Alternative to Reclosing - Application of Pulseclosing Technology to Looped Distribution Overcurrent Feeder Protection

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Abstract Pulse Closing is a very fast closing and opening of distribution switchgear contacts to determine the presence of the fault without subjecting the system to full fault current. The relative let-through energy (I^2t), of a pulse closing operation is typically less than 2% of a conventional reclosing operation. While this approach can be used as conventional reclosing to determine the presence of fault, it does so with the advantage of reducing stress on power system equipment and reducing voltage sags or power quality fluctuations experienced by customers located upstream to the fault.

Conventional looped distribution systems rely on overcurrent coordination to ensure that the appropriate devices isolate the fault from both sides. But conventional protection schemes have limited capability to properly coordinate a large number of devices in series or may require the use of communications assisted trip schemes to overcome the need for overcurrent coordination. Pulse Closing can be applied to overcome coordination limitations, allowing the expansion of a distribution loop to an unlimited number of series overcurrent protection devices without the need for communication between devices.

This approach can be used to hunts for faults without affecting upstream customers. It reduces the opportunity for sympathetic tripping of nearby devices. Maximum system restoration can be achieved within a few seconds after initial fault detection.

Pulse Closing can be applied on either radial or networked systems. This paper focuses on the application of the Pulse Closer technology to looped distribution systems because it shows many of the benefits gained by using multiple Pulse Closing devices in series.

Keywords **- Pulseclosing, Loops, Reclosers**

I. PULSECLOSING

Pulseclosing is a very fast closing and opening of distribution switchgear contacts to determine if the feeder is faulted without allowing full fault current to flow. This is achieved by closing at a proper point on the voltage waveform to achieve a minor loop of fault current. Closing just before voltage peak results in peak current approximately 1.4 times the symmetrical RMS fault current [1]. The operation generates just enough current to be measured and analyzed while keeping the energy let-through into the fault as low as possible. The shaded area in Figure 1 represents the minor loop of current of the pulseclosing operation. Notice that the largest current occurs in the second loop of current and it is avoided by opening the interrupters. During fault conditions, the magnitude of the current pulse is higher than normal load current, yet lower than the fault current duty that would be intentionally applied with a conventional reclosing operation. The current pulse waveform captured by the relay through the pulseclosing operation is analyzed and a determination is made whether or not the line is faulted from the predicted symmetrical current. If the predicted symmetrical current is less than the specified fault current threshold, then the pulseclosing algorithm in the relay concludes that there is no fault and closes the pole. On the other hand, if the predicted closing current is equal to or greater than the fault current threshold, then the pulseclosing algorithm concludes that the feeder segment is faulted and closing of the pole being pulsed is blocked and any closed poles are opened.

Because of the short duration of the pulse, the let-through I^2t energy from a pulseclosing operation for a given fault is less than 2% of what it would be for typical reclosers that time on TCC curves and clear after an additional 2.5 cycles. Conventional reclosing puts the full fault current back on the system for many cycles unlike pulseclosing, which closes on the point of the wave that results in a small current for a very short duration of time. Figure 2 shows a comparison in let-through current between a pulse closing operation and conventional recloser operations at three different point on a recloser TCC curve.

Pulseclosing accomplishes the same objectives as conventional reclosing while minimizing undesirable side effects. Apart from the initial voltage sag due to the fault, connected customers will not experience power quality problems during pulseclosing operations. Pulseclosing can be applied in both radial and looped circuits. In this paper we discuss few of the applications of pulseclosing in real world problems with looped distribution systems.

