 Americans and represents roughly five percent of the United States’ Gross Domestic Product (GDP). Power outages here directly impact the nation’s GDP. Building a Predictive Grid around Detroit can make a very large, positive impact on the local and national economy. In the Northeast blackout of 2003 that was caused by a tree hitting a power line and creating a cascading series of outages, the Daimler Chrysler plant in Ohio lost production at 14 of its 31 plants and had to scrap 10,000 vehicles (see Power Blackout Risks). By monitoring and detecting these events in Detroit, DTE Energy hopes to stop preventable outages from occurring – and significantly reduce the impact the power outages have on the local economy, businesses and households.

Preventing outages could make a significant economic impact to the nation as well. The nation’s aging, 100 year old electricity grid is starting to break down. Aging assets reaching their natural end-of-life cause nearly 25 percent of the outages on our nation’s grid. For example, it is estimated that the average U.S consumer loses power 90 minutes a year compared with 70 minutes in the UK or 53 minutes in France (source: IEEE). While many outages can be attributed to weather related incidents, estimates show that non-storm related power outages cost the country as much as $200 billion (source: Morgan Stanley). Many of the outages occur when assets start to breakdown or fail, and this is where a
Predictive Grid alerting utilities to problems before power outage occur could be a game changer, not only for a more reliable grid but for the nation’s economy as well. In this report, we show some of the work produced to date that begins to classify events that report the early indicators of grid problems, before they turn into outages.

The Predictive Grid® Solution Components
The Tollgrade LightHouse Predictive Grid platform consists of:

- **Medium Voltage (MV) Sensors** that are software-defined, inductively powered (battery-free) with flexible cellular or Wi-Fi communications. These sensor are easy to install with a “hot stick” (see below) and can be safely deployed on the line in a matter of minutes. Because of their ease of installation, low cost and no maintenance requirements, monitoring the distribution network is now an affordable reality.

- **Predictive Grid Analytics software** communicates with sensors to bring back all of the events that are captured by MV Sensors into centralized software, classifying power disturbances and outages to provide utilities with the situational awareness needed to quickly respond to load planning, outages, and power quality challenges.

The LightHouse platform combines its highly accurate sensor technology with Predictive Grid analytics software to classify grid conditions and assess the health of the network in real-time. This grid health data can then be analyzed by engineers within utilities so that they can better understand more of the “cause and effect” behind disturbances like momentaries, outages or equipment failures. Once events are classified, customizable rules and alarms can be defined to alert utilities to conditions that could cause grid failure like inefficient operating conditions, deteriorating asset health, or indications of anomalous behavior that are early indications of future outages. Visualization tools pinpoint locations where these problems occur so crews can reduce their foot patrol and drive times. For many utilities, they can get a 10-15 minute advance notice in outage situations. This, combined with the location information and event history, dramatically improves power restoration times and crew safety.

Key Findings
In this inaugural edition of our Predictive Grid Quarterly Report, our goal is to begin to build an industry-wide benchmark that can be used to measure the effectiveness of technology used to prevent outages and share lessons learned to help other utilities implement a Predictive Grid.

This report provides:

- Six months of sensor data gathered from multiple utilities (including DTE Energy) that show early warning patterns of disturbance that can help utilities take a more proactive stance toward preventing outages.
- Specific examples from the ongoing project at DTE Energy where the team has been able to classify events that could help other utilities prevent future outages.
• Valuable lessons learned at DTE Energy that will help others plan their Predictive Grid projects.

Some of the key findings included in this report that will be expanded in more detail include:

• 86 percent of the events Tollgrade monitored the last six months across their sensor footprint were a new category called “Line Disturbance” (Line Disturbances are short lived fault events that do not trip protection or typically raise alarms) compared to 10 percent momentaries and 4 percent power outages.

• Line Disturbances and Outages follow a similar pattern, where most events occur in the summer months then drop off dramatically in October, with a slight uptick in the winter during the months of November and December. This data shows how closely Line Disturbances are related to Outages and how important it is to view Line Disturbances as an early indicator to outages. A key finding of this report is that Line Disturbances should be closely monitored and adopted as a new category essential to preventing future outages.

• After three months of monitoring Line Disturbances on the DTE Energy network, the team has been able to classify actual events that cause power outages. We share the waveform analysis and discuss its significance.

• By monitoring Line Disturbances, other utilities have been able to take action, and as a result prevented outages from occurring. For example, a northeastern utility in the U.S. discovered a failing voltage regulator before it caused a power outage at 2,000 households, by quickly responding to Line Disturbance alerts from the LightHouse system well in advance of the eventual alarms that would have come into their SCADA system (details on the next page).

