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Demonstration of Pulsecloser Applications and Benefits in Ameren's Distribution Automation Program

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SUMMARY

To improve electric service reliability and protect grid assets, Ameren began installing pulseclosers on its system in August 2008. Pulseclosers feature advanced technology that significantly reduces wear-on-tear on distribution systems by limiting exposure of transformers and other line hardware to faults. The technology also offers a new approach to address challenging protection and reliability problems.

Ameren was an early adopter of this technology, and has since installed over 250 of these devices on its distribution system. This paper describes practical pulsecloser applications to highlight the benefits of this technology.

KEYWORDS

Pulseclosing, Pulsecloser, Loops, Reclosers

1. Ameren's Smart Grid Strategy

Ameren serves approximately 2.4 million electric customers across 64,000 square miles in Illinois and Missouri. Ameren Missouri and Ameren Illinois worked together to create a Smart Grid Distribution Automation strategy. One element of the strategy was to begin gradually deploying distribution automation (DA) solutions on a substation-by-substation basis. This approach allows Ameren to test and validate the effectiveness of technologies and methods before expanding use of DA technologies further into the service territory.

In 2006, as implementation of the Smart Grid strategy was being planned, Ameren Missouri was introduced to the concept of pulseclosing. Operating personnel saw the potential benefits, and Ameren was among the first to use this technology when S&C Electric Company began shipping the IntelliRupter® PulseCloser in 2008, which is the first device to feature Pulseclosing Technology™. Figure 1 shows a typical Ameren installation of this device.

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Figure 1. Example pulsecloser installation on Ameren's system

2. Pulsecloser Characteristics

Pulseclosing technology is a defining feature of a fault-interrupting device. After an IntelliRupter opens in response to a fault, it pulsecloses to intelligently test for fault current before closing. The relative let-through energy, in I^2t, of a pulseclosing operation is typically less than 2% of a conventional reclosing operation. Pulseclosing technology limits the exposure of line equipment and hardware to additional fault currents when testing a circuit to see if a fault has cleared, which ultimately helps extend asset life and improve electric service reliability.

Figure 2 shows a typical sequence of operations when the fault is permanent. The current traces for all three poles are shown. After the initial trip, multiple pulseclosing attempts can be made instead of a reclosing operation, and if the fault is still present, the pulsecloser will not close. (Note that the timeline is not to scale – the vertical lines represent different waveform captures that were captured in succession. Some times of no activity may not be shown.)

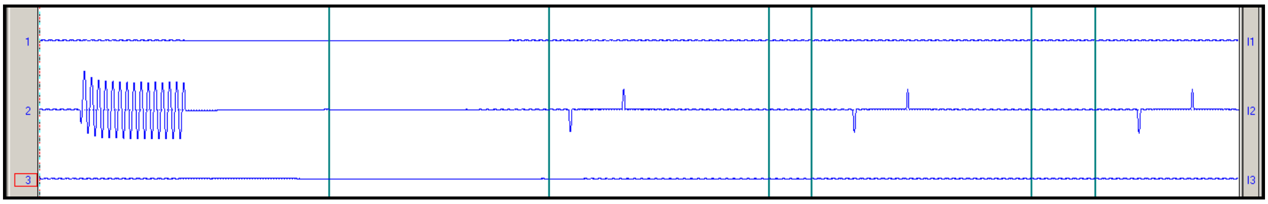

Figure 2. Example of a Permanent Fault on Pole 2 – Waveform shows initial fault plus several pulses to test the line

Figure 3 is an example of a temporary fault. Three pole currents and six voltage waveforms are shown. The pulsecloser interrupts a 2800A fault on poles 2 and 3. After 5 seconds, an automatic pulseclose is initiated to test the line. Pole 2 had the highest current for the initial trip (2870A) so it pulses first. No fault is detected so pole 2 closes. Pole 3 had the second highest fault current (2462A) so it pulses next, sees no fault, and closes. Then pole 1, which only had 168A of load current during the fault event, pulses and closes. The temporary fault is cleared and service is restored.

