Automated Distribution Scheme Speeds Service Restoration

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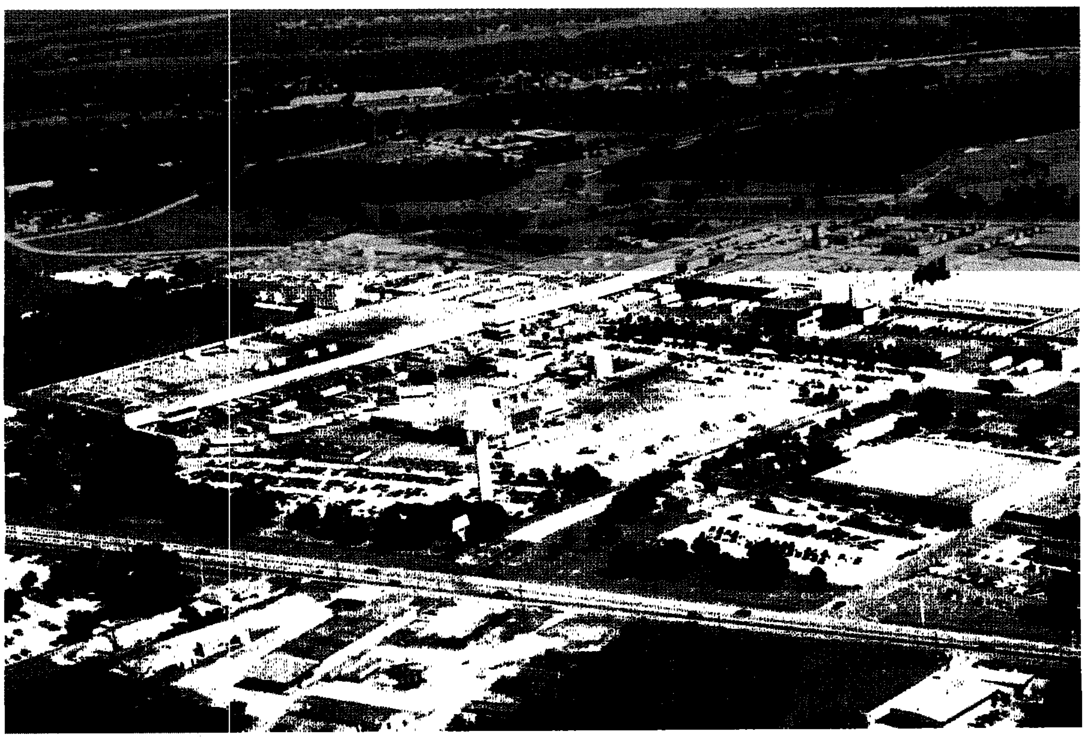
Lakeland Electric required an automated scheme that would restore power to a major customer in less than 60 seconds



Lakeland Electric & Water provided a state-of-the-art, automated, distribution system (built to withstand inherent weather-related situations) to the Publix complex in Lakeland, Florida, which covers 2 million square feet and houses a dairy processing plant, bakery, product plant, deli plant, data processing facility, purchasing department, and maintenance facilities.

In January 1993, Lakeland Electric & Water (LEW) took on the design and construction of a new 12.47-kV automated distribution system for the Publix Supermarket industrial complex. The industrial complex in Lakeland, Florida, totals 2 million square feet and houses a dairy processing plant, bakery, produce plant, deli plant, data-processing facility for Publix's entire retail network, purchasing department, as well as several maintenance

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facilities. The retail chain is LEW's largest customer with a peak demand of 15.5 MW and a load factor of 81 percent.

The entire distribution system was rebuilt to physically endure the effect of hurricanes and lightning strikes

Publix's rapid expansion plan has placed a great deal of pressure on this facility to perform at peak level with no interruptions of product flow. The task at hand was to provide Publix with a state-of-the-art, automated, distribution system built to withstand the inherent weather-related situations in central Florida, lightning and hurricanes.

Distribution Problems

The original distribution system consisted of a wood-pole line with underground radial feeds to transformer vaults. The complex was served by two 12.47-kV feeders off of separate transformers in the same substation. Load growth in the complex had exceeded the capability of one feeder to serve the entire load in the event of a contingency. The internal system was more than 25 years old and in need of replacement.

Publix's experience in south Florida with Hurricane Andrew left a feeling of extreme vulnerability with the existing power source. They had several stores leveled by the hurricane and witnessed, first hand, the complete destruction of the mostly wood distribution system in Homestead.

