IntelliRupter® PulseCloser® Fault Interrupter Current-Measurement Tolerances

Some utilities evaluating the S&C IntelliRupter PulseCloser Fault Interrupter have questioned whether its use of single-phase Rogowski coils for current measurement produces accurate overcurrent protection responses. Consequently, this publication will compare the current measurement precision of the S&C IntelliRupter fault interrupter against three-phase reclosers equipped with iron-core current transformers (CTs).

Background

Essentially, only two factors influence the measurement precision of an overcurrent-protection element:

- The sensing tolerances of the primary-to-secondary current or signal transformation
- The measurement precision of the control or relay processing the secondary current or signal produced by the sensing tolerances of the primary-to-secondary current or signal transformation

The S&C IntelliRupter fault interrupter is equipped with extremely precise Rogowski coils for sensing single-phase primary current. These coils remain linear across an extremely wide range of primary currents, and their output signals are sampled 128 times per cycle by a protection-and-control module.

Once S&C assembles an IntelliRupter fault interrupter, it calibrates primary-current and -voltage measurements, and the company performs production testing of the completed product before shipment. This means it is holistically tested to ensure its in-service performance will exceed its protection specifications, which are the most precise in the industry. ***Note: Please see S&C Data Bulletin 766-211 for more detail.***

On the other hand, substation circuit-breakers and three-phase reclosers often are assembled using components from different manufacturers. Consequently, they are seldom, if ever, tested together as a system, and the primary-current measurement is never calibrated.

Breaker and recloser current measurements are uncalibrated principally because protective relays and controls don't enable calibration. The reason this capability is absent is recloser manufacturers generally ship breakers and three-phase reclosers with relatively inaccurate protection-class, single-phase, iron-core CTs.

While protection-class CTs can vary in accuracy, the most common are the ANSI Class C and IEC 10P20 CT. The performance specifications of these CTs essentially require them to have a 10% maximum ratio error at 20 times the rated primary current. This means a 600:5-ampere protection class CT should have a less than 10% primary-to-secondary current transformation error from 600 amperes to 12,000 amperes.

However, experience suggests most iron-core CTs are reasonably accurate when sensing load current. So, the 10% ratio error of a Class C or 10P20 CT is more likely to occur at 20 times the CT's rated primary current. But, this also means the CT sensing error increases as primary current rises.

Current Signal Processing Testing Method

S&C ran Monte Carlo simulations to determine the statistical probability of neutral-current sensing and measurement accuracy. In this instance, the Monte Carlo testing method randomly varied the CT ratio error and the total measurement tolerances of the IntelliRupter fault interrupter thousands of times for a constant primary current.

S&C chose this testing method because, although a CT must not produce more error than specified, its performance will vary between ideal (no error) and maximum error. Consequently, this Monte Carlo testing approach establishes the percentage of time a CT will sense (or the IntelliRupter fault interrupter will measure) a neutral current accurately or inaccurately.

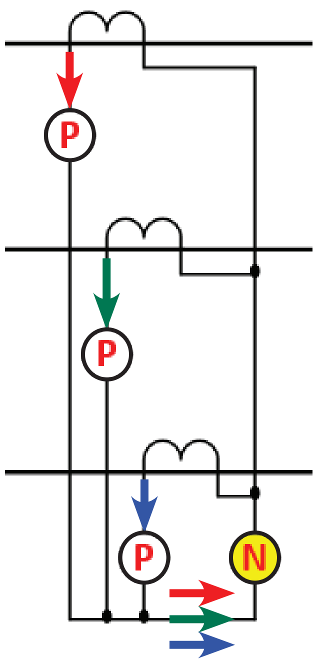

Figure 1. Iron-core CT simulated current would flow through "N".

To demonstrate how precise the IntelliRupter fault interrupter's measurements are, S&C chose a more accurate iron-core, metering-class CT instead of a protection-class CT. This means instead of testing CTs having a 10% ratio error, ones with tolerances of a +/-1° and +/-1.2% ratio error were used. ***Note: The standard for protection-class CTs doesn't require them to conform to a phase-angle transformation tolerance.***

To be clear, S&C only compared the IntelliRupter fault interrupter's combined tolerances (its sensing and control measurement tolerances) to the performance of three single-phase metering-class CTs. This means S&C compared the sum of the secondary currents produced by the three CTs, or the neutral-current flowing through "N" in **Figure 1**, to the neutral-current measured by the IntelliRupter fault interrupter. ***Note: S&C excluded the accuracy of a protective relay or control neutral element ("N") and the effect of the control cabling between the CTs and relay, which would add to the neutral-current error produced by the three CTs.***

Also, the IntelliRupter fault interrupter's combined sensing and measurement tolerances and the CTs' +/-1° and +/-1.2% ratio errors were uniformly applied for all primary-current levels. So, while sensing and measurement tolerances might be less at lower primary currents for both the CTs and the IntelliRupter fault interrupter, S&C always randomly varied specified tolerances regardless of the current level examined.

Testing Results

As previously indicated, S&C randomly varied the ratio error of the CTs and the measurement tolerances of the IntelliRupter fault interrupter thousands of times while applying a constant primary current. Therefore, S&C used balanced three-phase primary currents of 100, 200, 300, and 400 amperes during the test.

This testing produced the results shown in **Figure 2**. The solid lines indicate the probable neutral currents the IntelliRupter fault interrupter would measure. For instance, 98% of the time the IntelliRupter fault interrupter would measure balanced, three-phase, 100-, 200-, 300- and 400-ampere load current as 1-, 2-, 3- and 4-ampere neutral current (and not 0 amperes) respectively.

