Tolerance-Based Time-Current Coordination

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Overview

When S&C Electric Company introduced the S&C IntelliRupter® PulseCloser® Fault Interrupter, the high accuracy sensing and operational precision of the product warranted a new look at the way protection behavior is represented. Rather than follow the existing convention of illustrating a Time Current Characteristic (TCC) as a single, nominal TCC line, S&C elected to demonstrate the precision of the IntelliRupter fault interrupter's time-overcurrent protection responses using TCC tolerance-response bands.

The reason for improving upon conventional coordination methods was that the single TCC line, which is coordinated using a Coordinating Time Interval (CTI), doesn't enable users to benefit from the IntelliRupter PulseCloser Fault Interrupter's significantly tighter response tolerances. This is true because the CTI coordination method simply separates single (nominal) TCC lines by a fixed time-value, and it doesn't account for protection-performance differences among devices being coordinated.

Background

CTI time-values may differ where fault-interrupter fault-clearing and relay-response times vary appreciably. And most users will select different CTI time-values when coordinating electromechanical relays versus microprocessor relays and controls. But once a CTI time-value is applied, the sensing and response tolerances of each device are ignored, and the time-overcurrent protection performance of all breakers and reclosers being coordinated are considered to be equal.

What differentiates the superior performance of the IntelliRupter fault interrupters from other breakers and reclosers begins with its use of Rogowski coils. These primary-current sensing devices are very precise and remain linear across an extremely wide current range. This is in sharp contrast to the 10% turns ratio error of the class C or 10P20 current transformer (CT) used in many breakers and reclosers.

The combination of Rogowski coils, coupled with the IntelliRupter fault interrupter's current-measuring accuracy, results in a +/–2% current-measurement tolerance during protection functions. (The steady-state current measurements, which are averaged over one second, yield a much higher +/–0.5% sensing tolerance.) Comparing this performance to the competition, and considering the class C or 10P20 CT as having +/–5% sensing tolerance, today's most popular relays have a +/–8% current-measurement error.

Further, the IntelliRupter fault interrupter's timing tolerances are also +/–2%. But today's widely used relays only have a timing accuracy of +/–4%.

Additionally, there is always a fixed-time error associated with today's protection element time response. In the case of the IntelliRupter fault interrupter, its fixed-time error value is +/–0.008 seconds. In contrast, today's more popular relays have a fixed-time error of +/–1.5 cycles, or 0.025 seconds at 60Hz.

And finally, the IntelliRupter fault interrupter's fault-clearing time of 2 cycles may rival the claims of some of today's alternative fault-interrupting products. But many of the devices presently in service have fault interrupters with fault-clearing times that vary between 3 to 6 cycles.

The IntelliRupter fault interrupter TCCs have superior precision when compared to S&C expulsion fuses.

With expulsion fuses, an operating-response band is developed using the fuse's minimum-melt and total-clear TCCs. Similarly, an IntelliRupter fault interrupter TCC tolerance-response band accounts for all the individual tolerances contributing to its minimum and maximum time-overcurrent fault-clearing response.

And instead of relying on a fixed CTI time-value, the basis for coordinating these TCC tolerance-response bands is rooted in how expulsion-fuse TCCs are graphically coordinated. As a reminder, the coordination of series fuses is accomplished by simply ensuring a fuse's slower (total-clear) and faster (minimum-melt) TCCs don't touch or cross adjacent upstream and downstream fuses for an appropriate level of fault current. Other manufacturers sometimes recommend using a 25% setback allowance to account for prior fuse damage. However, S&C fuses don't require derating for potential damageability.

But to appreciate why TCC tolerance-response bands provide a better means of coordination, graphic examples may better illustrate these benefits. For example, let's begin by coordinating two series devices using the CTI method. Figure 1 illustrates two IEEE Extremely Inverse single (nominal) TCC lines separated by a CTI of 250 milliseconds, which is frequently used when coordinating microprocessor relays.

