MOVING THE RELIABILITY NEEDLE WITH INTELLIGENT SENSORS AND GRID ANALYTICS

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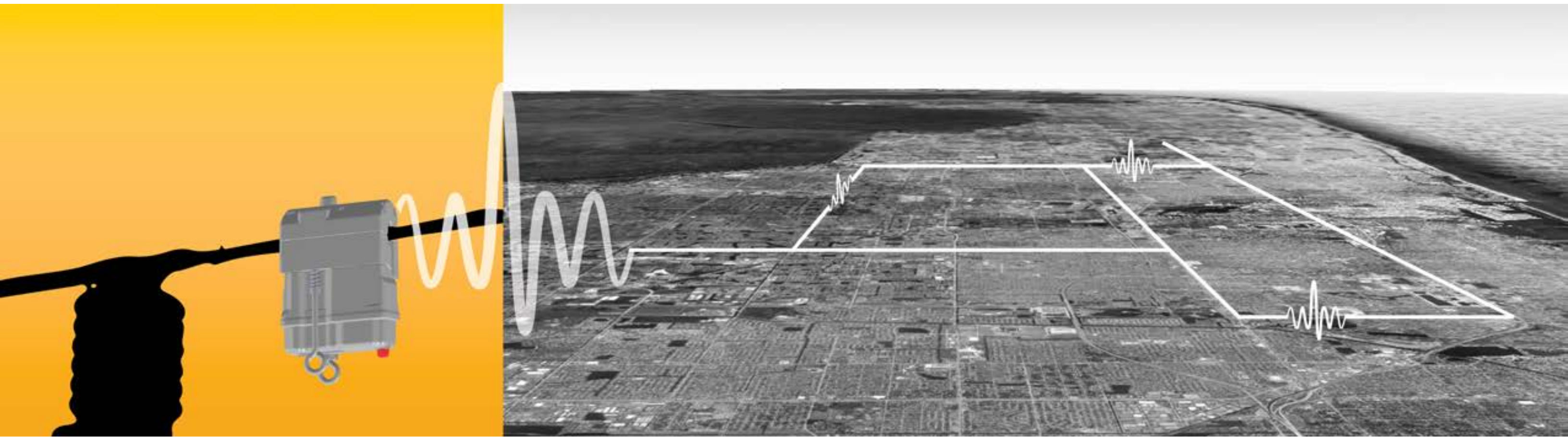


The Evolution of Distribution Grid Monitoring

When it comes to monitoring and control, the utility industry has long accepted a significant disparity between the two sides of the electrical Grid. On one side, high-voltage transmission is provided primarily through highly available meshed networks, and is highly automated and monitored through SCADA and Energy Management Systems (EMS). On the other side of the grid, distribution circuits are predominantly radial and have very limited monitoring and control. Although Substation Automation is prevalent in most distribution substations as well as Distribution Automation at strategic points on distribution circuits (i.e. - feeder midpoints and normal open points), remote monitoring and control is typically less than ~10% of all of the protective and sectionalizing devices on main feeder lines. Below the feeder level (laterals, taps, secondary circuits) remote monitoring is completely absent with the exception of customer meter points where smart meters are becoming prevalent to read, monitor and control customer service points.   So despite the widespread availability of substation automation combined with the targeted deployment of distribution automation, only 2-3 monitoring points typically exist on a distribution feeder between the substation and the customer meter that can provide visibility as to the state and of the network and the quality of the service being provided. Outage Management, Distribution Management and Mobile Workforce Management Mobile solutions have helped to automate specific workflow and network management processes, but the core business processes related to outage detection, mitigation and restoration for the majority of outages is still primarily dependent on customers or meters to initiate outage notifications and extensive crew travel time to find, isolate and restore these outages.

Continuous Improvement Achieved in Reducing Outage Durations

"If You Don't Measure It, You Can't Manage It"

Key workflows and individual process steps involved in responding to outages are reflected in **Figure 1.** The process steps are represented by T0-T9 (time stamps for each of the process steps) that are often used by utilities to measure the various stages of outage restoration. Outages restored with a single crew, without the need for additional crews and/or multiple restoration steps, would typically be completed with steps T0-T5. Complex outages that require additional crews to perform major repairs and circuit-level outages that may require multiple restoration steps (ex. feeder level outages restored with multiple restoration switching steps) would require additional steps T6-T9. For some cases process steps T6-T9 would be repeated when more than 2 restoration steps are required and be tracked as T10-T13.

