Comprehensive testing of recloser controls with minimal effort

With an ever-growing demand for a more reliable distribution grid, utilities are constantly looking for possibilities to optimize their distribution networks through the implementation of distribution automation. One of the methods used to improve the network and reduce permanent outages, is by utilizing pole mounted reclosers, due to their wide range of functionality. With the introduction of built-in voltage sensing on both its source and load side, automation can easily be achieved by local built-in logic to isolate a faulted section, and by closing in a tie recloser to supply power to customers from an alternate source. Automation schemes utilizing coordinated protection functions provide an easy, and low-cost solution for improving reliability, however the process of isolation and service restoration can take up to several minutes. For critical feeder lines where long temporary outages are not acceptable, reclosers equipped with high-speed peer-to-peer communication provide possibilities to locate, isolate, and restore power to unfaulted sections within seconds or faster.

To put such projects into operation, utilities often rely on manufacturers to design and implement the automation scheme. Thorough testing of the entire scheme prior to installation is critical to ensure that the switching logic works as desired for a multitude of fault scenarios which may affect network, and that the communication equipment can support the resulting network traffic. The testing process is integral for the verification of the system, but can also be extremely complex, labor intensive, and time-consuming. OMICRON offers an easy to apply method for testing of any distribution automation network that will significantly reduce testing time while covering parameters which can verify correct operation of distributed automation schemes, which are typically not included in routine conventional testing.

Application example

There are different many possibilities for automating feeders using reclosers. A commonly used method is to connect two feeders at an interconnection point using a normally open recloser as shown in Figure 1. While the number of reclosers utilized in the scheme may vary, this example provides a general idea of the concept.

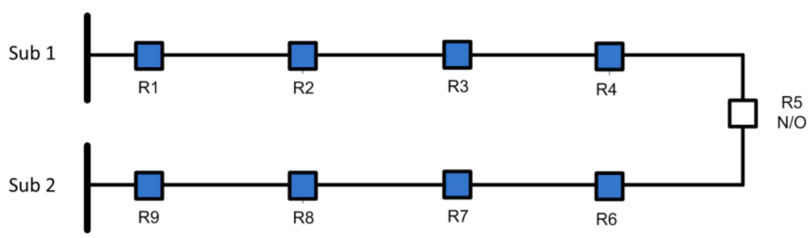

***Figure 1**: Typical feeder automation example with a tie recloser.*

If a fault occurs as shown in Figure 2, R3 must trip first to interrupt current flowing into the fault. To isolate the faulted section, R4 should open next. A check should then occur to see if the feeder supplied by Sub 2 can supply the additional load between R4 and R5. If the load can be supplied, the normally open R5 will close in, restoring power to customers who would otherwise be left out of service. Now that power is restored to customers between R4 and R5, R3 will try to reclose to check if the fault was only of temporary nature.

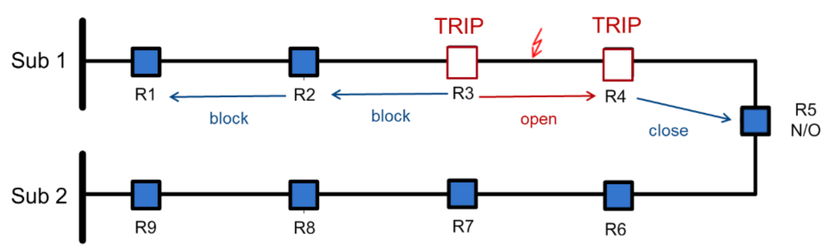

***Figure 2:** Fault location, isolation and service restoration in case of a fault*

Achieving this type of functionality can be done in a variety of ways, the simplest method will be to only rely on local logic in each recloser, which is based on a voltage function. In the case of a permanent fault, recloser R3 will typically try to reclose until lockout. Meanwhile, a timer in R4 will initiate after it detects a permanent loss of voltage, and eventually open after a set amount of time based on protection settings. Since R5 has lost voltage on either side it will start to count too and close in after a defined time. When purely based on voltage logic, this scheme will typically take a minute or more to restore power to non-faulted sections, which may not be acceptable for critical feeder lines. This isolation and reconfiguration process can be significantly improved by using communication to or between the reclosers in the field. In case of a fault, the recloser could then quickly send an open or closing signal to downstream and tie reclosers.

If the protection of the scheme is not based on communication or distributed logic, testing the protective functions of the recloser control could be performed with minimal effort via secondary injection testing for individual recloser controls. OMICRON recommends using the ARCO 400 test set which can be universally connected to the control cable interface of any recloser control with short recloser-specific adapters. The device simulates the recloser with up to six voltages and enables three-phase testing of the controller in both lab and field environments.

Figure 3: *OMICRON's ARCO 400*

Testing distribution automation scheme

Using the innovative software RelaySimTest, distribution automation schemes can be tested in the lab or field, all while being remotely controlled from a single PC. In addition to addressing the issues described previously, this solution greatly reduces the testing time while providing comprehensive reporting and troubleshooting possibilities.

In RelaySimTest, the power system under test can be modeled in a single line diagram editor, and devices such as reclosers and circuit breakers can be placed in the network. Infeeds are defined by entering the Source-Impedance-Ratio (SIR), the line data calculated by using line length and impedance, and the loads in the network specified using active and reactive power data. Using this information, RelaySimTest can calculate the resulting load and fault values for any user defined test case.