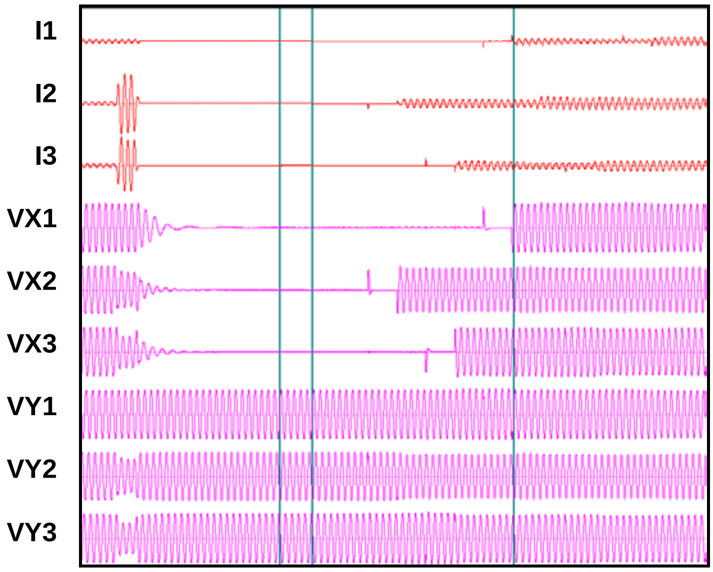

Figure 3. Example of a temporary fault

In part due to this functionality, Ameren Missouri has since standardized on the IntelliRupter as the three-phase fault-interrupting device applied on its 12 kV system. Another benefit is that IntelliRupters are versatile devices that can be applied in many applications, and Ameren can realize reduced training and operating costs by using a standard device. IntelliRupter features now employed by Ameren Missouri include the following:

- **Intelligent Fuse Savings.** This feature reduces unnecessary fuse operations, and thus reduces extended outages, by automatically determining if a fuse-saving "fast" trip should be used based on the fault current magnitude. At lower fault currents, the IntelliRupter will initiate a "fast" trip and prevent downstream fuse operations due to temporary faults. At high fault currents, a mechanical device cannot trip faster than a fuse will operate, so with Intelligent Fuse Savings, the IntelliRupter will not use a fast trip. This prevents unnecessary momentary outages to customers served by portions of the distribution system upstream of the blown fuse.
- **More pulseclosers can be installed in series.** An essentially unlimited number of pulseclosers can be installed in series with identical protection settings. This is not possible with other three-phase protective devices because difficulty in achieving proper Time Current Characteristic (TCC) coordination constrains the number of devices that can be installed in series.
- **Pulsefinding.** This feature takes advantage of the IntelliRupter's ability to imperceptibly detect faults by automatically performing fault-hunting. Pulsefinding thus allows devices to properly sectionalize the faulted section in situations where proper TCC coordination is difficult. Communications are not needed for this feature.
- **Single-phase tripping option.** This feature can reduce momentary outages for single-phase loads by approximately two-thirds.
- **Communications-enhanced coordination.** This feature further improves fault isolation when fully coordinating TCCs is not practical. It leverages fast peer-to-peer communication systems to slow the timing curve of upline pulseclosers, so that only the unit closest to the fault operates. Communication-enhanced coordination thus reduces momentary outages by reducing the number of trip operations by upstream pulseclosers.
- **Loop Restoration.** Loop restoration is a standard feature that allows multiple pulseclosers to function as part of a non-communicating automatic restoration system in the event of service disruptions including faults and loss of source.
- **Bi-directional overcurrent protection.** IntelliRupter allows for simultaneous bi-directional overcurrent protection, and does not require changing to different protection profiles depending on current direction.

- **Enhanced SCADA capabilities.** A long list of DNP control and status points are available. In particular, Ameren is using IntelliRupter's ability to report fault currents and provide voltage sensing on all six terminals.
- **Built-In IntelliTeam® SG.** IntelliTeam SG Automatic Restoration System is built in to every IntelliRupter. This functionality offers more advanced automatic restoration capability, including use of multiple sources, multiple tie points, and accounting for real-time loading information to avoid overloads.
- **Phase loss isolation.** This feature also leverages peer-to-peer communication to detect and fully isolate a three-phase section of line that has a broken conductor.

Ameren Missouri developed an approach to enable the different capabilities of the IntelliRupter for different applications, with consideration for distribution system characteristics, the topography of the area, and the load profile. Several of Ameren's first pulsecloser installations focused on quick restoration of sensitive loads. For example, many larger hospitals have associated medical buildings, nursing homes, and extended care facilities which do not require standby generation, but are nonetheless sensitive to extended outages. Since then, Ameren has applied IntelliRupters as midpoint sectionalizers, as well as at tie points where one or more midpoint switches are installed on a circuit, to provide restoration options to the tail end of feeders. Some of these applications are discussed in more detail below.

3. Application: Feeder Mid-point Protective Devices

Ameren has most frequently applied IntelliRupters as a feeder mid-point protective device. Different IntelliRupter functions are utilized depending on local distribution system characteristics, as described below.

