Case Study

Keeping Amusement Park Rides Rolling

White River Valley Electric Cooperative, Branson, MO

When transient fault-level voltages and short-time, fault-level, charging currents from capacitor operations blew fuses and caused an outage at a nearby amusement park, White River Valley Electric Cooperative stopped the trouble with synchronous, zero-voltage close, capacitor switching technology.

"If large (or) back-to-back capacitor switching will cause problems for your end users, you want to make sure that you minimize the impact. Synchronous, zero-voltage close, capacitor switching technology does a very good job at that."

Reiny Cash, Chief Engineer
White River Valley Electric Cooperative

BUSINESS CHALLENGE

If you own and operate an amusement park, you know roller coasters are a star attraction. The last thing you want is to have one stopped in its tracks by an unplanned power outage.

For Silver Dollar City, an 1880s-themed venue with some 2.2 million guests annually, this potential problem was much more likely to happen due to the demand that thrill rides operated at the park put on the electric system. "Being an amusement park with many rides, Silver Dollar City has a lot of motor load and pretty high demand that puts reactive current on the system," said Reiny Cash, chief engineer for White River Valley Electric.

Inside the park, the utility has a distribution automation scheme and pad-mounted capacitors. Along with the intelligence and automation in the park, White River has another large capacitor bank close to the park and, for years, the utility had been able to manage power quality simply by leaving the external bank turned on manually because it didn't have a switch.

That worked until 2013, when Silver Dollar City installed the Outlaw Run amusement ride. When the giant ride debuted, it was the world's steepest wood coaster. It's first drop features an 81-degree fall of 162 feet – more than 16 stories – making it also one of the world's fastest wood coasters, a gut-churner that topped out at 68 miles per hour. Voted Best New Ride of 2013 worldwide by Amusement Today, this ride is advertised as one that will test just about anybody's grit.

As it turns out, it also tested the capacitor bank just outside park grounds.

Mystery Arc Shuts Down Ride

The electrical source of this ride was tied into the vacuum fault interrupter (VFI) switch gear used for overcurrent protection on the capacitor bank outside the park, which happened to be a large 1200 kVAR unit. Soon after Outlaw Run was installed and undergoing routine testing, the cooperative received a call letting them know the ride had no power. Trouble shooters discovered that the VFIs had tripped on the switch gear feeding both the ride and capacitor bank near it. They suspected trouble with the capacitor itself: a bad cell, animal intrusion or some other simple cause that could easily be addressed.

When they opened the capacitor bank enclosure, however, they found absolutely nothing but some residue from the arcing that took out the fuse. The utility crew isolated the capacitor bank and got the ride back online. Then, they got to work researching possible reasons for the problem. It wasn't long before chief engineer Cash came across a white paper explaining how large capacitor bank switching causes voltage transients associated with high charging current.

When capacitors are switched off, they're discharged and almost at ground potential. As soon as you switch them on, they quickly charge from zero voltage to whatever the line voltage happens to be. If the cap bank is on a 13,800-volt line, the moment you switch that capacitor in, the capacitor bank charges from zero volts all the way to 13,800 volts, and usually there are over-voltage transients too. Quickly, the capacitor settles into the right voltage, but transients for a few cycles after switching are common. The larger the capacitor you switch in, the more transient fault current hits the line.

Cash calculated the amount of charging current at his capacitor banks and knew that it was likely a short-duration fault current that could easily take out a fuse over time.

The utility switched on the capacitor bank outside the park to provide reactive current because they needed the VAR support. But, due to the charging-current issue, engineers didn't want to leave the other bank inside the park on while the outer bank was in a fixed position, so they shut it off. That inner bank was 900-kVAR, which meant the utility had and needed a total of 2100 kVAR on the feeder serving the park. Engineers knew they must find a way to get capacitance back onto the line. That's when Cash and his team started

looking for a switch that would avert the heavy in-rush of charging current.

SOLUTION OVERVIEW

Fig. 1 – SmartClose Synchronous Vacuum Switch

White River engineers selected the Trinetics SmartClose® 3-Phase, synchronous, zero-voltage close capacitor switch. With built-in intelligence and six integrated voltage sensors, it senses when the 60 hertz sine wave passes zero voltage and closes in that instant. No voltage, no transients. Problem solved.

These zero-crossing capacitor switches have built-in sensors and intelligence, allowing the device to measure voltage and close at the zero point on the waveform on each phase of the system. That doesn't happen with competitive products.

Most other zero-voltage capacitor switches simply time the close on each phase to reflect that 120-degree difference between the phases. The problem is that the timing in which a switch closes is limited by its mechanical characteristics. Some capacitor switches may close in half a second, some may close in 10 cycles, some could take 40 cycles or more. And even if one of the capacitor switches happens to close when the capacitor voltage is zero, the other phase switches will close with a large voltage across them and there is no means to control the precise timing of the switches.

The SmartClose capacitor switches also can close within 5° of zero voltage, as opposed to the industry standard of 21°. In fact, there's even validation software so system operators can verify the switches are opening and closing on the zero axis of the waveform.

In addition, the SmartClose line of switches eliminates field calibration and commissioning and reduces the overall cost of installation. Partly, that's because the capacitor switches are pre-calibrated, another benefit of keeping intelligence in the switch.

"In our case, we assembled a new capacitor bank and had the switch mounted on the rack and ready to go," said chief engineer Cash. "Putting the rack together in the warehouse probably took us an hour and a half. In the field, it took about an hour – maybe even less – to get the capacitor mounted on the pole, energized and online. It was very easy."

