The calm after the storm

Human decision support in storm outage recovery

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It's a fact of life that interruptions in an electrical distribution utility happen. Although they can be minimized, there are many times – especially during severe weather conditions or accidents – where they simply cannot be prevented. Whether high winds cause trees to fall onto overhead lines or poles to snap thus dislodging overhead lines from cross-arms, one thing is for certain: electrical service is disrupted until the physical facilities can be replaced or repaired, and this almost always involves human labor. The speed and efficiency at which these repairs can be carried out depends largely on the type of decision support systems or tools available to the distribution utility.

One such support system is known, in general, as an Outage Management System (OMS). With increasing requirements on utilities to track and report outages accurately, an OMS becomes a valuable and a necessary tool. ABB's Network Manager is an industry-leading OMS that has been deployed in numerous diverse electric utilities. This article looks at how this and similar tools help repair teams restore power as quickly and efficiently as possible.

Operational profitability

Service interruptions can occur even when the weather is not so bad, such as heavy rain or strong winds. However, severe weather conditions such as hurricanes, ice and lightening storms have the potential to wreak havoc with electric utility transmission and distribution systems 1 and 2. While a distribution utility's goal is to restore service as quickly and safely as possible, severe storms can result in a massive number of customer outages that can take anywhere from days to weeks to repair, requiring hundreds or even thousands of field personnel. For example, large storms[1)] such as tropical hurricanes, major snowstorms and ice storms have required up to two weeks of effort with a peak crew size of 10,000 to restore service to all customers. On top of this, total restoration costs have exceeded US$100 million for a single storm.

In most cases, the repair process begins with customer calls or with some indication of service interruption such as the operation of automated devices. Typically in some countries, distribution networks do not have extensive remote field monitoring or control and often the only way a distribution utility knows a problem exists with the system is when a customer calls to report an outage. The OMS collects (ie, analyzes) a set of outage calls, and from the pattern of calls received it can determine the likely location and a possible cause of the outage. A crew is sent to the location of the outage to investigate further and make repairs.

1 Severe ice or frost can play havoc with power lines

2 Hurricane Damage to electricity poles

The best possible decision support tools or systems are required to restore power quickly and efficiently subject to the most stringent safety standards.

Prior to the introduction of computerized systems, the telephone calls received by the utility were either written up by hand on a "ticket" or entered into a computer and then printed. These tickets were manually sorted based on the circuit the customer was connected to, before being analyzed to (a) determine the electrical location of each customer associated with the ticket and (b) attempt to identify the root cause of the outage. This process may work well in day-to-day operations where the volume of calls is light and the number of outages is small and if the expertise is available in house. However, a paper-based system easily becomes overwhelmed during large storms where more than a million customer telephone calls may be generated. Also, as experienced labor retires, this expertise is no longer available.

Apart from the physical damage, the damage caused by large storms has a severe social impact. The human effort needed to carry out repairs requires the best possible decision support tools or systems that allow power to be restored as quickly and efficiently as possible subject to the most stringent safety standards.

Outage Management Systems

One such system is an Outage Management System (OMS). Utilities typically have an OMS to help log customer calls Factbox 1 and dispatch crews to the source of an outage. To be as effective as possible, an OMS requires an accurate and complete connectivity model, from the distribution substation breaker right down to the customer transformer. The low voltage

Footnotes

[1)] The destruction caused by catastrophic events such as Hurricane Katrina in the US in 2005 is not included.

[2)] For more detailed information, please refer to www.abb.com/industries/seitp408/1592686e90c27d6ac1257026003981d2.aspx – November 2006.