Several midpoint pulsecloser installations at Ameren Missouri are on feeders with heavy tree cover, many fused taps, and no downstream ties to other feeders. The Intelligent Fuse Savings feature works well in these applications, which would otherwise be more likely to experience fuse operations—leading to extended outages—due to temporary faults even under good weather conditions.

On circuits with less tree cover, Ameren adapts protective settings remotely based on weather conditions. Most Ameren distribution substations that are equipped with SCADA control also have capability to enable and disable feeder instantaneous overcurrent elements. This allows Ameren to enable the instantaneous element during storm conditions to save fuses, when temporary faults would otherwise blow a fuse and cause an extended outage on a tap. Under normal conditions, when faults are more likely to be "permanent," the instantaneous element is disabled, allowing a downstream fuse to blow.

4. Application: Fault Finding

Ameren Missouri decided early on in its DA program to standardize on a select few configurations for each type of distribution device. This approach was intended to simplify deployment and troubleshooting of DA devices.

Properly coordinating multiple protective devices in series can be difficult enough with the full complement of settings flexibility available on modern IEDs, but it is even more difficult when using a limited number of pre-configured options. Pulsefinding provides a good compromise. With pulsefinding, multiple pulseclosers in series can have the same protection settings. If two pulseclosers are installed in series with the same settings and a permanent fault occurs downstream of the second pulsecloser, both will trip initially. The upstream pulsecloser then will test the line and close. The second pulsecloser pulses, and if it sees the fault is still present it will lock out. Since pulseclosing only lets 2% or less of the fault energy through, the upstream pulseclosers or breaker do not "see" the fault when the second IntelliRupter pulsecloses, so they stay closed.

More customers experience a momentary outage than when the series devices are fully coordinated, but quite often that coordination cannot be achieved where a higher level of sectionalizing is desired. In addition, communications are not needed for pulsefinding. The devices simply react to system voltages and currents, and the operating sequence for a string of devices takes only a few seconds. If fast peer-to-peer communication is available between the two devices, then the communication-enhanced coordination feature is used to eliminate the momentary interruption for the customers between the devices. The waveform captures in Figures 4 and 5 shows a fault event involving two pulseclosers installed in series with identical protection settings, in this case without peer-to-peer communication.

When the fault initially occurs downstream of both units, both devices trip since IR1 and IR2 have the same protection settings. Then IR1 pulses and does not see the fault since downstream pulsecloser IR2 is also open. IR1 closes to pick up load between pulseclosers, then IR2 begins its test sequence. The pulses in both waveforms are due to the IR2 test sequence. Note that load before the fault is 66.7, 65.8, and 62.6 A for the three phases. After IR1 is closed it restores service up to IR2, and load current is 22.3, 24.0, and 22.4 A. Service is restored to these customers, automatically, and within seconds. When IR1 closes to return source-side voltage to IR2, then IR2 begins its test sequence. Since the line is faulted, IR2 locks out, isolating the fault.

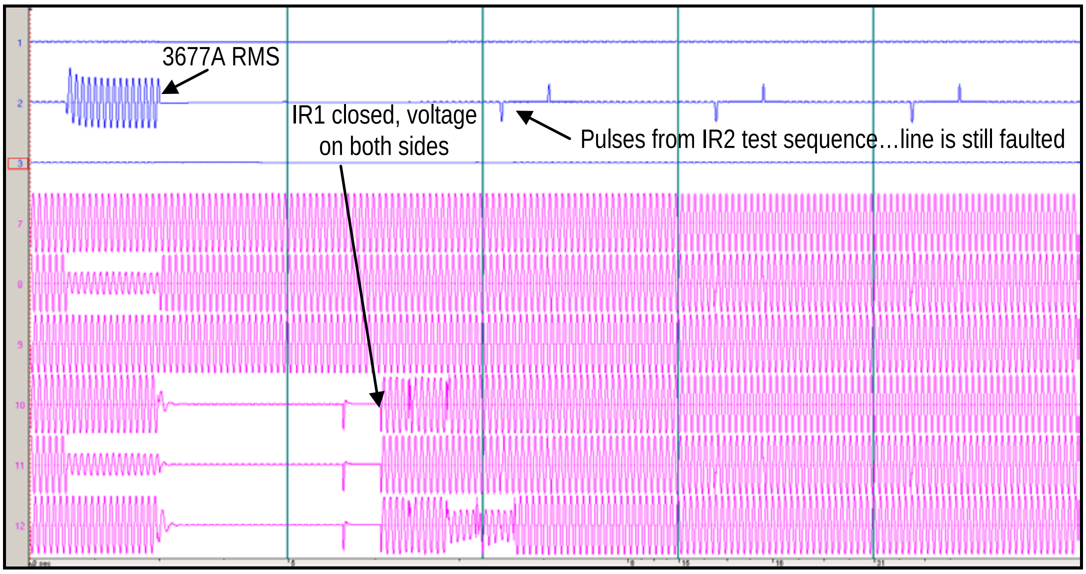

Figure 4. Waveform capture from upstream pulsecloser, IR1.