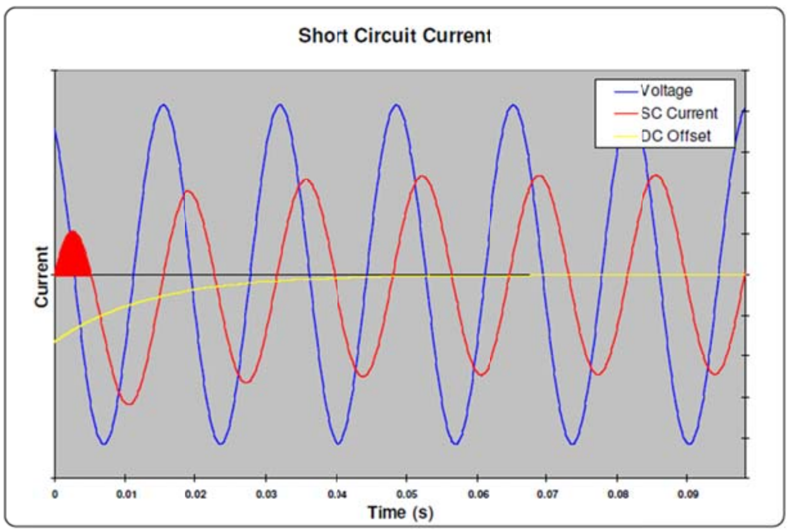
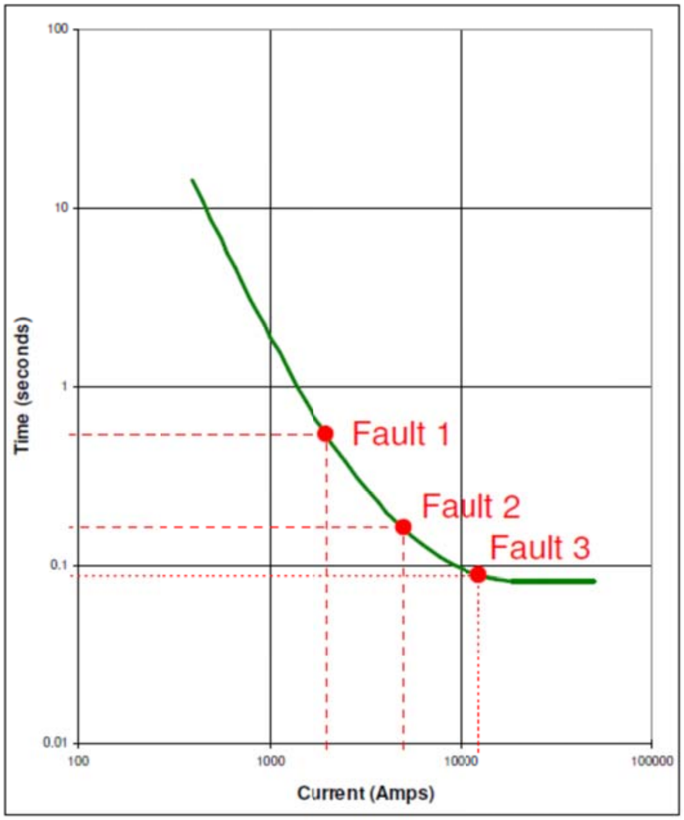


Figure 1. Closing for Minor Loop of Fault Current



Fault 1	RMS Current	Duration	I^2T
Conventional Reclosing	2,000 A	0.5420 s	2,168,000 A^2s
Pulseclosing	930 A	0.0053 s	4,800 A^2s *(0.22%)*
Fault 2			
Conventional Reclosing	5,000 A	0.1620 s	4,050,000 A^2s
Pulseclosing	2460 A	0.0055 s	34,400 A^2s *(0.85%)*
Fault 3			
Conventional Reclosing	12,500 A	0.0880 s	13,750,000 A^2s
Pulseclosing	6380 A	0.0056 s	236,900 A^2s *(1.72%)*

