RESTORING SERVICE TO CUSTOMERS HAS always been a top priority at the Alabama Power Company during my 45 years there. Although the task is the same, the methods and technologies that can be brought to bear on it have changed and improved dramatically. Technology has helped the company improve its response to system disturbances. Automation technology deployed in the distribution control room, in distribution substations, and at discrete sites along the distribution feeder provides system intelligence regarding the state and condition of the electric distribution system. Automation technology also facilitates the presentation of supervisory control and data acquisition (SCADA) telemetry to the distribution operator. Meanwhile, advances in desktop computing workstations permit the geographical display of distribution circuits in a wide-area view, which improves the visibility of the distribution system for the operator. The big-picture or wide-area view that was once displayed on the paper map board is now presented in the control room on its desktop workstations. Today, application integration is providing the next round of technology improvement in the distribution control room. Advanced applications within an integrated platform are providing techniques to improve the efficiency and reliability of the distribution system. Together, these advanced applications improve service restoration. This article describes the past, present, and future of service restoration technology at Alabama Power.

By G. Larry Clark

A Changing Map
Service Restoration: A Basic Priority
All utilities—and particularly electric utilities—set high expectations for service restoration. Using the latest and most advanced technology can help meet service restoration goals. An associate once described the electric utility’s basic tasks like this:

- ✓ Turn the lights on.
- ✓ Keep the lights on.
- ✓ Turn the lights back on when they go out.

Electric service will be interrupted from time to time due to afternoon storms, natural disasters such as hurricanes and tornadoes, ice and snow storms, high winds, and lightning. When these events occur, the available tools and analytic techniques are applied to locate the fault, isolate the faulted area, complete repairs, and restore service to the faulted area. This is accomplished by the control room staff closely coordinating with field personnel.

When system disturbances occur, everyone becomes immediately focused on that third basic task: turning the lights back on when they go out. Over time, the methods and technology available to perform that task have changed and improved.

One example of this improving technology is the mapping or model of the electric system. In the past, the status of the electric system was displayed on a paper map board that was typically mounted on the wall. The map board depicted the location of switches and isolating points. Pins on the map board indicated the state of each switch; different pin colors denoted the various states in which a switch could be placed. The map board was located near the radio, so that the operator could communicate with field personnel while viewing the map board and recording all switch steps and activity. A typical map board is illustrated in Figure 1.

While the map board may sound archaic by today’s standards, that and the radio were the most effective ways to manage the electric system, even during system disturbances. The best available technology was applied, and the utility staff came together to restore service using the tools that were in place.

Technology Implementation
Technology implementation over the years has improved the response to system disturbances and service restoration efforts. Radios, for example, substantially improved communications to transmit trouble calls to the crew headquarters, where the calls were dispatched to field personnel.

Utilities eventually began developing outage management applications to take and dispatch trouble calls. Customer account records were associated with specific distribution line devices to more swiftly locate outages. Many times, the operator could begin preliminary switching order preparation while field personnel were en route to the outage location. The switching order would be refined once the actual conditions on the ground were reported by field personnel. In those early days, self-healing techniques were being employed, even if they were not known by that term. Restoration operations were as “smart” as possible with the tools that were available.

Automation Technology
Today, automation technology deployed in distribution substations and at discrete sites along the distribution feeder provides system intelligence regarding the state and condition of the electric distribution system. Distribution automation (DA) is a foundational technology that facilitates the emerging smart distribution grid. DA technology is deployed throughout Alabama Power’s service territory.

DA is based on SCADA technology. SCADA facilitates communication between dissimilar technologies and provides a seamless system wide solution. DA deployment starts in the distribution substations, where full instrumentation and measurement technology provide for remote monitoring and control of substation facilities.

In the early days of DA deployment, distribution line monitoring sites were deployed to begin collecting distribution line data including phase voltage and current and real megawatts of power. The remote terminal unit (RTU) reported calculated values, including the three-phase MVA and power factor per phase. Now, existing gang-operated disconnect switches are retrofitted with line-post sensors and motor operators with an RTU that has control capabilities, multiple address system radio, and an antenna system. Pole-mounted reclosers are automated to provide for remote conditions on the ground were reported by field personnel.