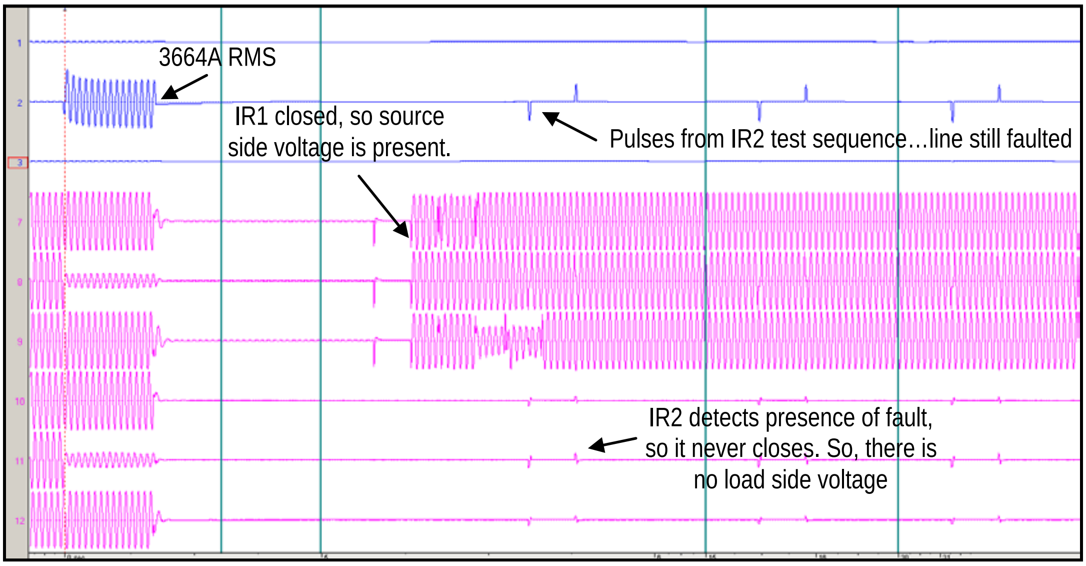

Figure 5. Waveform capture from downstream pulsecloser, IR2, for the same event.

5. Simple Looped Feeder Automation

The idea of non-communicating loop automation is that the protective device installed at a normally open point senses loss of voltage and then starts a timer. After a predetermined time delay that allows for all other normally closed protective devices to complete their operating sequence, the tie device closes to see if a fault is present. If not, the device remains closed and the connected circuit has now picked up load.

Previously, Ameren Missouri decided not to implement loop automation to avoid exposing an unfaulted feeder to a fault and otherwise unaffected customer to a voltage sag. Pulseclosing eliminates these concerns. With no communications between devices or to/from SCADA, we can test a faulted circuit from a tie point without exposing the unaffected feeder to fault currents or voltage sags. Ameren Missouri has implemented this functionality at a number of normally open tie points.

In some applications, Loop automation settings are only installed on the normally-open tie switch. Normally-closed mid-point devices installed on either feeder are configured with standard protection settings. This is a clean and simple way to provide automatic source transfer by only enabling loop logic in a single stand-alone device.

6. Justifying DA Investments

Developing a deployment plan for DA technology like the pulsecloser is a challenge that many utilities face. A justification must be made to determine the benefits from applying the technology in different parts of the distribution system. Ameren used multiple methodologies to evaluate which circuits would most benefit from DA solutions. One approach that Ameren applies involves looking at KVA hours of avoided outage time per year, based on a 3-5 year history of outages on a feeder or substation.

Ameren also considered feeder construction characteristics. Backbone feeders in many locations have significant back-lot private property construction and substantial tree cover, neither of which can be easily fixed given Ameren's existing easements. These feeders were considered ideal locations for DA technology. Though automation technology can't eliminate all outages, it can greatly mitigate the scope and duration of an outage by sectionalizing the feeders into smaller, protected sections.

Based on the 5-year outage history of the feeders, IntelliRupters were justified solely through their application as a protective device. The ability to apply IntelliRupters at tie points provided additional benefits above and beyond this initial justification.