Conversely, the dashed lines in **Figure 2** show the probable neutral-current error produced by just the iron-core metering-class CTs alone. For example, the first dashed line on the left indicates that 98% of the time it's probable these CTs would produce a 4-ampere neutral current (and not 0 amperes) for a balanced 100-ampere, three-phase load current.

Application Considerations

Sensitive Earth-Fault (SEF) protection is the most sensitive overcurrent protection applied on medium-voltage distribution feeders. Utilities generally use this type of protection to detect high-impedance single-phase-to-ground faults on feeders whose loads are exclusively connected phase to phase.

So, when applying SEF protection, **Figure 2** also indicates that load levels will influence the SEF minimum response current setting. To be clear, the minimum current and time-delayed response of SEF

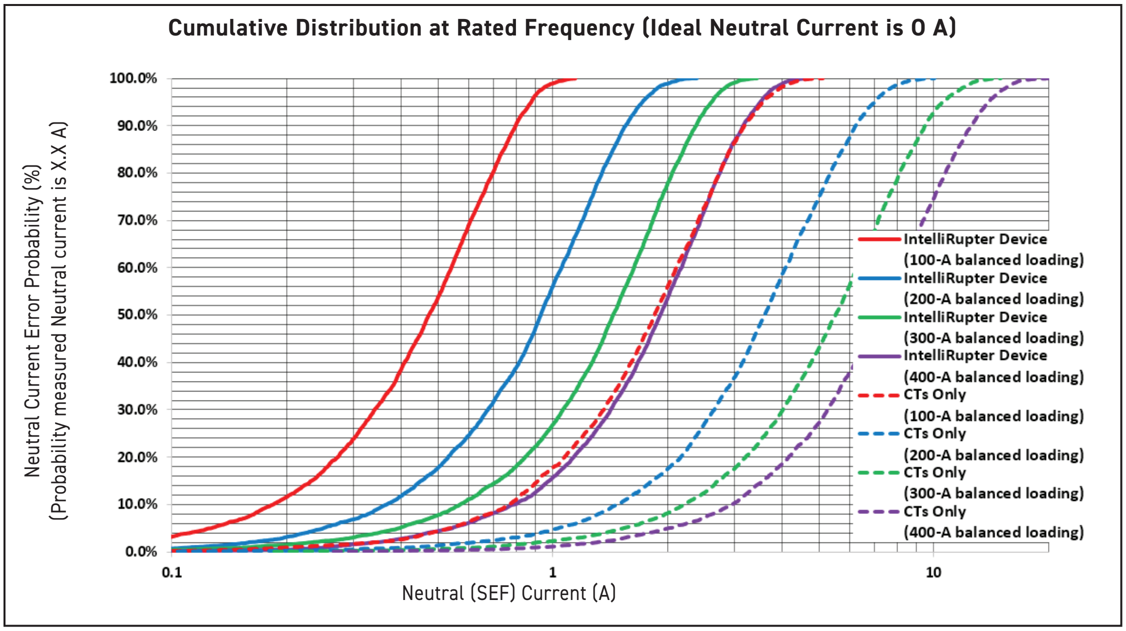

Figure 2. Comparison of iron-core metering-class CTs and the IntelliRupter fault interrupter neutral-current measurement for balanced three-phase load currents.

protection should prevent load from causing an undesired SEF-protection operation.

As an example, the minimum SEF-response current for a balanced three-phase, 300-ampere load ought to be:

- More than 3 amperes when applying the IntelliRupter fault interrupter (98% of the time it would measure this current as an SEF event of 3 amperes (third solid line from the left.)
- More than 12 amperes, plus relay or control SEF-measurement tolerances, when using three single-phase, iron-core, metering-class CTs (98% of the time these CTs would produce a 12-ampere neutral current (third dashed line from the left.)

Although this testing demonstrated that three single-phase, iron-core CTs can produce varying neutral currents based on balanced three-phase load levels, this current will increase when unequal three-phase loading occurs. However, because SEF protection is applied on feeders where load levels are generally low, it's uncertain whether load imbalances cause unexplained breaker and three-phase recloser SEF operations.

Conclusions

This exercise has proven the IntelliRupter fault interrupter's integrated, calibrated, and production-tested sensing and measurement system is superior to three single-phase iron-core CTs alone. So, when the measurement tolerances of a relay or control system are added to the error produced by these CTs, the overall protection tolerances of breakers and three-phase reclosers worsens.

However, many users successfully configure SEF protection using minimum response currents in the range of 5 to 10 amperes. Also, relays or controls providing this SEF protection are frequently supplied by single-phase, iron-core CTs having a 10% sensing tolerance. And the reason this generally works is iron-core CTs have less current-ratio error at lower load levels. ***Remember, S&C uniformly applied rated CT-sensing tolerances during testing, regardless of the load-current level.***

That said, there are instances in the United Kingdom where SEF protection is practiced, and one utility replaced existing three-phase reclosers with IntelliRupter fault interrupters. Surprisingly, the IntelliRupter fault interrupters occasionally began tripping because of SEF events after they were installed.

Because SEF events hadn't previously occurred, field crews were initially suspicious of these operations. However, the utility eventually found pre-existing damaged line-post insulators caused the SEF tripping, vindicating the performance of the IntelliRupter fault interrupter and questioning the performance of the previous reclosers.

Consequently, if a utility values precise sensing and secure measurements, the superior performance of the IntelliRupter fault interrupter becomes the obvious choice. But more importantly, its in-service performance will improve the sensitivity and security of protection operations when compared to today's breakers and three-phase reclosers.

By Michael Meisinger, © 2017 S&C Electric Company