The upper TCC line represents a pickup of 900 amperes and a time-multiplier or time-dial of roughly 4.8. The lower TCC line represents a pickup of 600 amperes and a time-multiplier of 1.0

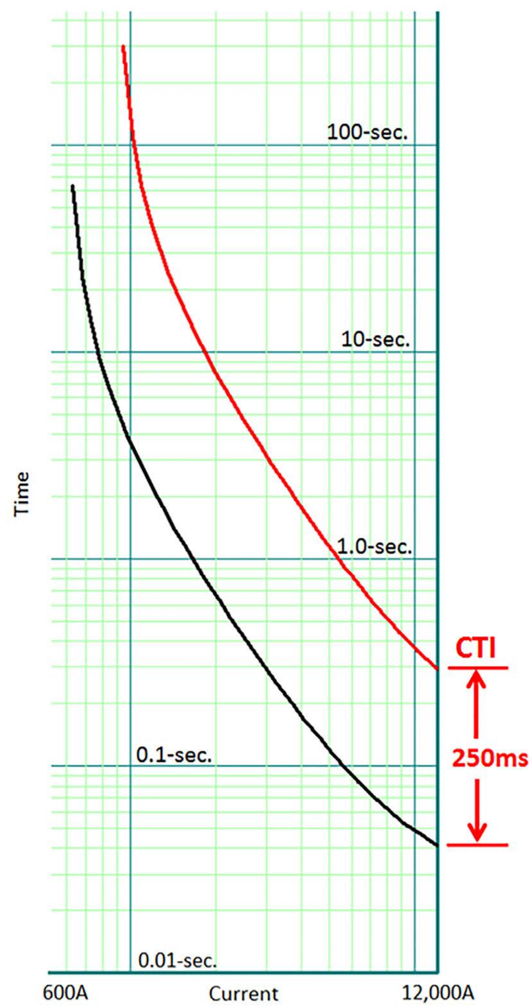

Figure 1. IEEE Extremely Inverse single, nominal TCC lines separated by a CTI of 250 milliseconds.

Figure 2 now adds the specification tolerances of an IntelliRupter fault interrupter to these single TCC lines. These tolerances are:

- +/–2% current (includes any contribution from the primary-current sensing device)
- +/–2% time
- +/–0.008 seconds fixed-time error
- +2 cycles fault-clearing time

As seen in Figure 2, there is an appreciable gap between the top and bottom TCC tolerance-response bands, and this gap is in fact 188-milliseconds.