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operation and control. Distribution line capacitors are automated to manage the reactive load flow at the discrete point of application on an individual per-phase basis. The capacitors are automatically and individually switched for reactive load requirement per phase. The RTU manages the switching of the capacitors at the discrete point of application based on the line measurements from the line-post sensors. Distribution line regulators are being automated in support of the Green Circuits initiative. The Green Circuit is an EPRI term describing an efficient distribution circuit that is capable of supporting the smart grid goals and objectives. Additional automation schemes include the sectionalizing switch, automatic transfer switchgear, the underground network relay, and the standby generator. Algorithms are developed and loaded in each line DA RTU to support fault current detection and to measure harmonic content on a per-phase basis. The distribution line site provides data per phase regarding:

- voltage
- current
- megawatts
- megavars
- MVA (calculated)
- power factor (calculated)
- fault detection
- fault current magnitude at the substation breaker
- percentage of total harmonic distortion (%THD) for voltage and current.

With the deployment of DA to gather and relay data, SCADA technology has been introduced in the distribution control room. In addition to the wall-mounted map board, the operator now receives system intelligence from the discrete distribution line monitoring sites and has a better view of the electric distribution system. Automation technology facilitates the presentation of SCADA telemetry to the distribution operator, and the SCADA alarm application alerts the operator to system disturbances.

Operators are able to apply SCADA telemetry for better outage response. Outage events reported by the customer accounting system are now confirmed and supplemented by SCADA telemetry, and new restoration tools have been added to the operator’s toolbox. The operator can thus begin to identify the location of the faulted section of the distribution circuit while field personnel are en route to the trouble site. The DA technology is the operational “eyes and ears” for the operator, creating the opportunity for smarter restoration tools.

**Desktop Computing**

As stated earlier, advances in desktop computing workstations permitted the geographical display of distribution circuits in a wide-area view, improving the operator’s view of the distribution system. The electronic map board (EMB) was developed to display the switching diagram, and the wall-mounted map board moved to the desktop workstation. An EMB is illustrated in Figure 2. EMBs improved the operator’s access to areas of the map board not covered by the wall-mounted board.

While the EMB was still a static representation, the operator using an EMB saw symbols denoting the location of automated devices along the distribution circuits, while background text in the SCADA displays facilitated interaction with the EMB. Operators themselves were the link between SCADA and EMB. Outage management information, SCADA telemetry, and the status of the electric system, as shown in the EMB, were all as simulated by operators in order to respond to system disturbances. With the help of improved navigation techniques for EMBs, operators located outages based on predictions from the outage information system and confirmations from the SCADA and DA systems, achieving a new level of service restoration.

With the advent of EMBs, new efficiencies were introduced into the control room that complemented the SCADA distribution technology. The desktop operating environment began to appear in the control room. The operator was presented with new techniques for managing the day-to-day operating environment. The improvements in operator efficiency included:

- a desktop configuration that presented operating software tools, such as distribution substation SCADA, DA, outage management information, electric system switching diagrams that used EMB technology, more productive desktop software tools, and communications, in a console fashion
- greater visibility of the electric system through EMB technology, which helped to create associated relationships between distribution SCADA and the switching diagram
- navigation techniques utilizing the electrical addresses from the outage management information.

With SCADA and EMB, the operator remained at the desktop or console location to carry out the daily tasks of operating the electric system. Gone were the days when the operator had to go to the map board on the wall to make operating and switching decisions and then return to the desktop to carry them out.

The big-picture requirement quickly went the way of old technology as the EMB gained a firm foothold in control rooms.
as the official switching diagram. A common misconception was that the wall-mounted paper map board was needed for the big picture. With the old technology, everything was posted on the map board so as to depict abnormal switch states, operating notes, unusual operating conditions, storm assessment notes during wide-area disturbances, and other relevant information. All posting was manual in nature. When conditions changed or the storm restoration was complete, the manual posting had to be reversed. The big picture was only obvious when viewed from across the room. When the operator went to the mapboard, the intention was to consider the operating requirements for a specific switch or location. With the EMBox at the desktop, the big-picture issue melted away. Navigation and zooming techniques supplanted the need for a separate big picture—both the big picture and details were available on the desktop—and improved the operator’s use of the electronic switching environment at the control room console. Desktop computing made a significant improvement in the control room.