Predictive Grid Trends from All Sensors the Last Six Months

Tollgrade LightHouse Sensors are currently deployed at over 30 utilities on three continents, including DTE Energy. As part of our CGI Commitment, we are working to develop new industry benchmarks by gathering data monitored by LightHouse Sensors across all of our deployments and classifying that data in our Predictive Grid Analytics software. A key metric in this benchmark is a new event category called “Line Disturbance” that previously could not be measured without Tollgrade Sensors because Line Disturbances do not trip the protective devices most utilities install on their grid.

![Monthly Trends 2H 2014](image)

86% of events are Line Disturbances
10% of events are Momentaries
4% of events are Outages

Figure 1: All Data Monitored by LightHouse Sensors 2H 2014
Our analysis shows that over 86% of the events monitored the last six months were Line Disturbances – which turn out to be an important clue needed to prevent future outages.

Key Findings

- **86 percent of events classified by sensors are Line Disturbances** that precede an outage and are the early warning indicators that some disturbance has come into contact with the power line (e.g. a tree or two conductor wires touching) or an asset on the grid is about to fail (e.g. voltage regulator or pole top transformer failing – both of which are outlined more in the report). By analyzing Line Disturbances, utilities can start to predict problems before they cause an outage. Because Line Disturbances do not trip any protective devices, utilities have not had visibility into these events or understand just how frequently they occur on the network.

- **10 percent of the events classified by sensors are Momentaries** which are short outages that cause clocks to blink, computers to lose their data or automobile manufacturing lines to stop unexpectedly, damaging equipment. EPRI estimates that momentaries and power quality events cost businesses as much as $15-$20 billion annually. Tollgrade LightHouse Sensors specifically classify and alert utilities to momentaries as they are happening in real-time. Included in the Momentary event notification details, sent to a utility by LightHouse, is the location where the problem is occurring so it is much easier for troublemen to go out and find problems that otherwise would be very difficult to pinpoint.

- **Only 4 percent of events classified by sensors were actual power outages.** As we build trending data over the next two years, this is a metric we hope to watch closely to see if utilities using LightHouse Sensors experience fewer outages compared to their peers not monitoring the distribution network.

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**Trends and Analysis – 6 Month Trends**

The graphs in Figure 3 show the overall monthly trends for each event type. Line Disturbances and Outages follow a similar pattern where most events occur in the summer months then drop off dramatically in October, with a slight uptick in the winter during the months of November and December. This also shows how closely Line Disturbances are related to Outages and how important it is to view Line Disturbances as an early indicator of an outage. By contrast, Momentaries are the highest in the summer months (most likely due to lightning strikes) and dramatically drop off in the winter.
Summer Months: July, August and September
Line Disturbances and Outages are highest in the months when leaves are on the trees. When trees hit the power line, this causes a slight disturbance that is registered by the LightHouse Sensor. By knowing where trees are hitting the power lines, a utility can better pinpoint their vegetation management budget and prioritize tree trimming exercises. Additionally, the number of Line Disturbances, Outages and Momentaries was highest in July and August which is typical of thunderstorm season.

Winter Months: October, November and December
During the winter, the cause of Line Disturbances and Outages shift from vegetation to other reasons such as ice storms, cars hitting poles during ice storms and trees falling over during wintry conditions. Understanding these overall trends will help utilities better understand how to look for problems on their network and get ahead of power outages.

The Predictive Grid in Action: The Importance of Line Disturbances
On December 3, 2014, LightHouse Smart Grid Sensors installed on a 34.5kV network started reporting Line Disturbances at about 16:00 hours on B and C phases of the distribution network at a large Northeastern utility in the United States. Over the course of the next several hours, additional Line Disturbances were reported with a similar waveform shape. The utility waited for several events to occur and then dispatched a troubleman to investigate the area. The sensors located the origin of the fault so there was no need to patrol the entire 20 mile section of network looking for problems in the dark.

When the troubleman arrived at the substation, he found a voltage regulator arcing internally and about to fail. A voltage regulator is a large oil filled device that contains a significant amount of oil that spills when its tank ruptures. Seeing the gravity of the situation, the utility acted immediately and in the next hour was able to prepare a plan of attack by taking a planned 20 minute outage to isolate the equipment and make the repairs. Had the voltage regulator ruptured, it would have spilled oil onto the ground and caused a fault which would have blown the 34.5kV fuses, interrupting power to about 2,000 customers for two to three hours causing a total 360,000 Customer Minutes Interrupted (CMI).
Tollgrade LightHouse Sensors were the key to identifying this failing device. There were no visual indications that the voltage regulator was about to fail. The fault current was too low to be detected by the substation relays connected to the circuit breaker. Therefore, the circuit breaker did not have any momentary interruptions and there was no notification by any SCADA devices. Without Tollgrade LightHouse Sensors, this utility would have been dealing with a full power outage impacting 2,000 customers.

