Georgia Power Exposes Misbehaving Capacitors

Utility develops capacitor monitor capability to ensure optimum conservation voltage reduction.

By **Van Holsomback**, *Georgia Power Co.*

The smart grid uses gathered information and data to help improve efficiency, reliability and distribution of electricity to utility customers. As Georgia Power neared the completion of its advanced metering infrastructure (AMI) deployment, engineers began to look for ways to use the vast amount of data available from the AMI meters to improve the overall operation of the distribution system. As often occurs when a new technology is deployed, engineers discovered a use for the technology that was not in the original business model. Southern Co. partnered with Marwell Corp., which specializes in traditional meter socket adapters, to create an adapter that would allow a standard 120-V AMI meter to monitor and report the health of a capacitor bank.

The concept of using an AMI meter to report the health of a three-phase capacitor leveraged the proven method of analyzing the neutral current of a wye-connected capacitor bank as an indication of capacitor health. The idea was simple: If the AMI meter could report the current in the neutral, an analysis of the data would indicate capacitor banks with high neutral current because of one or two phases being out of service. The thought of placing the meter in the neutral path immediately drew concerns about the meter's ability to withstand the fault current, which is sometimes present in a capacitor's neutral. This concern was mitigated by electrically coupling the meter to the neutral with a current transformer (CT).

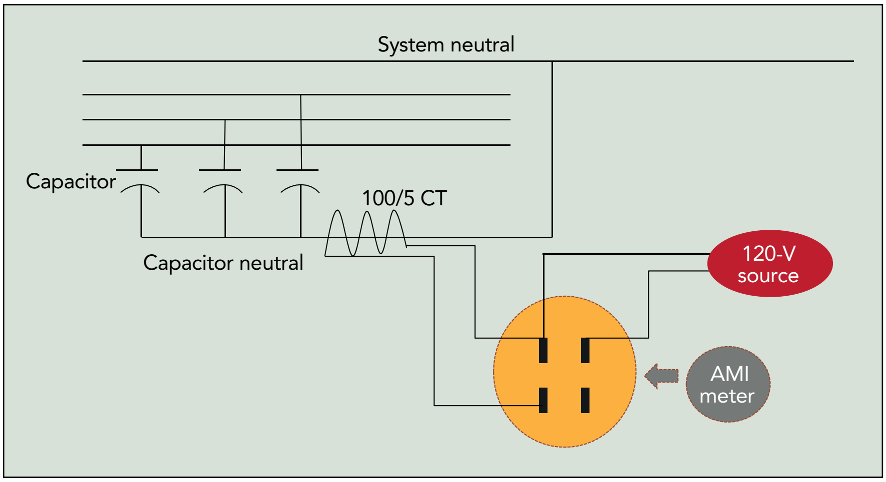
Field Trial

Georgia Power tested the concept by building five adapters using stock meter bases and revenue CTs. Georgia Power's metering and distribution automation engineers quickly turned the idea into a working model and installed adapters on existing switched and fixed capacitor banks. Local line personnel were asked to go to the locations and change the status of the capacitors. By analyzing the data, the day of a status change was detected and confirmed with the linemen. Following the successful testing, Georgia Power contacted Marwell, which previously had developed specialized meter adapters for Georgia Power's use, to create an adapter that would be compact and easy to install.

Georgia Power ordered enough adapters to install a monitor on every capacitor bank in a small operating headquarters, approximately 50. The metering department received the adapters and installed uniquely programmed 120-V residential meters in the adapters. Complete units were then shipped to the field for installation. The monitors were installed in the spring during the normal annual inspection. The true field trial was underway.

An AMI-based capacitor monitor installed on a switched capacitor bank.

Since Georgia Power's capacitors did not have a neutral bushing, both the neutral and the rack ground were placed through the adapter's CT. For switch banks, the 120-V source to power the meter was taken from the 120-V transformer, mounted on the rack to power the capacitor control. Fixed banks either used existing secondary on the pole or a potential transformer was installed. The results of the initial deployment were impressive, as approximately 10% of the capacitors



This wiring schematic depicts how the meter is connected to the neutral of the capacitor bank with a current transformer.

were reporting a problem before the end of the summer with no false reports.

Beyond Inspections

Historically, Georgia Power had contractors or employees from a maintenance team perform an annual inspection of each capacitor location in the state. This inspection required a physical visit to each location, which typically occurred during January and February. If the capacitors had failed, then repairs were made on the failed capacitors in the spring. While the manual inspection process was effective at identifying defective units, the program was not effective at identifying units that became abnormal after the inspection.