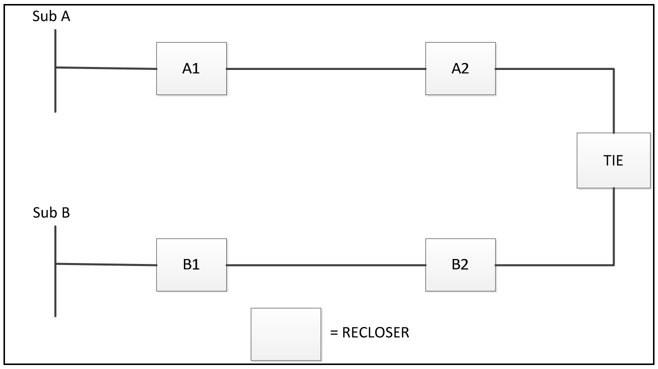
Figure 2. Example Fault Currents using a Recloser TCC Curve

Table 1: Let-Thru Energy for Figure 2 Faults

II. PULSECLOSING IN LOOPED DISTRIBUTION SYSTEMS

Looped distribution systems are designed to automatically restore service using a normally-open tie recloser to a nearby feeder. For a looped system as shown in Figure 3, a fault anywhere in the open loop will be cleared by a mid-line recloser. Upon detection of loss of voltage by the tie recloser and after a time delay, the normally open tie recloser closes. Assuming that the fault is still present, the tie recloser would close into the fault, then trip and finally lock out. No further reclose operations are allowed for the tie recloser because of the voltage sags and power quality problems introduced during each reclose operation.

Applying a pulseclosing device at the tie point as shown in Figure 3 is ideal since operations to test the feeder would not be restricted to a single test as it is the case with conventional reclosing. The tie device may issue multiple pulseclosing operations without causing voltage sags and power quality problems. If at any point during the multiple pulseclosing operation the relay determines that the fault is no longer present, then the tie recloser is allowed to close. Otherwise, after a number of programmed pulseclosing attempts, the tie device would lockout and remain open.



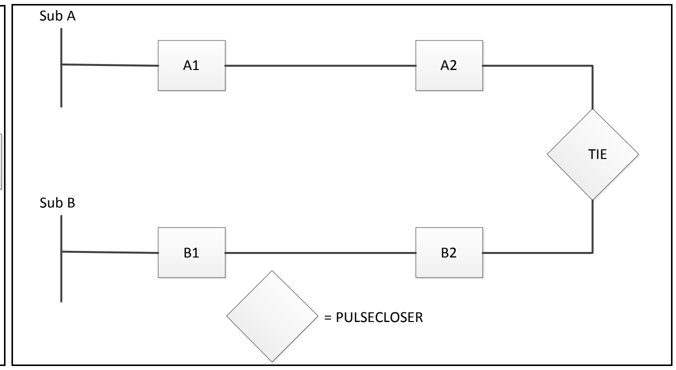


Figure 3. Recloser Loop **Figure 4. Recloser Loop with Pulsecloser Tie**

The conventional reclosers in the looped system of Figure 3 and Figure 4 could be replaced with pulseclosing devices to eliminate the voltage sags and power quality problems that are associated with conventional recloser operations.

III. PULSECLOSING AND COORDINATION CONSTRAINTS

Coordination of many devices in series may not be possible after taking into consideration each of the protective device's current pickup and response time tolerances. Pulseclosing may be used to hunt for the presence of a fault. Figure 5 shows a radial system with device A1 as a conventional recloser and device A2 as a pulseclosing device. For faults downstream of A2, the A2 device must open prior to A1 if both devices are coordinated. Assuming that both A2 and A1 miscoordinate as shown in Figure 6, both A1 and A2 could open at the same time or A1 could open before A2. If A1 were to open before A2, then A2 would detect an overcurrent condition followed by a loss of voltage. Under these circumstances, logic in A2 would cause A2 to open. Following a successful reclose operation from A1, A2 senses the return of good source voltage and performs a number of pulseclosing operations to test the line. Each of the pulseclosing operations does not affect the power quality of the energized system. If the fault is present, then A2 locks out after completing a pulseclosing sequence. Otherwise, if A2 through pulseclosing makes a determination that the fault is no longer present, then it closes. Customers between A1 and A2 may experience a brief outage between the time that A1 opens and the time it recloses, but service is restored successfully.