Figure 3: Picture of Voltage Regulator and Waveform Indicating it’s Impending Failure
DTE Energy

DTE Energy started rolling out Tollgrade LightHouse sensors in late 2013 across a portion of their electric grid. DTE Energy’s total electric grid consists of approximately 2.1 million customers, 2,600 feeders and over 1,000 distribution substations. The overall LightHouse deployment is being planned as a phased rollout following the project milestones listed below. Currently, DTE Energy is in the “Sensor Installation” and “Event Classification” phase. For the purposes of this report, we will focus on Event Classification.

Event Classification

During weekly meetings, each event captured by the Tollgrade LightHouse system is reviewed by the project team. These events are then cross-referenced against DTE’s outage system. If a corresponding outage or trouble call is found, the cause of the outage is recorded. As more waveforms are collected, Tollgrade is developing a system for classifying these event “fingerprints” for each type of outage, such as a tree, animal or vehicle contact. These fingerprints can then be used to develop a better database of events to automatically classify faults, which in turn can be used by DTE Energy (and other utilities) to prevent outages. For example, if the system determines that an asset like a transformer or voltage regulator failed, the repair crew can take action to do preventative maintenance rather than be caught off guard by an unexpected outage on the network.

In this report, we share three significant event types classified by the LightHouse Sensors:

- Underground cable failure
- Electric wire falling to ground
- Pole top transformer outage

We explain each in more detail below.

Underground Cable Failure

Single phase underground cables are typically found in underground residential developments (URDs) and supply between 50 and 100 houses. Many of these cables in the United States were installed in the 1970’s when there was a large suburban expansion. Utilities are actively working to replace these 40 year old cables, but the size of the initiative is overwhelming. Detecting cables that are approaching imminent failure using Tollgrade LightHouse sensors will allow utilities to take that cable out of service prior to causing an outage.

![Underground Cable Failure Waveform](image)
During our initial monitoring period, we were able to classify the waveform for an Underground Cable Failure event (see Figure 5). By classifying this event, DTE Energy will know when this type of failure occurs on their network so they can respond more proactively and intelligently.

**Wire Contact**
Throughout the United States, most of the distribution system is overhead, built on poles running up and down streets. These wires are exposed to many outside forces such as wind, ice, vehicles and trees. The wires can also contact each other in cases where there was a mechanical failure. In many cases, these wire to wire contacts are only temporary and very difficult to find if someone is not in the immediate vicinity when it occurs. However, if the problem goes unresolved, it will result in flickering lights and possibility a power outage. Tollgrade LightHouse sensors allow a utility to detect that there is wire to wire contact occurring and by providing some key data of the event can help the utility narrow down the area to investigate.

During our initial monitoring period, we were able to classify the waveform for Wire Contact (see Figure 6). By classifying this event, DTE Energy will know when wires make contact so that they can take proactive measures to resolve this situation before it causes flickering lights or any impending outages.

**Pole Top Transformer Outage**
Pole top transformers supply low voltage power to residential areas and small businesses. However, they are exposed to several outside forces such as wind, ice, trees and animal contacts. If overloaded, they can also fail internally causing an outage to the homes connected to this transformer. Tollgrade LightHouse sensors allow a utility to determine what type of failure occurred. If a transformer failure is suspected, the lineman can take a new transformer with them immediately on the truck, eliminating time for a new transformer to be delivered after they are on-site.

During our initial monitoring period, we were able to classify the waveform for a Pole Top Transformer Outage (see Figure 7). By classifying this event, DTE Energy will know immediately when the outage occurs and that the cause of the outage was the pole top transformer so that they can restore power to the homes connected to the transformer more quickly.

**Next Steps**
DTE Energy plans to roll-out the next stage of the project with “Phase B” LightHouse MV Sensors over the next two quarters. While sensors are being deployed, event classification and weekly project team meetings will continue to classify events which could be preventable outages. Additionally, the Tollgrade Sensor data is in the process of being integrated with DTE Energy’s SCADA system so that crews will be able to react immediately to LightHouse data over the course of this year.
Lessons Learned

The purpose of the CGI Commitment is to not only prove out the concept of a Predictive Grid in action, but to share key lessons learned from the DTE Energy deployment so that other utilities can adopt best-practices that can better prepare them for their Smart Grid Sensor roll-out, and how to best utilize data that is capable of preventing future outages.

We share some of the key lessons learned from the first three months of our CGI Commitment below.