Capacitors are especially susceptible to lightning, which occurs frequently in Georgia during the early spring or summer months. Georgia Power has more than 6,000 capacitors all over the distribution system, averaging more than two per circuit. Capacitors are especially critical during peak times in the summer. If they are not on-line, more reactive power must be generated and delivered.

The purpose of the inspection program was to identify and repair all the abnormal capacitors before their output was needed during the high-demand summer period. These capacitors also maintain a flat voltage profile across the entire length of the feeder circuit. The flat voltage profile allows Georgia Power to operate a conservation voltage reduction (CVR) program without bringing the voltage below standard levels. Georgia Power's CVR system is based on control of substation regulation through the supervisory control and data acquisition (SCADA) system. But each capacitor bank works autonomously without any SCADA communication.

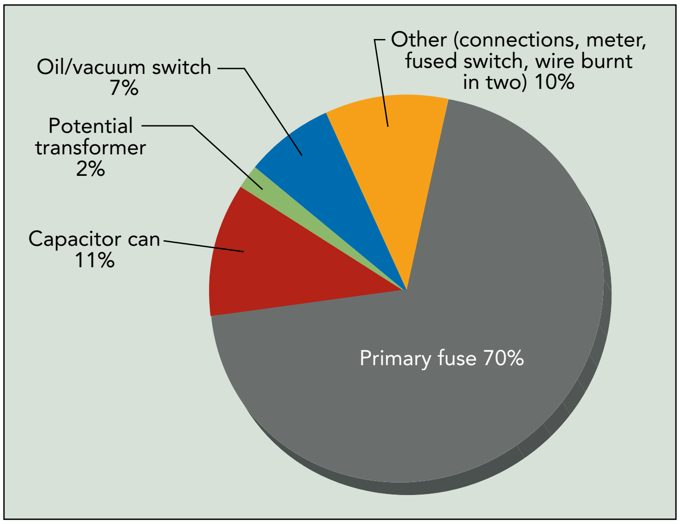
Based on the results of the initial deployment, it was obvious an annual spring inspection cycle was not effective at ensuring the capacitors were available in the summer months. Since Georgia Power was including an expansion of the CVR system in Southern Co.'s Smart Grid Investment Grant (SGIG) application, a business case also was developed to include adding monitors to all new and existing capacitor banks. Alabama Power included adding monitors to all of its fixed capacitor banks (Alabama Power already had SCADA control of its switched banks) in Southern Co.'s SGIG application. To maximize crew efficiency, the monitors for existing capacitors would be installed in lieu of the spring inspection. To date, Georgia Power has installed more than 6,000 monitors.

System Refinements

As the monitors began reporting, tools were modified to develop a capacitor monitoring system. Based on experience, the neutral current threshold to identify an unhealthy capacitor was set at 15 A. Setting this threshold allowed an internal website to be created that mined the AMI data and reported monitors that had exceeded the current threshold or capacitor meters that had not reported within the last 100 hours. The 15-A threshold has eliminated any false reporting of capacitors with a natural imbalance because of individual phase regulation.

The meters that have stopped reporting indicate that the phase of the capacitor that is off-line also feeds the on-site potential transformer. Georgia Power also created detailed inspection instructions for crews responding to reported health problems. Instructions include the use of a handheld amp probe to measure the neutral current and the current directly into each capacitor. The monitors have been successful at identifying conditions not readily noticeable such as fuses that do not fall open and high-voltage switches indicated as closed but are actually open internally. There also was an emphasis placed on ensuring the correct size fuse was installed and all cables were installed properly. Before the instructions were developed, crews routinely would have to revisit capacitors that looked normal visually but actually had problems.

Two conditions are difficult to determine with the current system. The first condition involves a fixed capacitor without a potential transformer on a very balanced feeder. In most capacitors, a small amount of neutral current flows through the neutral that registers with the AMI meter. But, since Georgia Power deployed its monitors with a 100/5 CT, some banks do



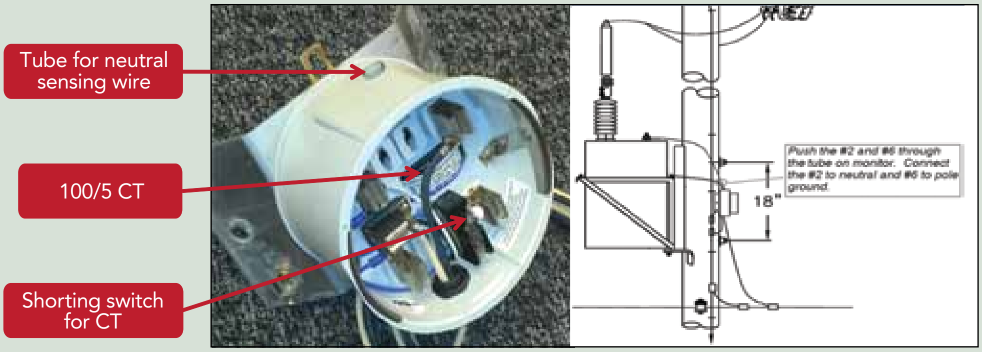
Monitors identify various types of capacitor problems.

not register any current if the bank is healthy. By not registering any current, these banks cannot be culled from the banks that report zero current because their three fuses are open.