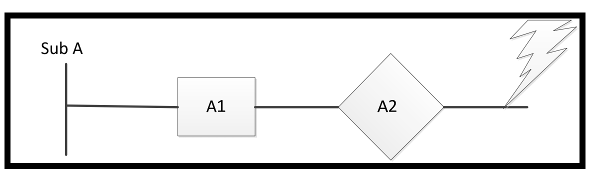


Figure 5. Pulsefinding with Upstream Recloser

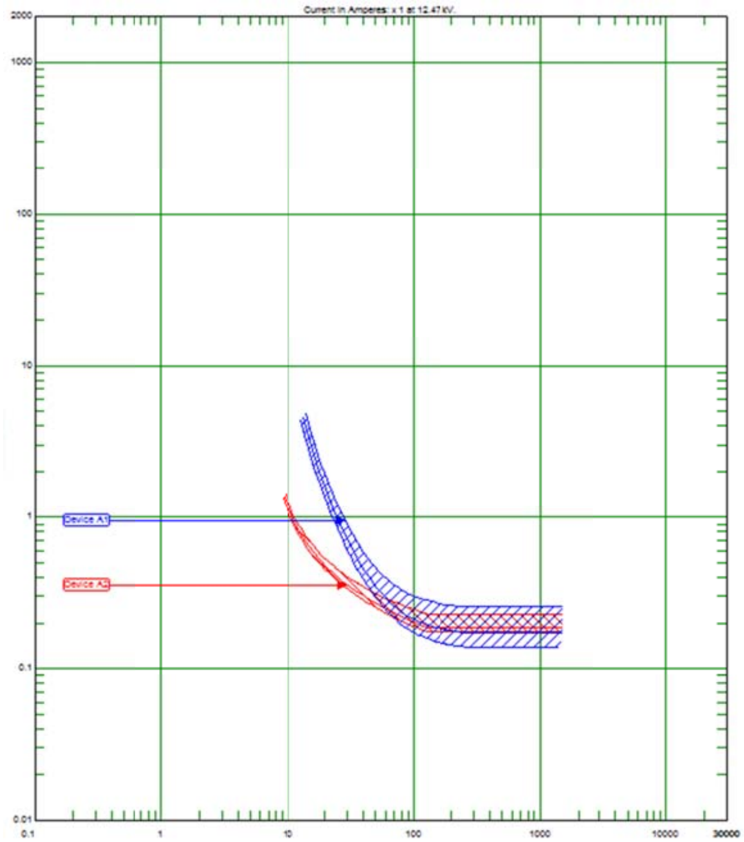


Figure 6. Miscoordination Between A1 (Blue TCC) and A2 (Red TCC)

IV. PULSE CLOSING AND FAULT HUNTING

Fault-hunting allows crews to find permanent faults downstream of a substation. The concept as applied to reclosers consists of closing the source breaker and closing the next downstream recloser one after another until one recloser opens after finding the fault. With a pulseclosing device, the process is similar except that the process does not create voltage sags, power quality problems, and loss of life to equipment.

V. FIELD RESULTS

Figure 7 is the oscillographic data for a field event in which a single phase to ground fault on Phase B (I2) caused the “Y” terminal of the pulsecloser relay to open due to the operation of an overcurrent relay setting. The pulseclosing device proceeded to test the line with intervals of 2, 5, and 10 seconds. It determined from the first two tests that the fault was still present. On the third and last test the relay determined that the fault was not present, so it allowed the “Y” terminal of the device to close.

