

Progressive Capacitor Automation *Yields Economic and Practical Benefits at KCPL*

By Carl Goeckeler, P.E.

As usual, summer in the Midwest saw utilities reaching annual peak demands for electricity. Hot temperatures and high demands often have distribution operators scrambling to keep systems up and running. Kansas City Power & Light Co. (KCPL) is one Midwest utility that could breathe a little easier this past summer, thanks to a distribution automation project that began several years ago.

In 1994, pending the onset of deregulation, the utility, which serves more than 430,000 customers in western Missouri and eastern Kansas, made the decision to automate its distribution operations in order to cut costs and improve customer service. Capacitor automation was one of the earliest of several programs to be planned and implemented as part of the overall automation project.

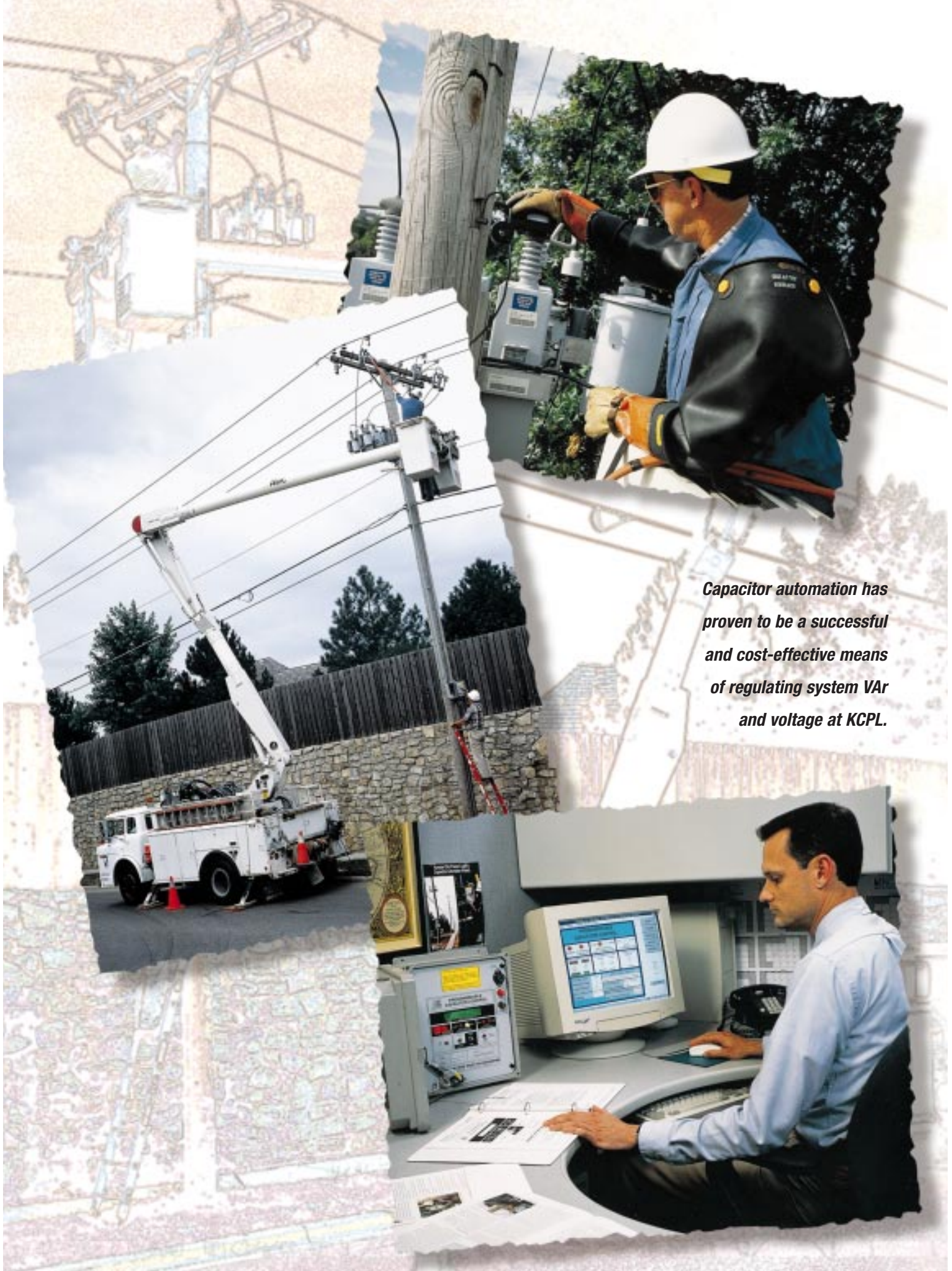
The automated capacitor control system is made possible through use of a CellNet (San Carlos, Calif.) wireless communications system, capacitor controls and WinMon graphical user interface (GUI) from EnergyLine Systems (Alameda, Calif.) and Cycle Software (Cambridge, Mass.) LiveData Servers. The combination of these products provided KCPL with the features and flexibility it needed to control the capacitor banks, view real-time and historical data, create reports and give users throughout KCPL's corporate network access to the data from their desktop PCs. The project is nearing completion of the rollout stage. By early 1999, KCPL had automated 576 capacitors in the metropolitan area. Of this number, 368 are VAr controls. The remaining devices are mostly temperature controls with a few time controls. All controls have voltage override and capacitor neutral current detection.