Finally, SmartClose switches are solid dielectric switches with a C2 re-strike free rating that use vacuum bottle technology to stop arcing. That eliminates the need for oil and all the maintenance that comes with it.

BUSINESS JUSTIFICATION

"The fact that this switch is packaged as a plug-and-play assembly where the end user really does not have to know anything more about it is, I think, the biggest benefit."

Reiny Cash, Chief Engineer
White River Valley Electric Cooperative

Because elimination of large voltage transients was a key reason White River Valley Electric changed its capacitor switch technology, better power quality for all customers in the area was one of the main benefits this solution provided. In addition, the utility gained:

Restrike-free switching: Also called transient recovery voltage, re-striking voltage appears across the breaker contacts they open. It can result in short-duration high frequency. Because the SmartClose capacitor switch is designed with robust switching mechanism and vacuum interrupter technology that is rated Class C2 re-strike free, it avoids this potentially harmful voltage.

Easier installation: Other zero-voltage capacitor switching solutions use secondary controllers that receive signals from the main controller mounted on the pole. That means there's more wiring and more complicated installation. On top of that, the intelligence is in those secondary, middleman controllers, not the switch. That means installers must run the controllers and switches through calibration exercises multiple times during installation so that the secondary controller can learn how long it takes for switches to close and time its zero-close operations. That, too, requires special training for field workers and more time during the installation process. This one-time initial calibration does not guarantee that the switch timing will remain constant over years of operation and temperature variations.

The SmartClose zero-crossing capacitor switch is a complete plug-and-play solution that requires zero additional training and zero field commissioning. In addition, it doesn't force a utility to use a new controller. Utilities can use any capacitor bank controller along with it, even a simple Time-of-Day or Temperature based controller.

Maintenance-free operation: SmartClose is a solid dielectric switch. "The switching is actually being done in a vacuum chamber as opposed to being done with contacts that are under oil, where you are going to get carbon build-up each time that they operate," Cash explains. "There is maintenance that is associated with oil-based switches after a certain time, such as a three-year cycle. Those old switches need to be taken down and serviced. These switches can reduce your maintenance and operating costs."

Lower capital expense: Oil-based switches are typically rated for 2,000 operations. Since closing of the SmartClose capacitor switch is times at zero-voltage, there is no electrical stress during the closing operation, which further improves the life of the product. The capacitor switches are rated for 50,000 operations, giving them decades more service that's maintenance-free.

Set-and-forget technology: Using systems with multiple controllers means recalibration will eventually be needed. That's because field technicians set the calibration of the controller and switch during installation, but a few years down the road, those mechanical switches will slow down, and the controllers won't know it. The SmartClose does. It also knows the voltages on all the phases of the line because each phase has its own sensors associated with it. When mechanical switches slow down, Smart Close sees and reacts.

High levels of VAR support in proximity: White River Electric's chief engineer Cash chose the SmartClose switch because he saw it working well for a nearby utility. He explains: "They had an installation over in the Joplin, Missouri area near an industrial park where they had several capacitor banks close together. The transients from switching

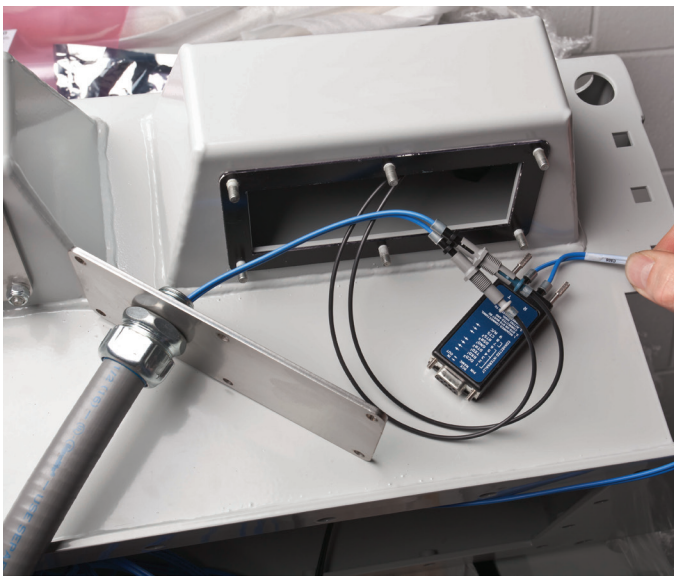

Fig. 2 – Zero-voltage close waveforms being downloaded from the SmartClose capacitor switch with fiber-optic cable.

were causing issues on variable frequency drives inside some of the manufacturing firms in this industrial park. When they utilized these zero-crossing switches, they had no more problems."

Reduced line losses: "VAR support is an economic issue," Cash says. That's because the power triangle requires utilities to be supplying watts, VARs and volt-amperes. Reactive energy must be supplied somewhere, and if its not being supplied by capacitor banks, it needs to come from a generating station. That adds line losses to the system, as well as the additional cost of generating those VARs.

"By utilizing your capacitors and switching them in an intelligent manner, you can help reduce those losses tremendously," Cash notes. He says that SmartClose switches help utilities add capacitance in sensitive areas where it's crucial to minimize power quality issues that capacitor switching operations could cause.

Given the many benefits, it makes sense that engineers at White River Valley Electric are thinking of investing in SmartClose technology again.

"We are looking at and going ahead and getting another one of these SmartClose switches to use on another capacitor bank serving the park," Cash says. "They are in the process of installing a new ride, and we want to make sure that our capacitor switching operations on are not going to cause any issues for the newer high-tech control systems that are going to be on that ride."