The 100/5 CT was chosen since it was what Georgia Power initially deployed in the prototypes. Future installations will have a smaller-ratio CT that will provide greater resolution at low amperages. These CTs will saturate above the 15-A threshold. But, resolution at currents exceeding the threshold is not required. Approximately 20% of the fixed banks powered

Fixed or Switched Capacitor Banks

- AMI monitors can be used on all fixed or switched capacitor banks.
- The internal CT reads the current on the neutral bus of the CAP bank.
    - Capacitor monitor has a built-in 100/5-A CT. This CT will be shorted by an internal switch when the meter is removed.
- The AMI monitor has a ¾-inch plastic tube running inside the enclosure that goes thru the 100/5-A CT.
- The AMI meter stores the hourly reading and transmits the data daily to a database.



A view of the adapter without the AMI meter installed.

from existing secondary do not register any current flow when all the banks are in service. Fortunately, the normal failure mode is for only one or two fuses to open. Georgia Power plans to perform a visual inspection of these fixed units in the spring to determine whether a conversion to a different CT ratio is warranted.

The second condition is when the controller on a switch bank fails. These capacitors might stop switching as desired. By studying the raw consumption data (not just the units exceeding the threshold value), one can determine when a switch bank is on-line or off-line. A higher-resolution CT would make this analysis better at determining if switch banks are closed continuously or are never closing. Since the Georgia Power system operates consistently at a near-unity power factor, SCADA data collected at the substation also will be analyzed to determine individual feeders with control problems.

Field Refinements

Georgia Power also has worked with the Electric Power Research Institute to create a web application that allows field personnel to enter capacitor repair information through their smart phone or laptop. Just recently deployed, Georgia Power

The neutral and rack ground from the capacitor bank are going through the current transformer, which is internal to the meter adapter.

is attempting to use this system to determine the root cause of capacitor failures so specifications or material can be changed to lessen the failure percentage. Line personnel have been receptive of inputting repair information through a quick web application instead of filling out paper inspection records.

Office personnel can view repair records in near real time. During the first week of using the smart phone input system, it was noticed a particular repair crew was reporting no problem found on units identified by the monitors. By consulting with the crew, it was learned they did not have an amp probe, which prevented identification of a bad oil switch.

Georgia Power also is evaluating a modification to the capacitor monitor to allow a reconnect/disconnect AMI meter to monitor the neutral current and act as the capacitor controller. The reconnect/disconnect monitor adapter has embedded electronics that open or close the capacitor switches to mimic the state of the meter's internal disconnect.

Initial development trials went very well and Georgia Power expects to field-test 10 beta units soon. The beta units will have cable to allow it to be plugged directly into the junction box to which the control cable is currently plugged. The adapter also will have two toggle switches (manual/automatic and open/close), which will allow the capacitor to be operated on-site.

Georgia Power currently has a distribution management system capable of centralized capacitor control. The distribution management system will be used if a high penetration of distributed generation appears on a circuit and keeps the decentralized system from operating effectively.

Returned Value

Because of the success of the project, AMI capacitor monitors are now being used across Southern Co. and by other utilities, as well. At the time of the installation, a standard inspection was performed. Since the installation, data revealed some form of health problem in many units. Without the AMI monitor, these banks would not have been found until the next annual inspection and would not have been available during peak loads.

The AMI meter can use any AMI communications technology. The system at Georgia Power employs a tower-based radio-frequency technology, but a mesh radio or power line carrier technology also would work. The host utility can use whatever AMI system it is currently using. Even a drive-by system could be used as a monthly inspection.

Georgia Power has filed a patent for the capacitor monitor and has an exclusive licensing agreement with Marwell to manufacture and sell the adapter. Marwell also has partnered with another company to develop a system to remotely read the capacitor monitor meters for utilities that have not started their AMI deployment. TDW

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Editor's note: For information about the capacitor monitor, contact Kyle Farmer at kyle@marwellcorp.com or 909-794-4192.

Companies mentioned:

Georgia Power | www.georgiapower.com

Marwell Corp. | www.marwellcorp.com