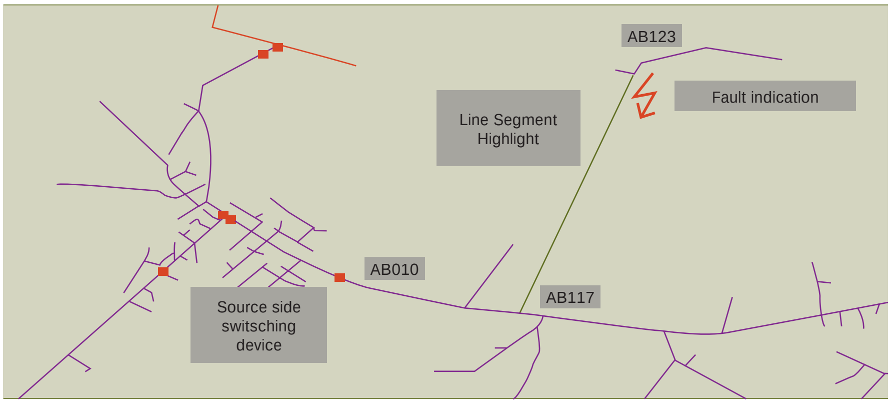
Factbox 1 Outage Management System – an overview

An Outage Management System (OMS) provides the capability to efficiently collect, identify and resolve outages and generate and report valuable historical information. The OMS accepts inputs such as customer phone calls, SCADA telemetry data, automated meter reading inputs and other real-time data and determines the likely locations of the equipment failure or damage that has caused the current set of outages. This analysis substantially reduces the need for humans to patrol distribution feeders to locate the root causes of outages. Furthermore, the OMS can automatically create, dispatch and keep track of repair crews, and it provides software tools to secure their safety as they work. Graphical tools in the system allow distribution control room operators to visualize the state of the network, the pattern of incoming calls, confirmed outages, and the planned location and tasks of the restoration crews. It can interface with mobile crew dispatch systems to keep track of and communicate with mobile crews. The OMS also provides a collection of advanced analytical tools – such as load flow and short circuit calculations, fault location and restoration analysis – that allow the utility to create efficient restoration plans and calculate Estimated Time to Restore (ETR). With these the utility can provide regular updates to the customer of the outage situation and restoration status.

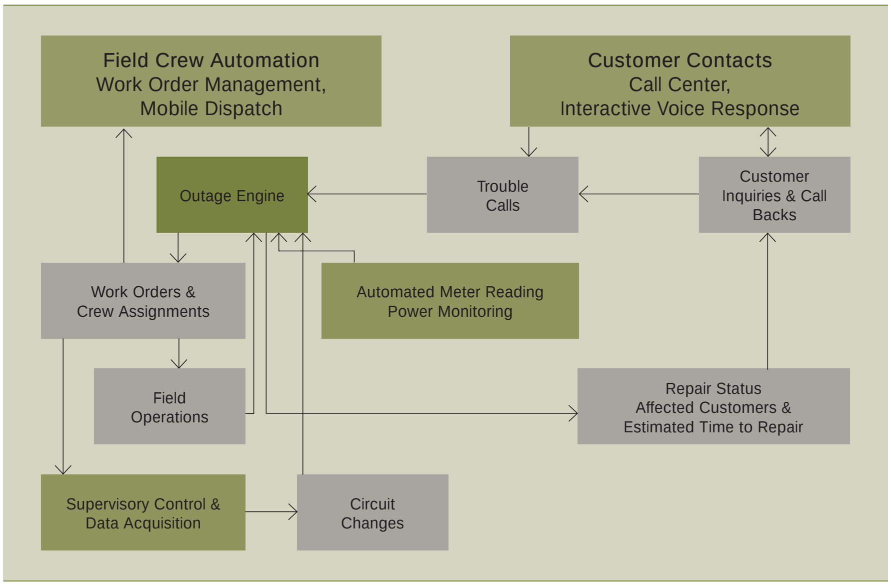
side is usually not modeled in the interests of reducing the overall network model size and the cost-effectiveness of collecting and maintaining this level of detailed data.

An OMS is characterized by a graphical user interface (GUI) that can display from one to several feeders at the same time. The entire distribution system, known as a "world map", can also be shown in a single display. ABB's Network Manager DMS[2)] is an industry-leading OMS and a typical graphical display is shown in 3.