Project Results

The VAr sensing controls have allowed KCPL to minimize reactive current flow more efficiently, both daily and hourly. The analog values from these controls provide information to the distribution engineers, who can now make better decisions regarding capacitor placement.

One product feature that greatly assists KCPL's effort to identify maintenance needs is a neutral sensor alarm. A current sensor on the neutral of a grounded wye connected capacitor bank allows KCPL to detect blown fuses, defective switches or incidental problems, such as a bad control cable. KCPL can monitor maintenance needs on all three phases for a small additional cost. With this alarm and the voltage override feature, KCPL has greatly reduced low voltage, high voltage and voltage balance problems on its distribution system.

Before capacitor automation, KCPL was challenged to patrol the capacitors in a timely manner. If capacitors were patrolled too early, ensuing storms and operating problems would introduce new maintenance problems before the summer peak load period. If the patrol was put off too late, it became impossible to repair all the capacitors before the summer peak. KCPL has now eliminated the patrols for automated capacitor banks. The utility has been



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able to manage capacitor maintenance by reviewing the alarms weekly. Many times the capacitors are field-checked and repaired within 24 hours of acknowledging the alarm. By reviewing the VAr flow data from the automated controls, engineers can determine operational problems of non-automated capacitors.

KCPL has thus been able to reduce the number of customer voltage complaints. The utility's power quality engineer uses the information from WinMon to address circuit problems proactively, before customers experience inconvenience to their businesses. As a practical example, the power quality engineer reports that four years ago it was common to have all 10 of the company's three phase recording voltmeters installed on customer complaints (with a waiting list). Now, he said, it is rare when more than two are in use for customer complaints.

Practical Considerations for Benefit/Cost Analysis

KCPL's capacitor automation project contained several layers of costs and benefits. First, KCPL received significant benefits from the installation of a programmable VAr control through the neutral sensing option. Its considerable operating intelligence was previously unattainable with conventional electro-mechanical temperature sensing controls.

The second layer was the ability to communicate with the controls through KCPL's CellNet Data Systems meter reading network. As part of the utility's meter reading system, KCPL and CellNet developed an innovative service solution.

Table 1
Results from Johnson County and Southland Service Centers

Year	MW Peak (Actual)	MVAr Peak (Actual)	Cumulative MVAr Growth	Cumulative MVAr Reduction*	Corrected PF (Actual)
1995	1022	188	Base Year	Base Year	98.3%
1996	1056	190	16.5	14.5	98.4%
1997	1064	187	20.3	21.3	98.5%
1998	1089	180	32.5	40.5	98.7%

**Contributed from the Project
Note: These values assume that the load growth for 1996-1998 is at 90% uncorrected power factor.*

Table 2
Capacitance Purchased (1989-1998) and Savings

Year	MVAr Capacitance Purchased	Savings Per Year (Avoided Purchase, Installation, and Maintenance of Capacitors)
1989	70.0	None
1990	61.4	None
1991	59.4	None
1992	37.6	None
1993	66.8	None
1994	24.0	Transition year (automation began)
1995	19.7	\$393,000
1996	13.6	\$454,000
1997	13.6	\$454,000
1998	24.4	\$346,000
Total		\$1,647,000

Note: The first shaded region indicates years before capacitor automation. The average yearly purchase of capacitors for 1989 through 1993 was 59.0 MVAr; for 1995 through 1998, this average was 17.8 MVAr. The yearly savings equals [the difference between the average annual purchase before capacitor automation and the new annual purchase, in MVAr] x [\$10.00 per kVAr installed and maintained].

A radio infrastructure was deployed throughout the Kansas City metropolitan area. Additional services such as communication for capacitor automation were much easier to justify because they were available at an incremental cost.

The basic functionality offered by CellNet included GUI screens that would show the open or closed status of a bank, report any alarms and allow remote control of the bank.

The final layer was the use of EnergyLine's WinMon, a more powerful GUI, and Cycle LiveData servers to connect CellNet and KCPL's corporate network. KCPL chose a client/server approach using EPRI/UCA Manufacturing Message Specification (MMS) and Live Data Servers. The servers convert the

protocol(s) used by field devices to MMS, which can then be transmitted throughout KCPL's corporate TCP/IP network. Users anywhere on the network have access to live distribution automation data via PC-based workstations with Cycle LiveData software.

EnergyLine was selected to provide the programmable capacitor controls for the project. KCPL supported the vendor's efforts to adapt its WinMon product for distribution automation because it was originally developed for heating, ventilating and air conditioning control. WinMon is used to view and organize data. Setpoints in the controls are easy to read and reprogram. In addition, valuable troubleshooting and data logging screens can be accessed using WinMon.