Lightning is a major cause of outages in the summer months in central Florida. Lakeland is located in the area of highest isokeraunic activity in North America as measured by the EPRI lightning research network. Lightning intrusion into the electric distribution system at Publix had long been a problem, causing frequent damage and numerous outages over the years.

Many of the outages at the complex were lengthy due to damage on the external feeders. Once the feeder breakers had gone to lockout, it was necessary to ride the circuit out to determine the course of action for restoration. This frequently could take a minimum of 45 minutes and, depending on the problem found, could take hours to repair. During these lengthy outages, Publix was prone to lose product at the bakery plant. Publix could no longer tolerate this length of restoration time, given their production requirements.

New Distribution System

There are six automated switches in the system. A motor-operated, 1,200-amp Alduti-Rupter® switch from S&C Electric Company serves as the main feed switch into the complex. There are also five S&C Scada-Mate® switching systems; three are alternate feed switches and two are internal segmenting switches. At Publix's request, LEW feeds the complex through one *super feeder*, designed to accommodate a load of 22 MW. It was constructed out of a new 60 MVA distribution substation (Winston Substation) to the Publix site, underbuilt on a new spun-concrete transmission pole line. There are three alternate feeders from two different substations. Two of the feeders are the original ones from LEW's West Substation, and the other is from a new substation named Sutton (See Figure 1).

Each Scada-Mate switch incorporates a Harris DART feeder RTU to provide SCADA capability. A Harris sub-remote unit, located at the Alduti-Rupter switch, houses a DART for the switch and a Harris D20 data concentrator. The data concentrator communicates with all of the feeder RTUs and reports back to LEW's Harris 5000 SCADA master system on demand. The data concentrator is the *brains* of the automation system and is the platform for the logic software.

The communications network provided by H&L Instruments is entirely fiberoptic to minimize the influence of lightning and is installed in a complete loop configuration to provide secure, reliable, high-speed transmission of data. H&L's Fiber Loop System™ uses the Model 550 Fiberoptic Network Controller located at the data concentrator as the LAN manager; it is the mas-

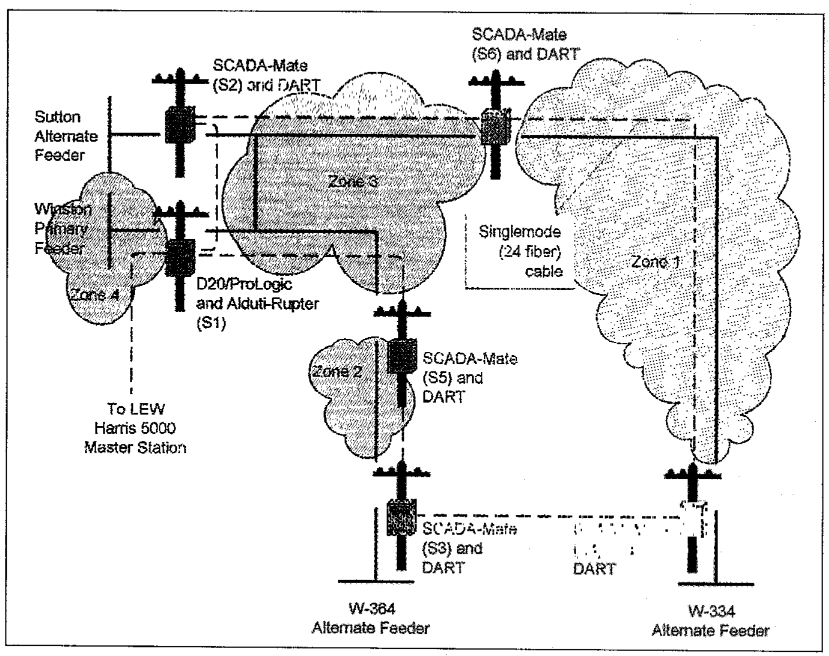


Figure 1. Distribution system

ter station. Model 552 Fiberoptic Transceivers are located at the feeder RTUs and are slave stations. Both the controller and transceivers are intelligent; their microprocessor-based designs enable them to store and forward data, perform health checks of the two fiber loops and electronics continuously. Upon detecting a problem, the controller automatically reroutes data around the break or weak point in the communications network, usually without losing any data.

The automation scheme consists of unique steps for program initialization, fault detection and fault location, fault isolation, and power restoration

The entire distribution system was rebuilt to physically endure the effect of hurricanes and lightning strikes. All underground runs to transformer locations were loop fed, providing the capability for feeding any transformer by alternate means with the loss of any one cable section.