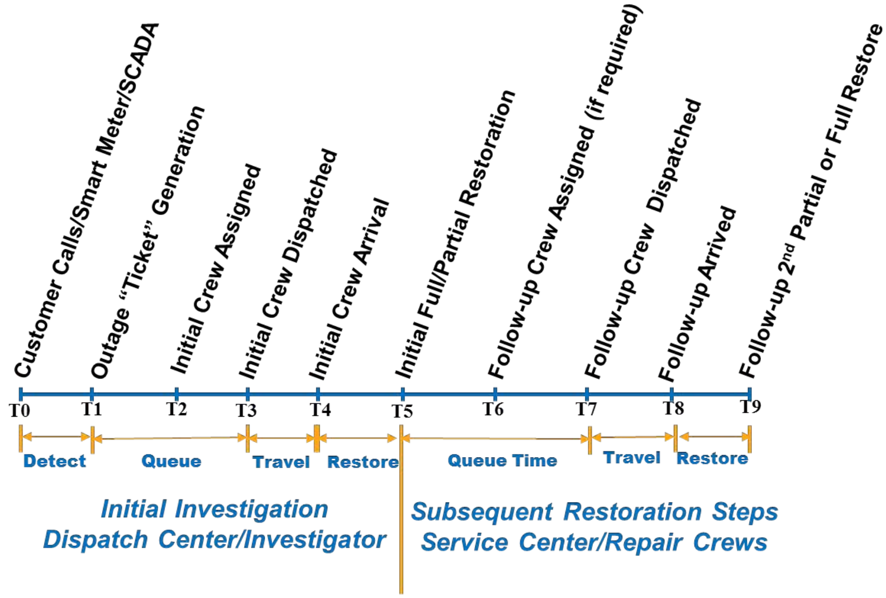


Figure 1

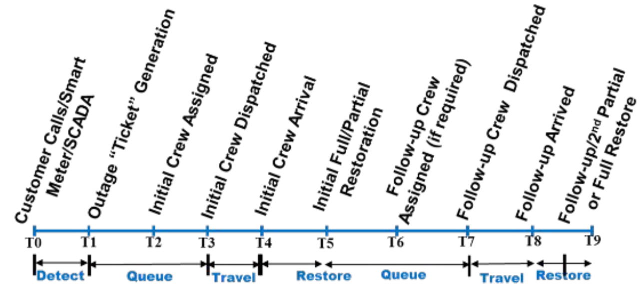
Restoration Process Steps

The sum of these process steps for all reportable sustained outages reflects how a utility performs outage restoration over a given time period, and is measured by using standard reporting indexes for system and customer average duration (SAIDI/CAIDI) and system average frequency (SAIFI). Historically, utilities have implemented network automation, improved restoration processes and applied software technology to reduce the overall duration of these process steps in various ways. **Figure 2** reflects past and current technology investments that have helped utilities reduce outage duration and the steps of the process that these technologies targeted.

For utilities that have applied these investments, significant improvements have resulted in reducing the duration of the process steps. Yet they continue to be challenged to maintain past improvements and achieve further reductions due to aging networks and facilities, adverse weather conditions, and reduced workforces. So for many utilities the "low hanging fruit" has been picked and new technologies and tools are necessary to maintain previous improvements and reduce them even further as customer and regulatory expectations rise.

Figure 2

Restoration Process Steps



Feeder Level Outages	Substation Automation	✓				✓				
	Distribution Automation	✓	✓	✓	✓	✓				✓
	DMS	✓	✓	✓	✓		✓	✓	✓	✓
All Outages	OMS/Mobile Workforce Mgt	✓	✓	✓	✓			✓	✓	✓
	AMI Smart Meters	✓								
	Fuse/Trip Saving Reclosers	✓	✓	✓	✓	✓				

In order for utilities to achieve the next level of outage duration reductions, additional real-time network visibility is required between the distribution substation and the customer meter. Cost-effective network monitoring and supporting analytic systems built for this purpose must communicate to backend systems across multiple and hybrid communications platforms typically used by electric utilities. These systems must include sensors that are easy to install, highly reliable, and require minimum maintenance so they can dependably transmit operational & analytical data to the monitoring system's back-office software as well as other operational and grid management systems.