3 Graphical user interface for outage management



4 The basic work flow for managing outages



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The primary real-time inputs to the OMS are the trouble calls from customers or emergency personnel as well as indications from automated devices such as those controlled by systems typically known as Supervisory and Control Acquisition Systems (ie, SCADA). The OMS is capable of receiving anywhere from a single call to a very large volume of calls Factbox 2 which it then analyzes and groups together to form something that is easier to handle. The grouped calls are transformed into what is referred to as an outage and sent onto the GUI that presents not only the location of the individual calls, but more importantly, the results of the analysis. Although a dispatcher handling the outages may want to display only outages as opposed to individual calls, the OMS can also display large call volumes in a geographic display in real-time, while at the same time providing the same information simultaneously to a large number of utility employees.

The basic work flow diagram for managing outages is shown in 4. The *Outage Engine* lies at the core of the OMS and comprises the *Trouble Call* and *Outage Analysis* functions, and the associated crew dispatch tools. It identifies customers with outages and then assigns, dispatches and follows the crew process until power is restored. The Outage Engine continuously analyzes the "as-operated" electrical network to define outages and keeps track of customers without power.

Characteristically in distribution systems it is difficult to maintain up-to-date knowledge of the "as-operated" network given its very dynamic, ever changing nature. The "as-operated" network may be very different to the "as-designed" or to the "as-built" network. Information about the "as-designed" and "as-built" network may be available from other utility IT systems such as Geographic Information Systems. If, however, a safe and efficient outage restoration is to be achieved, the current state of the network must be continuously maintained by the

Factbox 2 How to deal with large volumes of trouble calls

Trouble call volumes that were a rare problem only a few years ago are now commonplace. An OMS typically works in conjunction with automated call-taking/handling system typically referred to as an Interactive Voice Response (IVR) system. These systems can be further supported by third-party high call-volume systems for an overflow condition that overwhelms the utility call-taking system. One such third-party vendor is capable of taking millions of calls per hour.

software with the best telemetry and manual/voice inputs available.

Unlike transmission systems, a problem peculiar to distribution networks is the ability to add temporary devices, such as line cuts and jumper lines. Such temporary devices are uncommon in transmission systems, but are very common in distribution systems. Since most distribution systems run in a radial configuration, it is often necessary to operate feeder tie switches to reconfigure feeders, either to restore outages or to adjust to different loading situations. There is a need then to be able to (a) dynamically color lines according to the direction they are being energized from and (b) to color lines according to whether they are energized or not. Another characteristic of a distribution system is that change is the norm. For example, new residential developments, expanding towns and cities, and routine maintenance means that the distribution network model changes frequently. It is not uncommon for 10,000 or even 100,000 changes to occur in a single week! The ability to apply such changes incrementally while the software is up and running is a necessity.

Storm recovery

Distribution outage situations can be classified according to the scope of the damage and the number of customers impacted.

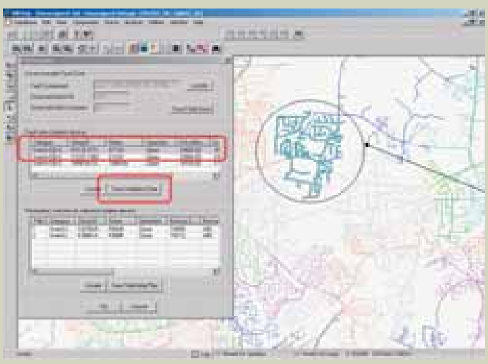
- Normal day-to-day outages due to minor storms, animal contact, and broken tree branches for example sit at the lowest level. These are usually handled locally through conventional outage management processes.
- The next level concerns outages that are caused by localized storms impacting a small area, damaging poles or primary equipment within an operating area and requiring more line crews than are normally scheduled. In cases where severe storms have impacted a wider area within the same operating area, extra "outside" resources may be required particularly if multiple feeders suffer mechanical damage.
- The second highest outage level is reserved for storms that impact multiple operating areas and where more than 10 percent of customers may be without power. In these situations resources from other utility operating regions need to be called in.
- At the highest impact level, centralized storm management is needed after a severe storm to coordinate both internal crews and extra resources called in from other utilities or contracting agencies.