Avoided Costs of Capacitor Banks

Table 1 shows the results of two service centers on the Kansas side of the Kansas City metropolitan area. The load served from these two service centers comprises approximately 36 percent of the KCPL load in the metropolitan area. These two service centers were the initial areas covered by the capacitor automation program and contain the installations with the longest operating history. During the four-year rollout of capacitors in this area, there was a net removal of 5 MVAr of capacitors. As the load grew, the distribution reactive power requirements grew by a total of 32.5 MVAr. However, capacitor automation allowed the remaining capacitors to control the load more efficiently. During this four-year period, the system power factor for these two centers improved from 98.3 percent to 98.7 percent.

CAPACITOR AUTOMATION

These numbers illustrate that capacitor automation at KCPL has released the equivalent of 45.5 MVAR of capacitance (the 40.5 cumulative MVAR correction plus the 5 MVAR capacitance removed) in these two service centers. Based on a conservative value of a switched capacitor bank at \$8 per kVAR installed, this results in a hard dollar savings of \$364,000 for this portion of KCPL's system. The savings of purchasing, installing and maintaining a distribution capacitor with a switched control easily equals \$10 per kVAR (see Released Maintenance Costs below).

For the entire metropolitan area, the power factor increased from 98.4 percent in 1995 to 98.5 percent in 1998, while avoiding over 165 MVAR of purchased, installed and maintained capacitance. As Table 2 depicts, this is a total savings of \$1,647,000.

In addition, 33 MVAR has been released from unneeded locations and moved to other substations or circuits where the capacitance was needed. The loss reduction from this 33 MVAR of relocated capacitance is substantial. In most instances, the installation was removed because the power factor was excessively leading at the circuit or substation. The new location was chosen where power factor was excessively lagging. These capacitor bank relocations minimized the VAR flow closer to the load, thereby reducing losses at the former and the new sites.

Released Maintenance Costs

A capacitor bank requires considerable maintenance over its life because of lightning damage and frequent switching. Capacitors are subject to high frequency voltage disturbances during lightning strikes that cause the capacitor's impedance to be temporarily reduced. For switched capacitors with oil switches, KCPL studies showed that 25 to 35 percent of the installations commonly needed annual maintenance of some form. Table 3 illustrates KCPL's maintenance experi-

ence. This makes the cost of maintaining a capacitor bank throughout a 30-year life significant. KCPL has initiated a program to use vacuum switched capacitor banks to reduce maintenance needs.

The savings from deferring the installation of a capacitor bank are two-fold. Not only will the cost of purchasing and installing the banks be saved, but the utility will also save annual maintenance expenses of the deferred capacitors.

Benefits Exceed Expectations

KCPL desired a capacitor automation system that would be able to operate automatically as much as possible. Although the remote control capabilities through WinMon were attractive, its real value was in the ability to easily retrieve alarms, change setpoints and read historical data.

Engineers have leveraged this ability and now can conveniently monitor the performance of capacitors as a function of voltage and VAR setpoints. Over the year, they review setpoints from practically every control. The ease of accessing and changing these setpoints has enabled the engineers to fine-tune the VAR flow of the KCPL distribution system. Alarms from the control also alert WinMon users to possible problems. The troubleshooting options in the control also help users get to the source of the problem cost effectively.

The value of capacitor automation was clearly demonstrated at KCPL in the summer of 1998. Just before midnight on August 19, KCPL experienced an equipment failure at its Hawthorn generating station, taking the plant out of service. This caused concern because Hawthorn #5 is the only large KCPL generating station in the metropolitan area. Weather

Table 3
KCPL Maintenance Needs Identified by Automation

Problem	1997 (350 Banks)	1998 (500 Banks)*
Failed oil switches	29	33
Hardware accidentally set to "Local" or "Manual"	18	15
Primary fuse to capacitor blown (solved by replacement)	28	41
Defective capacitor unit	12	15
Control power transformer	3	8
Miscellaneous	8	10
Total	98	122
Total Percent	28%	24%

*1998 numbers include only 10 months

forecasters were calling for another day with temperatures near 100 degrees.

Transmission dispatchers asked distribution dispatchers to turn on all available distribution capacitors to boost the voltage and VAR flow to support the remaining generators. Dispatchers worked with engineers to switch on capacitors as quickly as possible using remote control switching through WinMon. As a result of this proactive switching effort, 90 MVAR of additional capacitive support was supplied to the transmission system. The system power factor on this day was raised from 98.6 percent to 99.1 percent due to the remote switching. Before capacitor automation, KCPL would have been unable to meet this request in such a short time frame.

Conclusion

Capacitor automation has proven to be a successful and cost effective means of regulating system VAR and voltage at KCPL. The quality of voltage to customers has improved, and capacitor maintenance can now occur throughout the year as required, eliminating the need for patrols. Better use of existing capacitor banks, retrofitted with automated controls, has deferred purchasing, installing, and maintaining 165 MVAR of distribution capacitors. ■

Editor's Note: This article was adapted from the author's presentation at the 1999 DistribuTECH Conference and Exhibition.

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