Helping Utilities Achieve the Next Level of Reliability Improvements

Figure 2: Grid Data

Deployment of Sentient Energy's Grid Monitoring System that includes MM3™ Line Sensors and Ample Management Software is providing utilities with the ability to quickly deploy line monitoring devices to achieve the next level of significant reductions in outage duration at a fraction of the cost and implementation time of typical automation projects such as Substation and Distribution Automation. Large scale deployment of Sentient's Grid Monitoring System that quickly detects and communicates fault indication at selective locations on a distribution feeder can improve all of the restoration process steps in targeted use cases as reflected in Figure 3, and be implemented within weeks. Reductions in customer minutes interrupted can be achieved ranging from 25%-40% depending on the specific use case (impacts will vary based on factors such as the level of existing grid automation, restoration processes used, and crew availability) by reducing the duration of individual process steps T0-T9. These individual process step improvements will result in a cumulative effect to improve the industry standard metrics such as SAIDI and CAIDI.

T0 Customer Calls/Smart Meter/SCADA; T1 Outage "Ticket" Generation; T2 Initial Crew Assigned; T3 Initial Crew Dispatched; T4 Initial Crew Arrival; T5 Initial Full/Partial Restoration; T6 Follow-up Crew Assigned (if required); T7 Follow-up Crew Dispatched; T8 Follow-up Arrived; T9 Follow-up/2nd Partial or Full Restore

		T0–T1 Detect	T1–T2 Queue	T2–T3 Queue	T3–T4 Travel	T4–T5 Restore	T5–T6 Queue	T6–T7 Queue	T7–T8 Travel	T8–T9 Restore
Feeder Level Outages	Substation Automation	✓				✓				✓
	Distribution Automation	✓	✓	✓	✓	✓				✓
	DMS	✓	✓	✓	✓		✓	✓	✓	✓
All Outages	**Grid Monitoring System**	✓	✓	✓	✓	✓	✓	✓	✓	✓
	OMS/Mobile Workforce Mgt	✓	✓	✓	✓			✓	✓	✓
	AMI Smart Meters	✓								
	Smart Fuse/Trip Saving	✓	✓	✓	✓	✓				✓

Figure 3

Grid data framework and analytics hotspots

The following use case descriptions reflect common line monitoring deployment options that target many or all of the process steps to drive new levels of reliability improvements.

Use Case Example #1

Overhead Feeder Fault Isolation & Restoration

Strategically deploying sensors at key points on a distribution circuit as depicted in **Figure 4** allows the main feeder circuit to be broken up into 3, 4 or more sections where Sentient MM3 sensors will immediately identify the faulted sections to operational users who can dispatch crews directly to the appropriate sectionalizing devices to isolate the fault and restore the non-faulted sections. Operational data, such as fault detection, can be communicated directly to utility operational systems (e.g., Outage and Distribution Management Systems) to generate outages and enable fault location pinpointing based on the last known load and fault magnitude reported by strategically located line sensors. Crew patrol time is dramatically reduced by limiting crew patrols to the sections of the circuit where sensors have detected network faults. This reduces crew travel time associated with extensive feeder patrols required today to find and isolate faults, and allows more customers to be restored in initial restoration steps. Overall, the customer minutes associated with a feeder-level outage will reduce T4 –T5 and T8-T9 as well as avoid and reduce subsequent travel and restoration times when extensive network switching with multiple restoration steps are required.