1. Overall, 86 percent of the events LightHouse classified were a new category called Line Disturbances – the tell-tale sign that an outage or asset failure may occur. Trending analysis over the last six months show that the pattern of Line Disturbances and Outages are closely related, giving more proof that monitoring Line Disturbances as a precursor to outages should become an industry standard. Currently, LightHouse is the only Smart Grid Sensor to register Line Disturbances, as protective devices already installed on the utility network do not see these types of events substantiating the need for deploying this new technology in the battle to predict and prevent outages. Utilities not looking for Line Disturbances on their network remain blind to knowing about potential issues and will not be well positioned to predict or prevent outages.

2. In their preparation to use LightHouse data more effectively, DTE Energy realized that adding sensors on the line near existing switching locations is preferable. If a fault occurs on the line, the sensors will pinpoint the actual section location. Utility lineman could then go directly to a nearby switch, open it and isolate the problem area while almost immediately restoring power to the remaining customers. This methodology will allow DTE Energy to have a significant impact on power restoration time for customers. The findings of this improved restoration time during outages will be shared in future reports.

3. DTE Energy leadership wanted to leverage the existing investment in their ABB/Tropos Advanced Metering Infrastructure system for the communication path for LightHouse Sensors, leveraging their smart metering investment into the distribution automation part of their network. As a result, Tollgrade delivered a version of their industry leading MV Sensor compatible with the Tropos wireless network. These sensors fit seamlessly into DTE Energy’s existing Tropos system and allow immediate, actionable intelligence into the health of the grid. This allowed DTE Energy to stretch their investment future.

4. DTE Energy is in the process of taking ownership of the city of Detroit’s electric grid which was previously run directly by the city. However, very little is known about this relatively unmonitored grid. For a minimal investment, DTE will be able to deploy Tollgrade sensors throughout the network and gain immediate visibility in a matter of weeks. Other solutions would require a much larger investment and take six to nine months to engineer, order material and construct. The city’s grid is already within the footprint of DTE’s ABB/Tropos AMI system, so the sensors will start providing data immediately after installation. We plan to focus on this part of the network in future reports and illustrate the economic impact of any outages we are able to avoid here.
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About Clinton Global Initiative America

The Clinton Global Initiative America (CGI America), a program of the Clinton Global Initiative, addresses economic recovery in the United States. Established in June 2011 by President Bill Clinton, CGI America brings together leaders in business, government, and civil society to generate and implement commitments to create jobs, stimulate economic growth, foster innovation, and support workforce development in the United States. Since its first meeting, CGI America participants have made over 300 commitments valued at more than $15 billion when fully funded and implemented. To learn more, visit cgiaamerica.org.

Established in 2005 by President Bill Clinton, the Clinton Global Initiative (CGI), an initiative of the Bill, Hillary & Chelsea Clinton Foundation, convenes global leaders year-round and at its Annual Meeting to create and implement solutions to the world’s most pressing challenges. CGI also convenes CGI University, which brings together undergraduate and graduate students to address pressing challenges in their communities and around the world. To date, members of the CGI community have made more than 2,800 Commitments to Action, which are already improving the lives of more than 430 million people in over 180 countries. When fully funded and implemented, these commitments will be valued at $103 billion. For more information, visit clintonglobalinitiative.org and follow us on Twitter @ClintonGlobal and Facebook at facebook.com/clintonglobalinitiative.

About DTE Energy

DTE Energy (NYSE: DTE) is a Detroit-based diversified energy company involved in the development and management of energy-related businesses and services nationwide. Its operating units include an electric utility serving 2.1 million customers in Southeastern Michigan and a natural gas utility serving 1.2 million customers in Michigan. The DTE Energy portfolio also includes non-utility energy businesses focused on power and industrial projects, natural gas pipelines, gathering and storage, and energy marketing and trading. Information about DTE Energy is available at dteenergy.com, twitter.com/dte_energy and facebook.com/dteenergy.


About Tollgrade

With more than 200 million lines under test, millions of utility outage minutes avoided annually and 25 years of experience successfully locating faults at the world’s largest electric utility companies and telecommunication service providers, Tollgrade is redefining the global standard for reliability. Our award-winning fault detection hardware and predictive analytics software is deployed on four continents to help operators avoid network outages and reduce customer downtime. Tollgrade has been recognized as one of the Top 13 Smart Grid Companies to Watch in 2013 by SmartGrid News, and received Fierce Energy awards in “Substation Automation and Distribution Automation” and “Asset Management.” Tollgrade was named the Smart Grid Sensor market share leader in North America by IHS Research, and has been recognized as a Platt's Global Energy Awards finalist in 2013 and 2014. To learn more about Tollgrade, visit www.tollgrade.com or read more about the benefits of grid modernization on our blog a www.tollgrade.com/blog.

For more information: