> Itron white paper

Managing Power Outage with OpenWay®

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Executive Overview

Reliability issues represent ongoing challenges for utilities. Customers see these challenges in occasional loss of power to their home or business. Utility managers and shareholders see these challenges in rising stress on energy delivery systems and in scrutiny by regulators of the consistency and quality of service delivered to ratepayers. Managing outages and power quality has a significant impact on the bottom-line performance of a utility. For example, improving key indicators such as the System Average Interruption Duration Index (SAIDI) can save utilities millions of dollars a year and improve relations with regulators, ratepayers and shareholders alike.

This paper describes the types of reliability issues a utility can encounter; how utilities currently handle these issues; and how a radio-frequency-based (RF) local-area mesh network such as OpenWay by Itron (referred to as the OpenWay RF LAN or simply RF LAN throughout this article) can provide significant benefits in improving response times, reducing restoration time and costs and optimizing asset management.

Introduction to Outage Reliability Issues

The modern distribution system begins as the primary circuit leaves the substation and ends as the secondary service enters the customer's meter socket. A variety of methods, materials, and equipment are used among utilities across the U.S., but the end result is similar. The electricity leaves the substation in a primary circuit, typically including all three phases. Primary circuits or distribution feeders emanating from a substation are normally controlled by a circuit breaker which will open when a fault is detected. Automatic circuit reclosers may be installed to further segregate the feeder and minimize the impact of faults.

Distribution systems are typically designed either as a series of lines radiating out from a single substation, or as a network of interconnecting lines energized by more than one substation or other points of supply—again using automated and manual switching devices to dynamically reconfigure the network as required.

Interconnected systems are generally found in more urban areas. Points of connection are typically open, but switches can be opened and closed as necessary to create varying power flow configurations. Switches can be operated manually by line crews or remotely from a central office. Interconnected systems are the most complex to build and maintain, but in the event of a fault or required maintenance, a small area of network can be isolated and the remainder kept on supply.

Radiating lines are typical of rural areas with load areas isolated by long distances. These systems may be easier to design, build, and maintain, but long distribution lines have an inherent lack for alternate supply paths which lead to larger SAIDI numbers.

Types of Outages

The Institute of Electrical and Electronics Engineers (IEEE) defines three types of outages or power interruptions based on duration:

- **Momentary** - Power interruptions lasting up to 3 seconds.
- **Temporary** - Power interruptions lasting between 3 seconds and a minute
- **Sustained** - Power interruptions lasting longer than a minute

Utilities vary on how they define their outages; they may extend, shorten or even combine these categories. For example, some utilities may classify any outage less than a minute as “Momentary” and outages that extend longer than five minutes as “Sustained”, totally eliminating the “Temporary” category.

Distribution system outages can be caused by a variety of events. In the United States, the most frequent causes of outages are from animal interference and accidents involving the distribution system. Outages caused from storms or natural disasters tend to be infrequent, but when they do occur, they are much larger in scale. Individual customers can also lose power due to localized problems such as overloading, poor wiring, and so on.

For the purposes of this paper, the classification of different Severity of the outage on the distribution system is also considered and shown below.

Fault Type	Definition	Affected Area	Solution
F1	Fault on the customer premise	One customer	Cleared by correcting the localized fault such as closing the open circuit breaker at home or business
F2	Fault on a distribution line between a fused transformer and customer premises	Several customers	Cleared by the transformer fuse
F3	Fault on an upstream distribution lateral	100 customers or more	Cleared by a fuse on the distribution lateral and/or correcting the fault that caused the fuse to trip
F4	Fault is on a main distribution line	Several hundred customers	Cleared by a line recloser or distribution station circuit breaker with reclosing relay
F5	Fault is on the transmission line	Several thousand customers	Cleared by one or more transmission station circuit breakers

To take all of this together means that we have two classifications of potential faults that need to be considered; *Duration* (Momentary, Temporary, Sustained) and *Severity* (F1, F2, and so on)

Key Outage Measurements

Outage performance is commonly measured by indices defined in the IEEE P1366-2003 standard. The most frequently used performance indices are described below

- **SAIDI –** The *System Average Interruption Duration Index* is commonly calculated by customer minutes or hours of interruption and provides information on total average time that customers are interrupted.
- **CAIDI –** The *Customer Average Interruption Duration Index* represents the average time required to restore service to a given customer per sustained interruptions.
- **SAIFI** – The *System Average Interruption Frequency Index* is designed to give information about the average frequency of sustained interruptions system wide.
- **CAIFI** – The *Customer Average Interruption Frequency Index* is designed to show trends in customer interruptions per year. It also helps show the number of customers affected out of the total customer base.
- **MAIFI –** The *Momentary Average Interruption Frequency Index* is the average number of forced momentary interruptions experienced per customer for a period of time (typically a calendar year).

These indices are important tools for key stakeholders to measure reliability and customer service improvements throughout the distribution system. Utilities seek to improve these indices by improving restoration efforts, increasing prevention methods, and lowering overall costs to shareholders.

Current Outage Management Practices

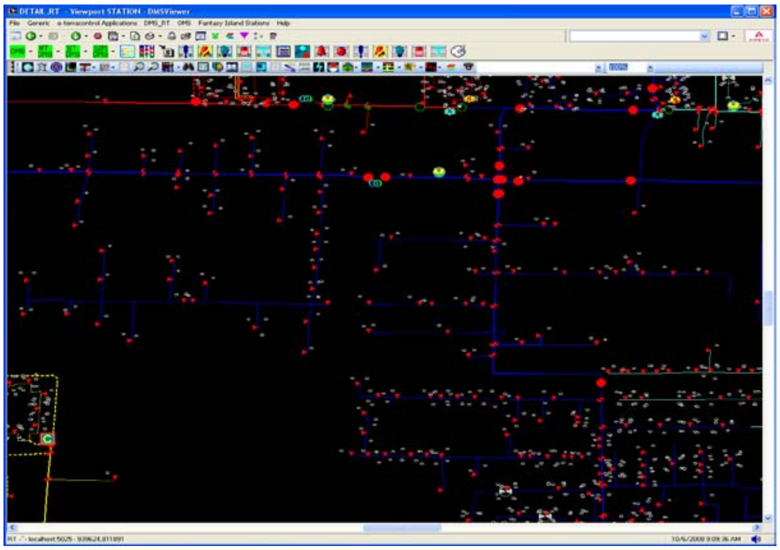
At the core of a modern outage management system (OMS) is a detailed network connectivity model of the distribution system. A utility's geographic information system (GIS) is usually the source of the as-built version of this network connectivity model. By combining the locations of outage calls from customers, an automated rules engine can predict the locations and severity of outages. For instance, since the distribution system is primarily tree-like or radial in design, all outage reports from an area that are downstream of a fuse could be identified as caused by a single fuse or circuit breaker upstream from the location of the outage reports.

Phone calls to report outages are usually taken by workers utilizing a customer information system (CIS) in a call center. Another common way for outage calls to enter into the OMS is by integration with an interactive voice response (IVR) system. OMS systems are also commonly integrated with supervisory control and data acquisition (SCADA) systems that can automatically report the operation of monitored circuit breakers, switches or other distribution assets.

In any outage, identification of the problem depends on duration and severity of the service interruption. Smaller outages, and ones that are more commonly caused by animals or accidents, have a lower probability of being detected and reported to the utility's OMS by existing systems. Large-scale outages have a greater probability of being detected and reported to the OMS system due to their impact on a significantly higher number of customers. However, because they are larger in nature, verifying restoration of power to homes and businesses can be difficult and costly. Moreover, compound outages resulting from a combination of issues are extremely difficult both to isolate and to confirm that restoration has occurred at every connection point. Take for instance a storm situation where a significant distribution primary feeder goes offline due to ice accumulation, and at the same time a fuse trips and a tree branch falls, taking down a customer's secondary service. The ability to identify and isolate these "nested" outages—and confirm each has been resolved—is very complex. If crews are released from a particular service area prior to verification of restoration of each of these incidents it becomes inefficient and costly to reroute them back to the same service area if problems are not corrected the first time.

Benefits Provided by the OpenWay RF LAN

The OpenWay RF LAN mesh network provides a number of outage and restoration benefits. Outage notification messages are presented to the utility in near real-time, without customer intervention through a traditional IVR system. These messages can be sent and processed within the OMS, and can provide geospatial visualization of outage locations.



OMS Screenshot

This is a typical example of a screenshot from an OMS. OpenWay helps monitor outages and restore power, and transmits messages as necessary to the OMS for processing.

The following capabilities enable the dispatcher to process information through all stages of an outage.

Enhanced Outage Detection and Reporting

- Predict the most likely open point and monitor sensor data inputs
- Recognize multiple system outages
- Dynamically track outage situations in real-time
- Monitor active outages
- Present which circuits are affected
- Identify customers affected by an outage
- Display the length of each active outage
- Manage crew assignments
- Reveal current outage status

Enhanced Performance Indices

- Improve power restoration, and thus reduce outage durations, due to more timely outage location and extent predictions
- Reduce average outage durations by prioritizing
- Reduce outage frequency through use of outage statistics to make targeted reliability improvements

Reduced Costs

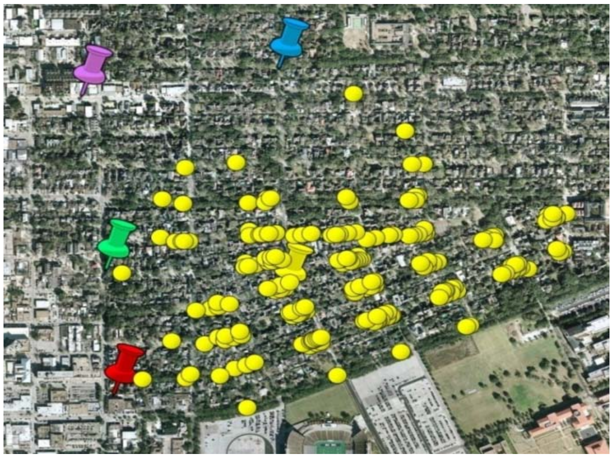
- Reduce wasted labor cost by minimizing "OK upon arrival" site visits—typically 70-75% of a utilities annual outage field visits
- Shorten response times for restoration efforts to outage areas
- Avoid costs of returning to areas previously serviced to pick up missed outage pockets
- Eliminate manual labor and errors when computing outage indices

Improved Public Relations

- Improve customer satisfaction through increased awareness and communication of outage restoration progress
- Provide estimated restoration times
- Improve media relations with accurate and timely outage and restoration information
- Reduce complaints to regulators by prioritizing restoration of emergency facilities and other critical customers

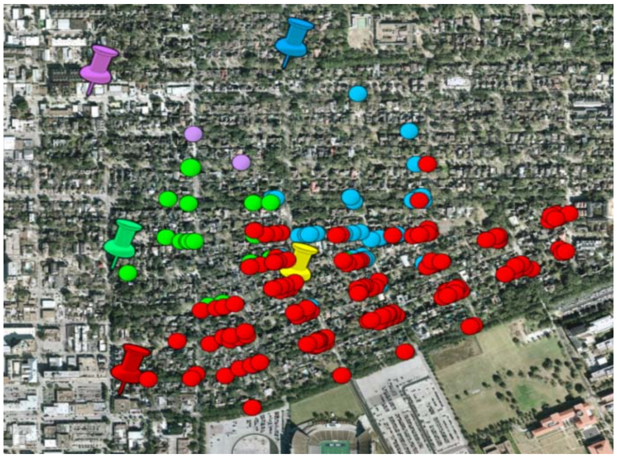
The Itron OpenWay RF LAN—like other mesh radio networks—is self-healing. The RF LAN continues to operate even when a single or multiple nodes break down or a connection is severed. This self-healing attribute makes the RF LAN very robust and reliable. Smart meters operating within this communications infrastructure are equipped with algorithms that manage real-time connectivity to the upstream wide area network (WAN) through an OpenWay Cell Relay by analyzing link margin, RF interference and the various available paths. Any node can dynamically change their connections to neighboring nodes or to alternate Cell Relays as conditions change, either immediately or over time. Each node retains intuitive knowledge of a number of different communication pathways at any particular time which allows it to adjust on the fly to ensure robust communications.

OpenWay provides self-healing benefits not only between nodes but also between Cell Relay points. The images below are real-life examples of what happened when lightning struck, rendering a Cell Relay inoperable. Notice how meters switched from associations with the yellow Cell Relay to the other Cell Relays after the interruption in service.



Before

Nodes reporting to a single OpenWay Cell Relay before a lightning strike are indicated by the yellow dots on the map.



After

Nodes reporting to multiple OpenWay Cell Relays after the strike are represented by several colors. The meters have used the “self-healing” technique to find additional hop paths to ensure communications with the network.

Because of their defining communication characteristics, mesh networks like the OpenWay RF LAN can play an important role in outage management when combined with other nodes on the distribution system such as switches, breakers and fuses, as well as provide valuable information to OMS systems for understanding the duration and severity on a utility's connectivity model. The OpenWay RF LAN can improve accuracy of outage identification and tracking of which customers are out of power; as well as which customers have had power restored. Features such as outage messages, node pinging and restoration messages can be used to identify every customer who is out, when they first went out and when they were restored. Measuring and tracking these outage events is the key to accurately reporting and ultimately improving key outage indices. The table below, sorted by meter and then timestamp, illustrates each individual outage and restoration event that occurred at the meter, regardless of duration.

Timestamp	Item	Meter	Description
1:48:30 PM	Event	2.16.840.1.114416.0.47972944	Primary Power Down
1:48:44 PM	Event	2.16.840.1.114416.0.47972944	Primary Power Up
1:49:37 PM	Event	2.16.840.1.114416.0.47972944	Primary Power Down
1:49:41 PM	Event	2.16.840.1.114416.0.47972944	Primary Power Up
1:50:40 PM	Event	2.16.840.1.114416.0.47972944	Primary Power Down
3:48:32 PM	Event	2.16.840.1.114416.0.47972944	Primary Power Up
1:48:30 PM	Event	2.16.840.1.114416.0.47972945	Primary Power Down
1:48:44 PM	Event	2.16.840.1.114416.0.47972945	Primary Power Up
1:49:37 PM	Event	2.16.840.1.114416.0.47972945	Primary Power Down
1:49:40 PM	Event	2.16.840.1.114416.0.47972945	Primary Power Up
1:50:40 PM	Event	2.16.840.1.114416.0.47972945	Primary Power Down
3:48:32 PM	Event	2.16.840.1.114416.0.47972945	Primary Power Up
1:48:31 PM	Event	2.16.840.1.114416.0.47972946	Primary Power Down
1:48:46 PM	Event	2.16.840.1.114416.0.47972946	Primary Power Up
1:49:38 PM	Event	2.16.840.1.114416.0.47972946	Primary Power Down
1:49:41 PM	Event	2.16.840.1.114416.0.47972946	Primary Power Up
1:50:41 PM	Event	2.16.840.1.114416.0.47972946	Primary Power Down
3:48:33 PM	Event	2.16.840.1.114416.0.47972946	Primary Power Up
1:48:31 PM	Event	2.16.840.1.114416.0.47972948	Primary Power Down
1:48:45 PM	Event	2.16.840.1.114416.0.47972948	Primary Power Up
1:49:38 PM	Event	2.16.840.1.114416.0.47972948	Primary Power Down
1:49:41 PM	Event	2.16.840.1.114416.0.47972948	Primary Power Up
1:50:40 PM	Event	2.16.840.1.114416.0.47972948	Primary Power Down
3:48:33 PM	Event	2.16.840.1.114416.0.47972948	Primary Power Up

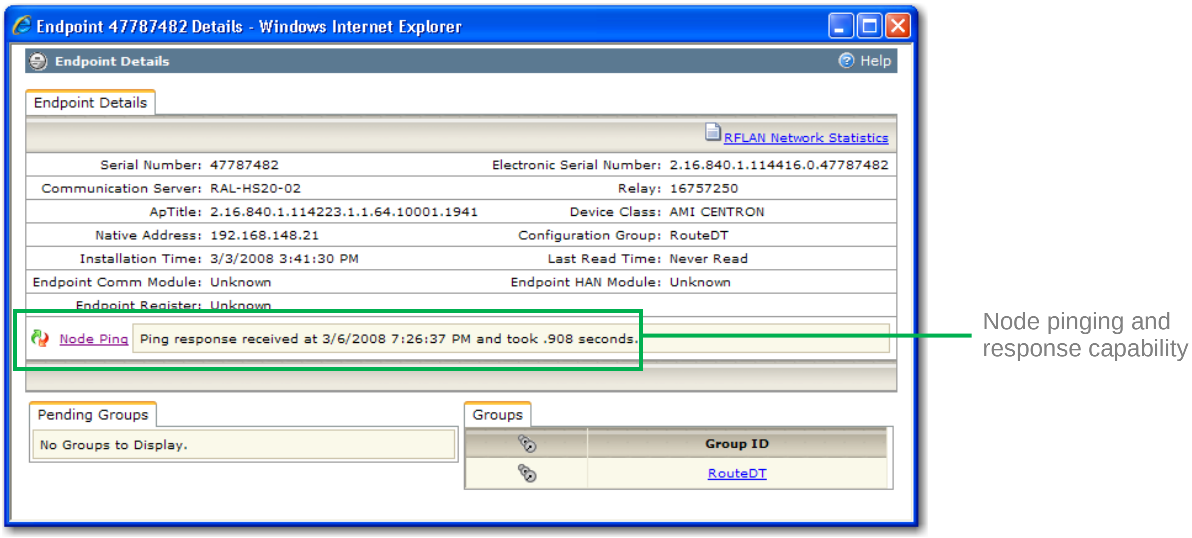
Outage Scenarios and Applications with OpenWay

F1 Outage: Single Customer without Power

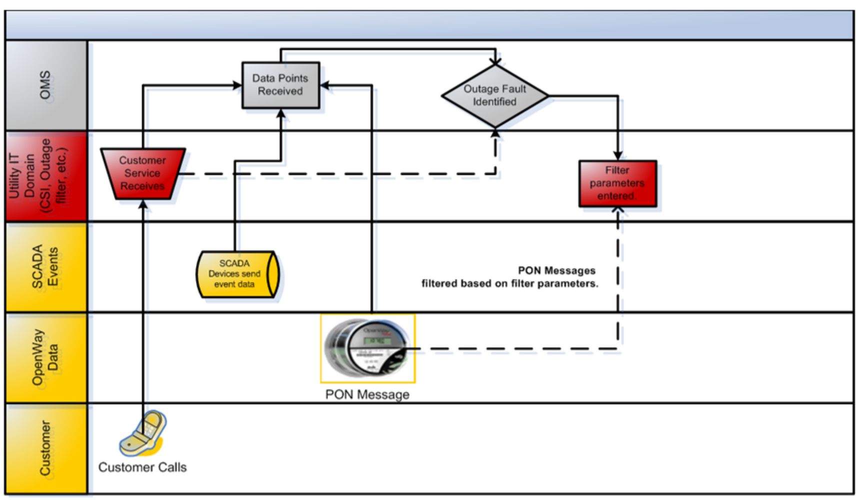
A customer contacts the utility to inform them of a power interruption. The utility needs to determine if the problem lies on the utility side of the electricity meter or within the customer's premise. The ability to make this determination remotely eliminates the cost of unnecessary trips to the customer premise.

The OpenWay network presents a number of key features to verify where the outage condition lies.

- First, if the meter had suffered an outage due to an interruption on service at the distribution system an outage notification should have been received, this is the utilities first indication that it is a utility-side fault.
- In addition, OpenWay provides both "ping" and "load side voltage check" capabilities that can determine in 60 seconds or less if a single meter is energized (see the screen shot on the following page) and if a meter has load side voltage present. By initiating an inquiry of this sort through the interface to the OpenWay AMI system, the call center operator can confirm whether power is available at the utility side of the meter, indicating the problem lies within the premise itself.



A customer service representative (CSR) can also verify with the Outage Management System (OMS) or (MDM) application to see if an outage notification was passed from the customer's meter up through the system for verification. This eliminates unnecessary trips to the customer premise for "OK upon arrival" visits if the outage is actually on the customer side of the meter.



In a recent Southern California Edison (SCE) business case filing after a pilot OpenWay project, the published savings recognized by SCE was $76.8 million dollars or approximately $15.20 per meter over the life of the project by eliminating this type of activity. Itron estimates typical cost savings benefits of more than $1 per meter, per year, in savings.

F2-F3 Outage: Neighbors or Neighborhood without Power

As previously mentioned, problems with a neighborhood distribution line may affect approximately hundreds of distribution customers.

When an OpenWay CENTRON meter loses power for one-tenth of a second it determines an outage event has occurred and stands by for up to five seconds. The media access control (MAC) layer—of the meter's RF LAN connection—enters into a special mode in which the MAC layer stops listening to the mesh network and sends three very short messages (powered by the meter's remaining energy stored in capacitors). The delivery of each message is randomized within a five second window in order to reduce collisions. These outage messages are then processed by other meters that can hear them within the mesh network.

If the meter recovers its power before the first outage message is sent, it cancels the outage sequence and will not send any outage notifications. If the power comes back after the first outage message is sent, then the node will continue to transmit the remaining two messages.

After outages messages are forwarded through the mesh network to an OpenWay Cell Relay, the messages are immediately passed to the OpenWay Collection Engine as an alarm, which can then be displayed to system operators though various system interfaces. Each alarm includes endpoint ID, event type, and date/time of the event. Other utility systems, such as an OMS, can subscribe to alarms received by the collection engine.

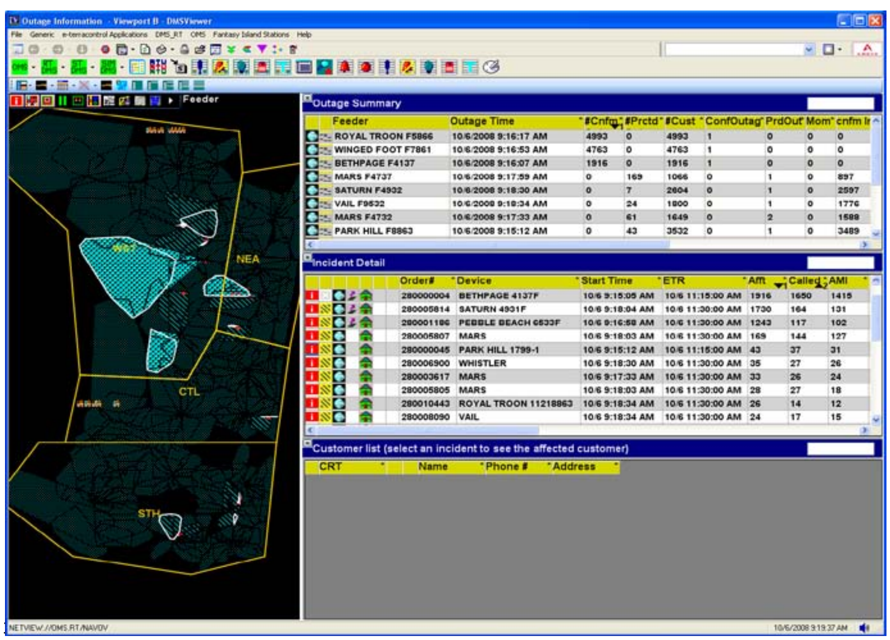
In the F2 and F3 scenarios, there is a high reliability that outage messages will be received and mapped. In general, for an outage affecting up to 100 meters, the utility will receive notification of the outage in less than 3 minutes with 95% percent reliability. Also in this scenario, the introduction of SCADA devices may add additional information on the location and severity of the outage.

Once these messages are received, the OMS can begin predicting where the fault is located while crews are dispatched to the outage areas.

F4-F5 Outage: Widespread Power Loss

It is important to note that even with widespread loss of power; the mesh network is still capable of accurately describing where the outage is occurring. The OpenWay system in concert with the OMS also provides important information on the magnitude of the outage, in addition to presenting operators with locations at which to open switches in the distribution system, containing the outage to the smallest possible area. As crews are sent out, dispatchers can provide nearly real-time data on where to look for the outage condition, saving "windshield time" and minimizing inconveniences to customers.

As messages are synchronized and mapped with GIS data or the online dynamic connectivity model, a perimeter describing the overall extent of the outage is created. In large-scale outages, outage messages are transmitted and processed as described in the previous section.



The OpenWay system can also ping a subgroup of meters that did not report an outage notification but are in the inferred outage area to validate they are in fact out of power or at least not communicating and to verify the extent of the inferred outage.

Confirming Power Restoration

Accurately determining the location and extent of a power outage is only part of the outage management equation. Equally important is accurately and quickly restoring power and confirming power restoration after an outage has occurred. The OpenWay RF LAN provides several options for confirming power restoration. Similar to the characterization of outages by both duration and severity we also need to consider these same grouping of events when discussing restorations

The OpenWay system provides two key functions to help confirm restorations:

- Restoration messages (sent from meter upon synchronization to the network)
- Meter ping capability.

These features are briefly described in the use cases below, along with how these features can be incorporated into existing utility systems, thereby providing significant benefits.

Restoration Messages

When power is restored to an OpenWay CENTRON meter that has experienced an outage, it generates a restoration message that is time-stamped and transmitted in a standard ANSI C12.22 structure (as differentiated from the native RF LAN protocol in the case of an outage alarm message) and passed via Cell Relay to the Collection Engine. The restoration messages begin to transmit this message after the meter has been re-established in the network. After an outage, a meter will try to resynchronize to the network via a *warm start*. On a *warm start*, meters attempt to communicate with the cell that they were previously synchronized to—prior to the outage. If, after power has been restored, the endpoint is still unable to communicate with its original cell, it will enter a *cold start* process and try to establish a new connection to the network. In the case of a warm start, restoration messages will be transmitted upstream within minutes of power restoration. In the case of cold starts, cell reformation may take longer.

With this option, other systems at the utility—such as the OMS—can subscribe to the restoration messages and automatically notify customers that power has been restored to their premise. In the use cases mentioned above, the meter restoration message can be combined with critical location data; this information can be used to build enhanced connectivity models for transformers, feeders and substations across the service area. Automated algorithms with third-party vendors (such as OMS providers) can be developed to leverage this capability, providing operators and dispatchers with additional options for action. This includes pinging meters based on transformer association per the utility connectivity model as information becomes available, either from delivered restoration messages or updates from field crews on faults they have cleared. This provides valuable insight into whether correcting faults has resolved all connectivity issues or if gaps still exist. It also provides confidence for dispatchers and field crews to move along to other affected service areas.

Meter Ping and Load Side Voltage Check Capability

The OpenWay system provides a mechanism for utilities to send a message to a meter or multiple meters using the ping function. Operators send a command to the meter, requesting its current status on the network. The ping message follows the ANSI C12.22 structure and the response provides a positive indication that the meter is energized and power is being delivered to the premise. In addition, load side voltage (LSV) checks—a command to verify the presence of load side voltage—can be used for additional verification of power restoration on a service. All or some of these functions could be used by CSRs to verify for customers that power is restored and that there may be an internal issue at the premise (such as a circuit breaker or wiring problem).

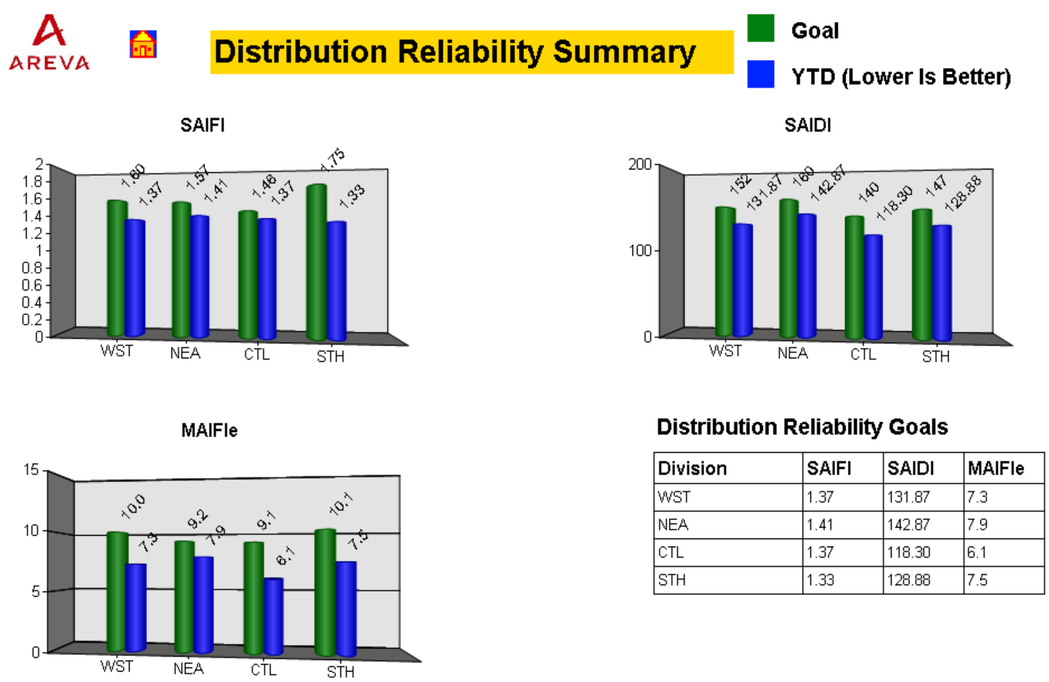
As a final consideration, a utility may want to give additional restoration priority to the locations of OpenWay Cell Relays, as they maintain power for at least four hours and will be used to pass restoration messages from other meters. Extended outages may emphasize the need to ensure power is restored to these devices and to ensure restoration messages can be delivered in a timely manner; this may be extremely beneficial for utilities when they are impacted by these larger outage scenarios.

The benefits of cutting even a day's worth of time during outage management can be worth tens of millions of dollars to a utility. Eliminating unnecessary wait time or dispatching crews to areas more efficiently can provide these additional savings and expedite restoration efforts.

Validating Meter Outage Times

In OpenWay CENTRON meters, every power outage and restoration is logged and stored in the meter as an event. During the next periodic read, these events pass through the OpenWay network and is managed and stored in the MDM application. Using the MDM and/or OMS, the utility can create reports on outage durations that fall within the time period they are analyzing, plus report on any interruptions that meet utility-specific definitions for momentary or sustained outages. Other key analytical work can analyze types of outages by feeder or frequency, or correlate it with other key data such as weather or CIS data to pinpoint recurring outage issues and fine tune planning and vegetation maintenance programs for these areas, thereby improving overall service to customers and reducing operational and maintenance expenses.

Analytics and reports such as these can provide time and cost savings when managing indices data and relay information to key stakeholders (such as management and regulators) in a timely fashion.



Division	SAIFI	SAIDI	MAIFIe
WST	1.37	131.87	7.3
NEA	1.41	142.87	7.9
CTL	1.37	118.30	6.1
STH	1.33	128.88	7.5

Key Communication Considerations for Outage and Restoration

Power interruptions resulting from animal intrusion or accidents are fairly manageable within most AMI implementations. Events related to single point failures are isolated, identified and resolved based on incoming outage alarm reporting from smart meters. However, the utility can never be absolutely confident that all customers have been restored until concrete confirmation is achieved. With current operating practices it is cost-prohibitive to contact 100% of the affected locations to confirm restoration and furthermore, not all customers are necessarily able to be contacted, especially with the increased number of portable phones which rely on power to operate. As an alternative, smart meters are capable of logging restoration events to provide the utility operations center with automatic and proactive resolution management—a significant improvement over today's approach.

This situation becomes exponentially more difficult when dealing with large-scale and potentially compound (or nested) outage situations. First, the AMI architecture must be designed in such a way to support a tremendous amount of alarm events occurring almost concurrently. Second, the design must be able to support large-scale query capability so that significant groups of affected locations can provide actionable data in a timely fashion. For example, all of the meters related to a particular distribution primary feeder or under a single switching device must verify their status before releasing a restoration crew from a particular work area. The worst-case scenario involves the crew leaving only to later find out that one or more service locations have suffered a secondary outage and are still in the dark. One way to minimize the necessity to query all the nodes related to a particular incident is to utilize smart meters capability to proactively notify that restoration has occurred; used in this manner, only those that fail to report need to be queried.

Conclusion

OpenWay provides many important features intended to extend value to all stakeholders through improved operations, improved rates of return to shareholders, and new and interactive ways to engage with your customers on the quality of their services.

OpenWay sets itself apart from the crowd of AMI systems flooding to market with several key and distinctive features including:

- Self-healing algorithms to improve overall connectivity of all nodes within the system.
- Proven open architecture and corresponding AMI ecosystem of best-in-class providers that enable OpenWay to deliver exceptional value.
- Extensive measurement capabilities of energy and power quality values for a more complete understanding of the load on your network.
- Significant alarms and notifications that improve the overall reliability and sustainability of your network.

At Itron, all of our more than 8000 employees are committed to using our extensive experience, industry insight, and established and emerging technologies to deliver on our promise to help you optimize the delivery and use of energy within your system.

About Itron

Itron Inc. is a leading technology provider to the global energy and water industries. Our company is the world's leading provider of intelligent metering, data collection and utility software solutions, with nearly 8,000 utilities worldwide relying on our technology to optimize the delivery and use of energy and water. Our products include electricity, gas, water and heat meters; data collection and communication systems, including automated meter reading (AMR) and advanced metering infrastructure (AMI); meter data management and related software applications; as well as project management, installation, and consulting services.

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