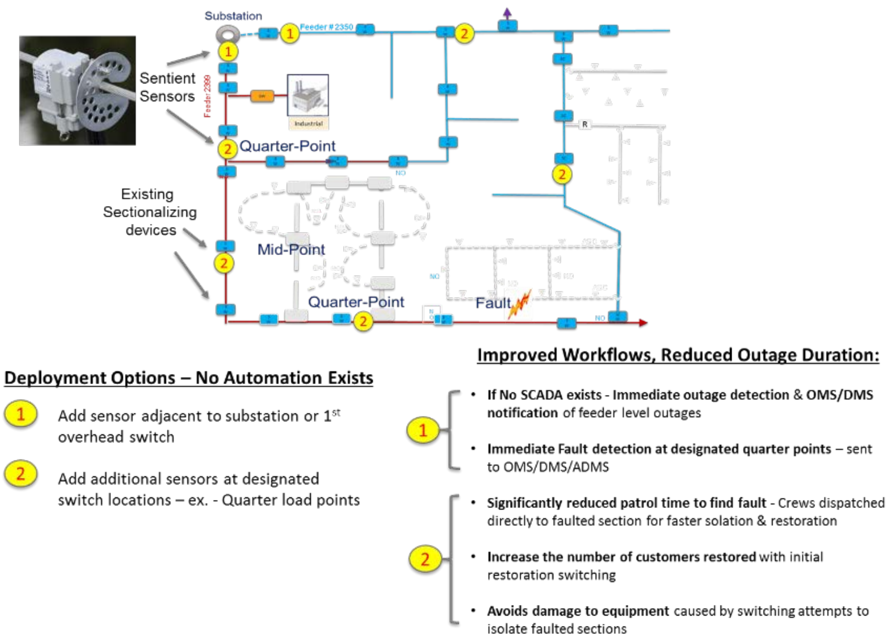


Figure 4

Overhead Feeder Restoration

Use Case Example #2

Telemetry Retrofit for Legacy Network Devices

Retrofitting of legacy devices that are non SCADA-controlled or monitored can be a very cost-effective way to gain real-time monitoring of distribution feeders. Deployment options include the installation of Sentient MM3 sensors adjacent to existing legacy sectionalizing devices on the feeder such as the substation circuit breakers, single and 3-phase line reclosers, auto-transfer devices and other protection or sectionalizing devices. Installation is accomplished in minutes without modifications to existing network devices. Once installed outage detection can be communicated immediately before customers call or meters report loss of power and transmit the event to operational systems confirming the faulted protective device as being open as well as provide last known load and fault magnitude information for power flow and fault location purposes. Crews can be dispatched immediately and directly to the fault location to isolate and restore customers as described in Use Case #1.

Use Case Example #3

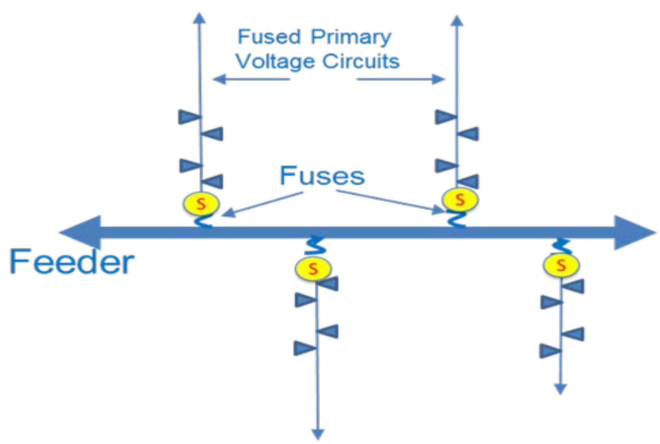
Monitoring of Commercial/Industrial Customers and Critical Infrastructure

Besides fault detection and pinpointing, Sentient MM3s are also capable of providing real time power quality data for large usage Commercial/Industrial customers, government buildings, schools, and critical loads such as municipal pump stations. The sensors can assist utilities and customers in the investigation of power-quality issues that would previously have never been noticed and to avoid future equipment damage, momentary outages and sustained outages.

Use Case Example #4

Primary Fuse "Laterals"/"Taps" Monitoring

As improvements are realized in the reduction of SAIDI and CAIDI for feeder level outages, utilities are turning their attention to 3-phase fused overhead and underground UG circuits. Sentient Energy currently is working with several customers in design modifications that will extend the capabilities of feeder line monitoring sensors below the feeder lever as depicted in Figure 5. These capabilities will extend the reach of visibility below the main feeder line into the primary fused circuits and provide additional levels of reliability improvements and cost reductions. While outages on these circuits affect less customers than outages at the feeder level, they occur much more frequently, are more costly to restore, and have no monitoring capabilities today. Integrating captured waveform data with AMI data also provides the ability to recognize circuit abnormalities, perform pre-arranged maintenance and avoid future outages.



Sensor Deployment Options

S — Add sensors adjacent to primary fuses for overhead "laterals"/"taps" &/or overhead to underground "dip" location

Summary

The next level of reliability improvements will be dependent on the ability to detect, store and analyze network disturbances that result in outages or are a prelude to outages. Applying distribution line sensors with advanced analytic platforms such as Sentient's Grid Monitoring System (GMS) and Grid Analytics System (GAS) is a practical and cost-effective alternative that can complement other automation efforts at a fraction of the cost. The use cases described in this paper are only a few examples of current customer use of

Sentient Energy's Grid Analytics System. The day will come when the combination of intelligent sensors and advanced analytics will be taken for granted, just as past technology innovations are taken for granted today. The growth of distributed generation, renewable energy resources, electric vehicles, and other distributed energy resources will only accelerate this trend.