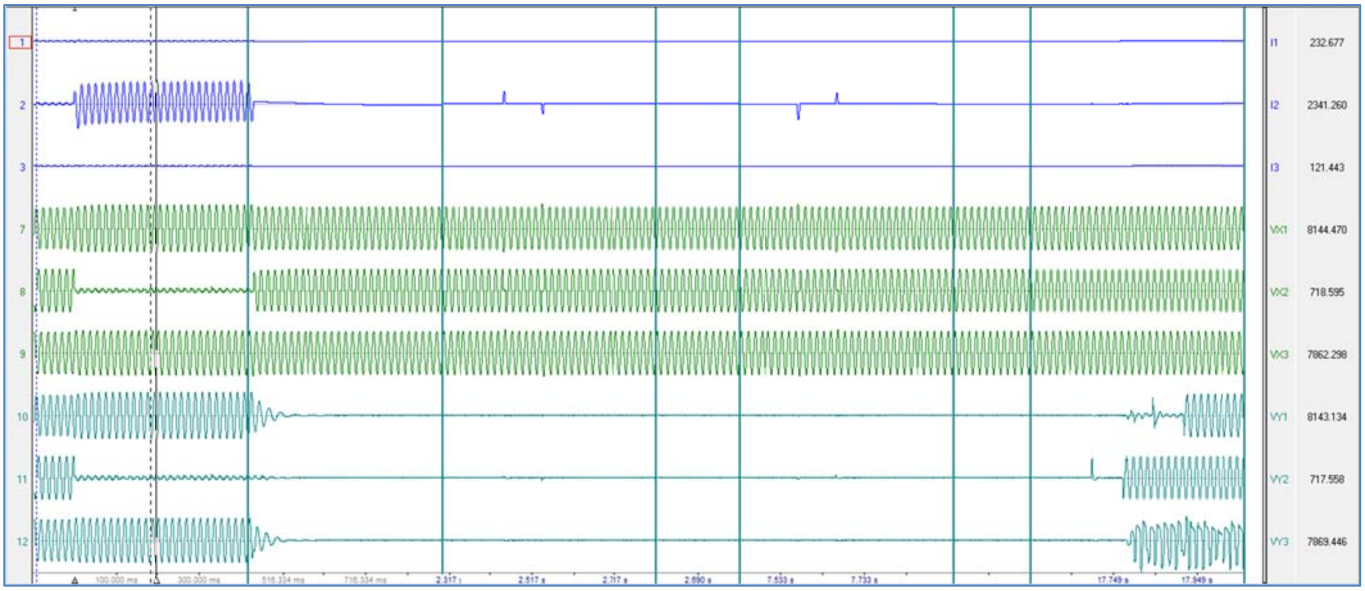


Figure 7. Oscillographic Data from Pulseclosing Event

VI. CONCLUSIONS

Pulseclosing technology is an innovative method to test overhead power distribution circuits for the presence or absence of a fault. It eliminates voltage sags that result from conventional reclosing.

Pulseclosing and pulsefinding overcome the coordination constraints of conventional recloser loop systems and allow for an unlimited number of fault interrupting devices to be used in series.

VII. REFERENCES

[1] IEEE Std 37.60-2003 “IEEE Standard Requirements for Overhead, Pad-Mounted, Dry Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for Alternating Current Systems Up to 38 kV,” Institute of Electrical and Electronics Engineers, Inc. 2003.

[2] C. A. McCarthy, D. Staszesky, “Advancing the State of Looped Distribution Feeders,” Presented at DistribuTECH 2008, Tampa, Florida

VII. BIOGRAPHIES

Christopher A. McCarthy is a Director in the Automation Systems, Strategic Solutions Department of S&C Electric Company in Chicago, Illinois. Chris has participated in R&D, marketing, and field application support for the S&C IntelliRupter®. Prior to joining S&C in 2006, he was with Cooper Power Systems for 11 years. His experience includes performing analytical studies, software development, and presenting engineering workshops in the fields of overcurrent protection, recloser applications, and optimizing reliability of distribution systems. He received a BSEE from the University of Illinois at Champaign-Urbana, a Masters in Electric Power Engineering from Rensselaer Polytechnic Institute, in Troy, New York, and an MBA from Keller Graduate School of Management. He is a registered Professional Engineer in the state of Wisconsin.

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