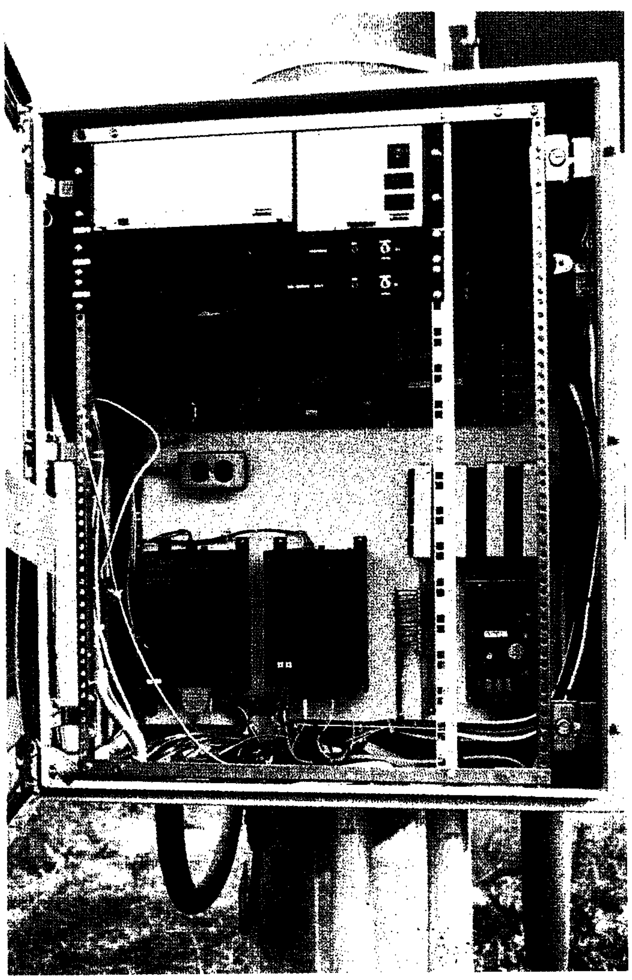
Automation Criteria

After realizing that the original design target of 1-second-maximum system reconfiguration was technically and logistically not feasible, 60 seconds was set as the target. To achieve this goal, LEW needed to provide fully automatic system reconfiguration. Traditional SCADA operation, in which LEW's electric system operators would perform remote switching, would still have required anywhere from 10 to 20 minutes to restore power to unfaulted sections, depending on the situation.

Harris, in collaboration with S&C Electric Company and H&L Instruments, was contracted by LEW to develop the system as a package for Publix. Harris utilized its ProLogic RTU-based ladder logic software to make decisions and issue commands to the switches.

The distribution system is broken down into four zones. Three of the zones are located within the Publix complex, and the fourth zone is the external feeder from Winston Substation. The automation scheme is able to operate under four initial switching arrangements, and looks at two levels of security to determine loss of voltage and presence of voltage on feeders.

The data concentrator at the main feeder switch acts as a polling engine for the system. It polls the six feeder RTUs for status and analog information. Using S&C's patented algorithm, the feeder RTUs provide fault detection information in the form of pseudo status points to the data concentrator. The programmable logic control application running on the data concentrator employs algorithms and logic developed jointly by LEW and Harris. It automatically determines the location of faults along the network, initializes fault isolation, and executes load restoration.



A Harris sub-remote unit located at an Alduti-Rupter motor-operated switch houses a WESDAC DART switch controller and D20 data concentrator, which is the brains of the automation system and platform of the logic software.

Should a fault occur on the distribution network, this automatic fault isolation and load restoration scheme is able to remotely operate the overhead switches to isolate the faulted section of the line and reroute power from an alternate feeder to unaffected sections. The automation scheme consists of a number of unique steps:

1. Program initialization
2. Fault detection and fault location
3. Fault isolation
4. Power restoration.

Program Initialization

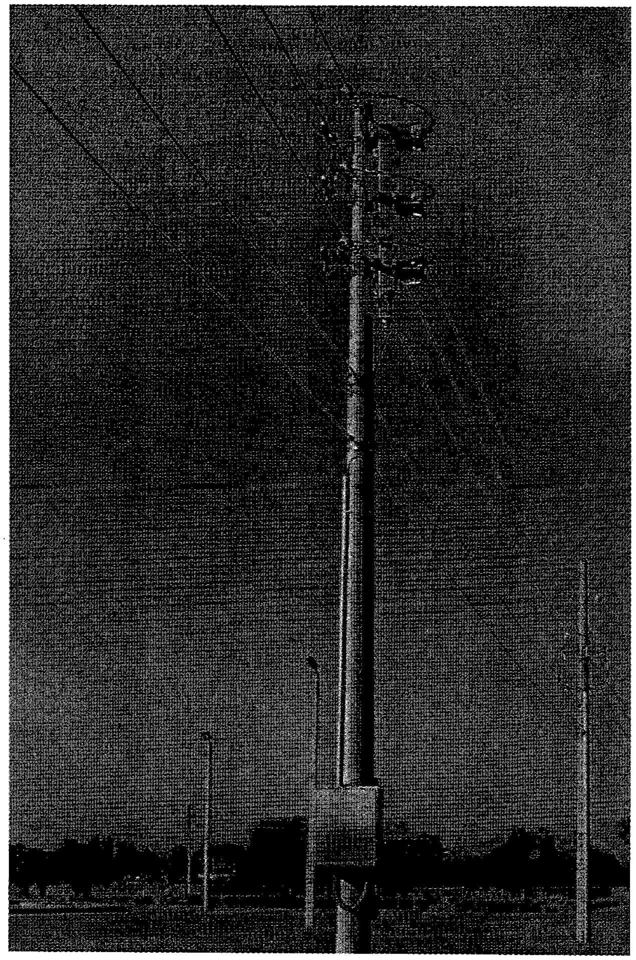
During this routine, the program determines the initial switching arrangement. The program first verifies that all prerequisites for running in automatic mode have been satisfied. A flag is then set to indicate that the program is running. The program subsequently checks the data concentrator's database manager for communication failures, fault conditions, and valid initial switching arrangements. If the program encounters a communication failure or system initialization error, the program flags these events to the data concentrator's database manager for reporting to the master station and aborts operation.

Fault Detection and Fault Location

The automation scheme is predicated upon the substation breaker operating to lockout. Fault detection is accomplished by monitoring for overcurrents followed by a loss of phase voltage. The location of a fault is deduced by determining which feeder RTU recorded a lockout event in association with an overcurrent condition.

Loss of voltage is detected by monitoring the phase voltages of each feeder and setting software flags when the voltages have exceeded a preconfigured magnitude threshold and qualification period. Each feeder RTU samples the ac voltage waveform at a specific sampling rate. These analog values are retrieved from each feeder RTU by the data concentrator. The program retrieves the values from the database manager, then increments a counter each time a phase voltage is above the preconfigured threshold. When the counter increments above the qualification period, a software flag is set. This software flag is then copied into the database manager as a loss of voltage status point that can be retrieved by the master station.

A lockout is detected by each feeder RTU's fault detection algorithm. If the breaker has operated and loss of current and voltage have been qualified for the reclose period, a lockout event is recorded as a time-tagged change of state. This event is then retrieved from each feeder RTU into the data concentrator's database manager. Lower levels of fault conditions are also qualified by the patented algorithm, but the lockout condition is the trigger for the LEW system to ensure Publix stays with the dedicated "system feeder" until it has completely locked out.



The complete feeder switching installation includes a 600A switch with integrated sensing, disconnect, and power supply, and a communications and control unit with feeder RTU, fiberoptic transceiver, and switch controls.

In the event that power restoration is impossible due to too many faulted zones, a multifault message is generated and the program stops.

Fault Isolation

Once a fault has been detected, the program sets a software latch to indicate that a fault has occurred in that zone. The software latch is then copied into the database manager as a status point that can be retrieved by the master station. The data concentrator is automatically instructed to open switches and isolate the faulted zone. The switch actions are subsequently qualified, and a zone isolation failure alarm is written into the database manager if any of the switches did not respond. The program then checks to see which switches did respond and proceeds to restore power to the isolated zones.

Power Restoration

The program first qualifies the ability to restore power by verifying presence of voltage on the alternate feeders. In the event of voltage absence, the program generates a feeder power failure message. If voltage is present, the appropriate switch is instructed to close. The switch action is then qualified, and a zone power restoration failure message is generated if the switch does not respond. If the zone is restored successfully, a restoration-successful and program-complete message is generated.