Next-Generation Operating System
Alabama Power is now transitioning to a next-generation operating system, known as an integrated distribution management system (IDMS). This type of system leverages DA and improves operating capabilities using advanced applications integrated within IDMS. The integration begins with SCADA and outage management systems’ being made available in a single user interface and displayed in a connected model sourced by geographic information system (GIS) data. Each customer can be viewed in the connected model, and the geographic data improve navigation when responding to system disturbances. GIS topology and attribution allow the implementation of advanced network analysis applications that enhance operational decisions in the control room, while smart grid functions improve distribution asset utilization, distribution reliability, grid efficiency, and demand management. These functions further contribute to improved service restoration.

IDMS is built on the SCADA and DA foundation. The next-generation operating system is illustrated in Figure 3. On 5 December 2012, Alabama Power implemented IDMS/DMS Phase I in its distribution control centers, integrating SCADA with the electronic geographic switching diagram and electronic switching orders. IDMS is being designed to provide the operator with a seamless integration of operating applications. For example, switching orders are no longer written by hand, and a new, single-user environment is provided to the operating staff in the control room, facilitating the introduction of advanced applications. As this article is being written, outage management functionality is being introduced within IDMS.

IDMS also includes a distribution operations training simulator for operator training. The simulator is a complete replication of the desktop environment and all the operational tools. SCADA capability is fully replicated in the simulator environment. When outage events are simulated for the operator on the desktop workstation, the operator responds to the event using the restoration tools. Everything from a single customer interruption to a wide-area disturbance caused by a natural disaster can be easily simulated in the training environment, helping operators sharpen their skills in responding to outages of all kinds.

For major storm events such as hurricanes, IDMS is deployed at staging areas established to respond quickly to damage. With the deployment of network digital communications to the staging areas via a Citrix client, IDMS is fully

![SCADA and Substation Switching Diagram](image1.png)

![Electronic Switching Order](image2.png)

![Electronic Switching Diagram](image3.png)

**figure 3.** The next-generation operating system: IDMS.
functional for wide-area service restoration. The Citrix client solution provides a method of hosting the IDMS application on a server so that the desktop can be presented on multiple clients wherever there is network connectivity available in a secure manner requiring a user account and password. The operator responds to actual conditions while working closely with the storm restoration team.

One Model

At the operator’s desktop, IDMS takes the form of a “one-model,” single-user environment as the basis for electric system operations with improved visibility of the entire electric distribution system. It facilitates the seamless operating environment, providing actionable operational intelligence to the operator. The IDMS solution is the operational nucleus of the electric utility.

Outage events and SCADA measurements are now presented to the operator in a connected, traceable switching diagram supported by the single-model solution. Navigation from the outage event record to the geographic location requires only a single click. The SCADA display is linked to the geographic display, establishing connectivity between the SCADA substation switching diagram and the geographic switching diagram. Figure 4 illustrates an outage event traced from the open (locked-out) substation breaker to the end of the line that is out of service. The halo image designates out-of-service facilities while the tracing function identifies normal, open devices connected to contiguous circuits, helping determine possible alternate sources for restoring service. The single-model solution provides a point-and-click function for selecting devices to be added to the electronic switching order. If necessary, and as operational needs dictate, the single-model solution provides ready access to any substation or distribution line device within Alabama Power’s 44,500-mi² service territory. Operators can back each other up in the control room and across the service territory. Every action is normally performed on the desktop at the operator’s console and can be communicated to field personnel by means of radio, which remains an integral tool in the control room.

The single-model solution provides the ability to perform a switching order in a study mode that is based on the extraction of real-time data from the online operational system. The operator can check and verify a switching order before performing the actual steps; this process is now being applied during actual restoration events.