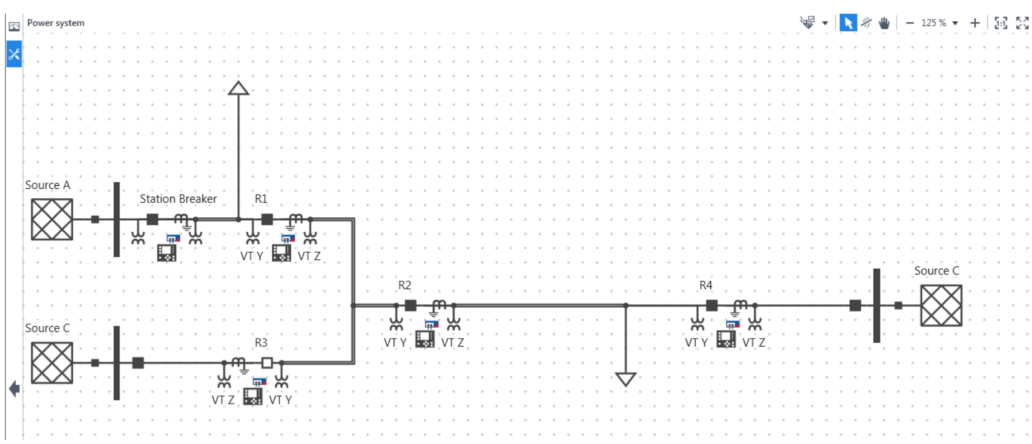

Figure 4: *Example of Power System Model in RelaySimTest*

The behavior of the circuit breakers and/or reclosers should be defined within the simulation software. If the circuit breaker and/or recloser opening and closing times are known or have been previously measured using a breaker timing test device, the software allows for the input of those times, which are taken into consideration to ensure a more realistic test. ARCO 400, has a built-in circuit breaker simulator, which can be extremely beneficial for testing purposes. Using the binary outputs of the test device, the 52a and 52b contacts can be simulated, which does not require the circuit breaker or recloser to be connected during the test.

For a lab or field test a single test set needs to be connected to each recloser control or relay to inject the appropriate currents and voltages inputs, binary inputs (52a/b), as well as receive the resulting binary outputs (trip/close commands). However, when performing a field test, protection points can be located several miles away from each other. The system must use either an existing communication network or an external cloud service with remote connection. In this case, all the testing devices need to be synchronized to GPS for a time-synchronized injection.

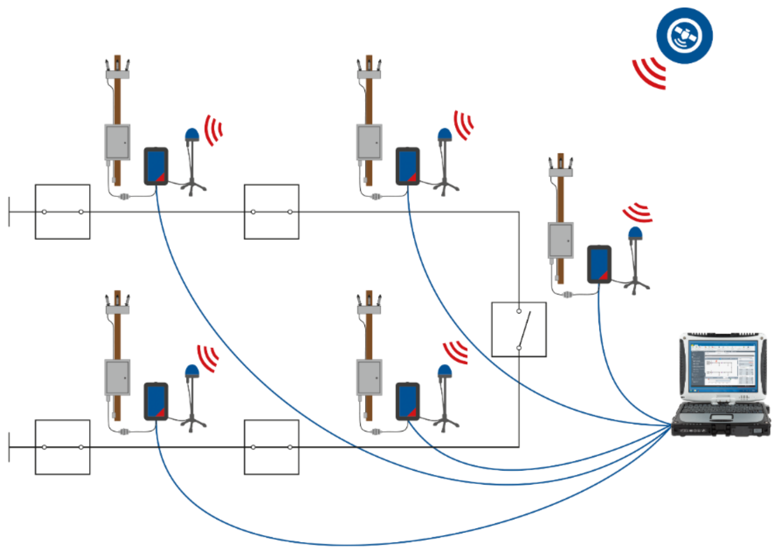

Figure 5: *Typical setup for GPS time synchronized transient simulation test of recloser controllers using test devices at each protection point.*

Once GPS synchronization is established, all test devices in the scheme can communicate with each other, as well as with the associated PC running the simulation software over the network. A requirement for this PC is that it must be given access to the network to establish communication with all the test devices. To synchronize all test devices at each protection point, individual GPS antennas (e.g. CMGPS 588) are used.

For each test case, a fault can be defined within the RelaySimTest single line diagram representation of the scheme; the software then calculates the resulting fault values for each device at each location. When the test is executed, RelaySimTest proceeds to send the calculated test values into all test sets. Upon receiving all of the test values at the test devices, the injection begins synchronously.

RelaySimTest uses “iterative closed-loop” testing approach to calculate new voltage and current values whenever an open or close command is issued by any recloser in the scheme. Using this method of test, the correct switching behavior of the scheme can be assessed, and it is immediately clear if the communication equipment can handle the amount of data once the equipment is installed in the field. Thanks to transient test signals, the overall performance of the automation sequence can be measured and assessed. Furthermore, it can be determined if corrective measures to improve the performance of the system need to be implemented.

Conclusion

The method and testing process using ARCO 400 and RelaySimTest is easily applied and allows communication based automated distribution schemes to be performed in a lab or field environment to verify the switching logic, communication equipment, and the communication network's ability to handle the data traffic. By using transient test values in addition, the actual performance of the scheme can be evaluated, and it could also be used to compare different communication technologies. By using the iterative closed-loop approach the switching operations don't need to be defined prior to the test. The software will learn the behavior of the scheme for a certain fault, and the engineer is only required to assess if the switching operations were performed correctly by the devices under test.