The work of restoring power effectively begins before a major storm has struck. The utility typically performs an assessment of the amount of damage it thinks may occur and where. Crews are then dispatched to staging areas to be in position to make repairs once the storm hits. When this eventually happens, the utility starts to receive damage assessment reports from survey teams in the field. This information pinpoints what portions of the circuit have been damaged and to where the dispatch maintenance crews must go. An example of the restoration support tool is shown in 5. It is highly likely that in a severe storm situation, all OMS decision support tools and services described in Factbox 1 are brought into play.

In a distribution system, change is the norm. It is not uncommon for 10,000 or even 100,000 changes to occur in a single week!

Two of these services, however, merit further elaboration. The first deals with the need to handle extraordinary restoration processes with a larger number of crews than usual. *Dispatch and Crew Administration* modules provide web-based capabilities to manage work orders and administer crew personnel, vehicles and equipment not only from the central control room but also from service centers or specially created "storm room" operations. Under normal conditions the distribution system is typically managed from a central control room, which is responsible for all routine switching together with a number of dispersed service centers, which might dispatch crews locally under the coordination of the central control room. In the normal configuration it is likely that users of the OMS in the service centers have less authority than cen-

5 A screen-shot taken from the restoration support tool



Traced restoration zone for selected isolation switch

6 A temporal trend display provides call and outage trends on a system or district basis over any defined time period

tral control room personnel. However, because of the massive increase in workload in a severe storm situation, the central control room may delegate much higher levels of switching and crew dispatch authority to the service centers, thus allowing it to concentrate on dealing with high level coordination and planning tasks plus switching actions on major network backbone elements. An extremely flexible and dynamically adjustable user authority scheme forms the basis for this capability. Each user logs in with a specific user role and area of responsibility. The user role is based on responsibilities and qualifications. Areas of responsibility define operating boundaries for each user, from a single device to a specified geography (eg, group of postal codes) or a predefined segment of the network, for example a group of feeders. These user roles and areas of responsibility may be pre-defined or easily adapted by a system administrator to permit a flexible and coordinated storm response from the service centers and the central control room.

As the frequency at which large tropical storms occur is on the upswing, improving damage prediction is fast becoming a necessity.

The second service deals with the need to provide accurate and timely information to all appropriate utility employees, including the central managers responsible for informing the public. A suite of web based applications in the OMS permit authorized users across the enterprise to view, query and act upon outage and operational information. Users need only an internet browser and appropriate access authority to use these tools. Among these applications, an *Executive Information module* provides a global view of the situation including summaries by district. Users can access sub-levels if detailed information is required. The summary data will typically include the number of outages, the number of hazardous outages, total customers without power, total critical customers without power, cumulative hours of total outages, maximum outage duration, number of calls received, number of crews available and assigned, etc. A temporal trend display is available to provide call and outage trends on a system or district basis over any defined time period 6.

The future

Upgrades and improvements are an inherent part of any software-based tool or system. However, as the frequency at which large tropical storms occur is on the upswing, many improvements may be needed sooner rather than later. Improving damage prediction is perhaps a sensible place to begin as severe weather in the form of hurricanes and ice storms continue to plague large areas of the inhabited world. By better forecasting the amount of damage a storm will cause, the resources required for restoration and the time needed to restore service to customers, a utility can effectively plan a way of getting resources quickly into place or on stand-by.

Storm damage prediction is based on an accurate weather forecast of variables related to distribution circuit damage. Taking ice storms as an example, a typical variable could be the amount of ice accumulation on trees surrounding overhead lines or on overhead equipment itself. Wind speeds and gust durations could be two variables associated with hurricanes. In any case, expected damage can be predicted based on historical information and susceptibility models, and this estimate would then allow crew requirements to be directly computed.

The OMS circuit models can be extended to analyze the relationship between crew allocation, predicted and verified damage as well as to calculate Estimated Time to Restore, ETR. During the restoration process, managers can not only use calculations based on these extended models to look at the trade-off between adding more resources and any resulting improvement in customer restoration times, but also to find the most cost effective use of the resources available.

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Future enhancements in storm outage management are discussed in greater detail in [1].

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