Program Benefits

While the most significant advantage of the system is its ability to automatically restore service in less than 60 seconds, there are also a number of operational benefits:

- Selection of automatic or local mode remotely from the master station or locally via a toggle switch
- Reduction of electric system operator stress by

automating certain functions, such as qualifying switch operations and the ability to restore power
- Simplified master station database management and configuration through consolidation of field events into messages that can be directly mapped to the master station.

Distribution automation offers realistic possibilities beyond traditional remote feeder switching applications

Real-Life Tests

The lightning activity in the LEW service territory during the summer of 1994 was unusually high. Double the number of lightning strikes were recorded than in the same time period in 1993. The true test of the system would be how it operated in heavy lightning conditions. Its first test came quickly, during extremely unusual operating conditions. A cascading transmission failure de-energized nine substations, including the main and all alternate feeds. There was no available source of power.

The main feed switch and the two internal segmenting switches opened, which disconnected the main feed and sectionalized the system into three zones. None of the alternate feed switches closed, as there was no voltage present on the alternate feeders.

Table 1. Performance record

Date	Condition	Fault Location	Cause	Restore Time (seconds)
July 18, 1994	Lightning storm	Zone 4	Major transmission failure	30
July 19, 1994	Lightning storm	Zone 4	Transformer differential	37
July 26, 1994	Lightning storm	Zone 4	Transformer differential	38
September 24, 1994	Clear night	Zone 4	Frog on insulator	37
October 8, 1994	Heavy fog	Zone 1	Lightning arrestor failure	42
July 7, 1995	Lightning storm	Zone 4	Transformer failed	38

Although Publix remained without power, the automation system worked exactly as designed, successfully passing the first real-time test. The system has since operated several more times (see Table 1). Each time, restoration was completed in 42 seconds or less, which is well below the design goal of 60 seconds. Two of these occasions involved severe lightning storms, and two were in calm conditions.

Customer Satisfaction

With past experiences of extended outages and restoration uncertainty, Publix was eager for a reliable and timely solution. The design requirements for the automated systems were intended to allow Publix to continue to meet its ever-growing production demands by minimizing the scope and effects of unplanned power outages. As demonstrated by its performance record to date, the system has performed flawlessly, much to the satisfaction of all involved. Funded and owned by Publix, the installed cost of the automation scheme was approximately \$250,000, which was 14 percent of the total distribution project cost (\$1.8 million).

This forward-thinking project demonstrates the realistic possibilities for true distribution automation outside of traditional remote feeder switching applications. Projects such as this, which have a direct and measurable affect on customers, allow for project-specific justification and give LEW a unique way to provide custom services to meet the needs of individual customers. Although Publix owns this system, LEW has arranged a long-term agreement to lease and maintain the system. They have also completed negotiations with a second large customer and are in discussions with a third.

Biographies

Everett Atwell is supervisor of T&D Engineering at Lakeland Electric & Water, Lakeland, Florida. He has worked for the utility since 1988 and has also been involved in system analysis, SCADA, and distribution automation. He previously worked for the Utility Board of Key West, Florida. Everett has a BSEE from the University of Notre Dame.

Tex Gamvrelis is a product manager for the Distribution Automation Business Team of Harris Canada, Inc., Control Division, Distributed Automation Products, Calgary, Alberta, Canada. He has managed a variety of transmission SCADA projects and has been involved in distribution automation efforts for the last 3 years. He received a BSEE from the University of Manitoba. He is a member of the Association of Professional Engineers, Geologists, and Geophysicists of Alberta, the Association of Professional Engineers of Manitoba, the IEEE, the Project Management Institute, and the Society of Automotive Engineers.

David F. Kearns is the senior applications engineer at S&C Electric Company, Chicago, Illinois. Prior to his 6 years with S&C, he was product marketing manager for Kearney VacPac Switches and was with Kentucky Utilities (Lexington) as their district engineer for distribution and a division underground engineer. Kearns has a BSEE from the University of Kentucky. He is a member of the IEEE Power Engineering Society.

Robert J. Landman is president, founder (1979), and director of R&D at H&L Instruments, North Hampton, New Hampshire. Prior to H&L, he worked for Textronix, Hewlett Packard, the University of California, the University of Maryland, and Pacific Gas & Electric's Engineering Research Department. He majored in physics at the University of California at Santa Barbara, California State University at San Francisco, and the American University, Washington, D.C. He is an IEEE Senior Member and a member of the American Society for Testing Materials and Semiconductor Equipment and Materials International. He is the author of the "SCADA and Communications" of Section 10 of the 13th edition of McGraw-Hill's *Standard Handbook for Electrical Engineers*.