The desktop console is now more functional and efficient. The relationship of devices along the distribution circuit to the source substation is readily apparent to the operator. The single-model operating environment brings additional efficiencies to the control room. These include:

✔ visibility of the overhead facilities and the connected underground facilities
✔ tracing to the end of the line and to all normally functioning open devices
✔ display techniques to facilitate the identification of isolating points in order to establish clearance for a portion of the electric system
✔ the integration of applications into a virtual single system, so that SCADA interruption events become confirmed outage management records without operator intervention; actual representation of the event is available at every device as a check against unauthorized access. It also allows the operator to check the status of a device in real time.

Application integration is at the center of control room improvements to enhance operational tools.

**figure 4.** An outage event, traced from the open (locked-out) substation breaker to the end of the line that is out of service.
Advanced applications on the new application integration platform that improve the efficiency and reliability of the distribution system benefit service restoration as well.

Connectivity of the electric system is provided (for example, a different line-haloing technique is presented to the operator when radial circuits are connected together or paralleled); and the integrated system recommends switching to restore service based on operator-selected criteria.

The operator’s efficiency at the desktop console is incrementally improved as the control room evolves into the control room of the future. This future is rapidly becoming a reality.

Application Integration
Application integration is providing the next round of technology improvement in the distribution control room that will benefit service restoration. Advanced applications such as unbalanced load flow; volt and var control; conservation voltage reduction (CVR); loss minimization; circuit reconfiguration; and fault location, isolation, and service restoration (FLISR), among others, continue to be deployed. FLISR promises the next improvement in service restoration. The single-model solution lets the operator run a FLISR solution to restore electric service. FLISR will develop switching solutions to restore service to the maximum number of customers in the unfaulted portions of the distribution circuit while maintaining adequate voltage levels and avoiding circuit overloads. Volt and var control and CVR can be applied to alleviate voltage problems and circuit overloads to restore as much service as quickly as possible. When line repairs are complete, the service isolation switching steps can be reversed to restore all service.

Advanced applications on the new application integration platform that improve the efficiency and reliability of the distribution system benefit service restoration as well. The electric system is maintained within acceptable voltage limits, and load violations are identified and remediation solutions are proposed, including switching steps. The operator chooses the best solution for optimizing service restoration.

The advanced applications were traditionally performed as back-office support to the control room because of the time needed to complete a given analysis. With the introduction of advanced applications in the control room, the operator will have ready access to system-level planning tools designed to run in real time. The operator’s ability to manage and improve the efficiency of the electric system will take another step forward. Such improvements will include the following:

✔ Voltage and load violations will be highlighted in the GIS-supported geographic display, providing the operator with the opportunity to intervene and take corrective action.

✔ The results of remedial action will be presented to the operator in the connected diagram, confirming the outcome of the decisions made.

The desktop computing environment is rapidly improving to the point that the next round of efficiency improvements may be best described as “improved click efficiency.” The operator will be investigating how best to achieve improved efficiency using fewer clicks of the mouse. Software applications frequently provide multiple paths to complete a given operational task, depending on the point of origin within the application. As the operator becomes familiar with these multiple paths, operator efficiency will increase while the integrity of the electric system is maintained.

Conclusion
The service restoration tools available to operators in the control room have evolved with the increasing capability of desktop computing workstations. The manual operations of old used wall-mounted map boards for switching purposes. These have been replaced with a GIS-sourced connected switching diagram built on a single model. Application integration is at the center of control room improvements to enhance operational tools. The integrated solution brings unbalanced load flow calculations to the operator’s desktop. Advanced integrated tools help the operator facilitate service restoration and perform day-to-day operating tasks. Techniques are evolving that will reduce the number of mouse clicks needed to perform an operational task. Efficiency in the control room is incrementally increasing with improved desktop computing, application integration, and the introduction of advanced applications. These technology advancements improve the operator’s response to system disturbances and advance the management of service restoration in the control room.

Service restoration is not just a job, a task, an assignment, or a corporate mission; it is a passion shared by people who take pride in restoring electric service. The reward comes in seeing customers’ lives return to normal as the lights come back on.

Biography
G. Larry Clark is with the Alabama Power Company, Birmingham, Alabama.