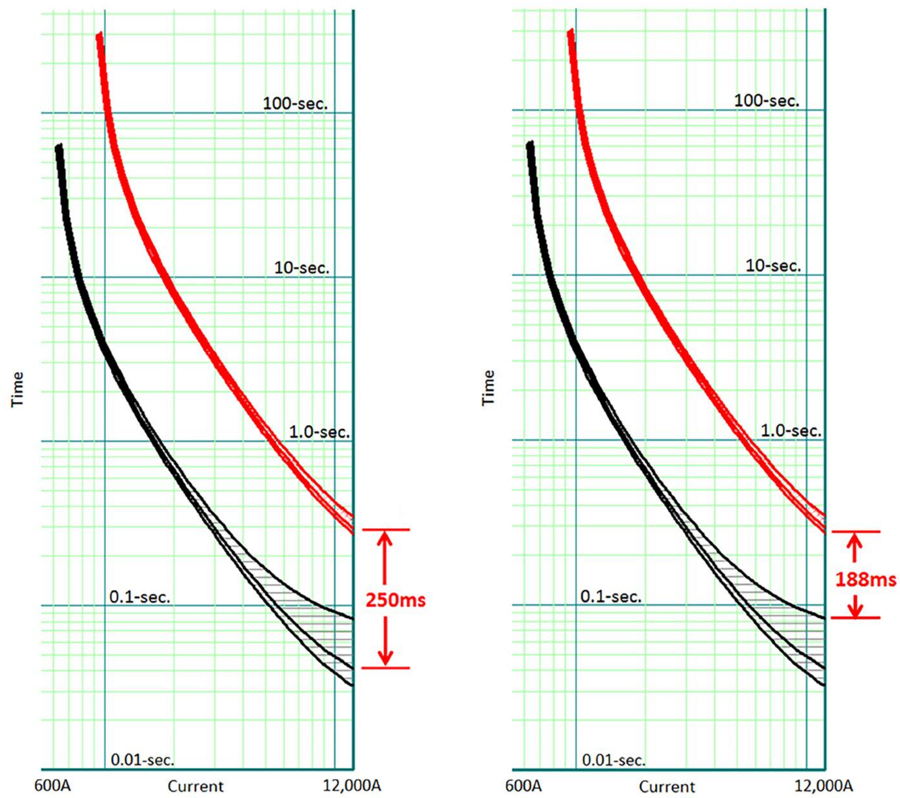

Figure 2. IntelliRupter fault interrupter IEEE Extremely Inverse TCC tolerance-response bands.

> This 188-millisecond gap is so large, Figure 3 on page 5 indicates that ***two additional IntelliRupter fault interrupters*** can easily be inserted between the upper and lower TCC tolerance-response bands with no coordination challenge whatsoever.

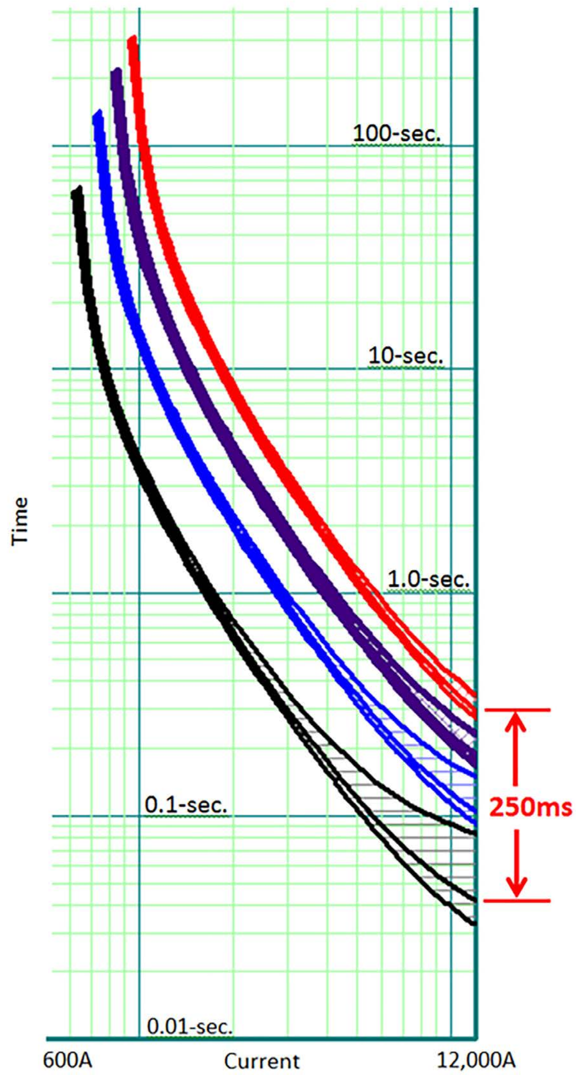

Figure 3. IntelliRupter fault interrupter's performance precision enables the addition of two more IntelliRupter fault interrupters.

TCC tolerance-response bands are not limited to the IntelliRupter fault interrupter. In fact, Figure 4 uses a relay-based recloser or circuit-breaker for the upstream device and an IntelliRupter fault interrupter for the downstream device. In this instance, one of today's more popular relays is used for the previous IEEE Extremely Inverse TCC coordination example. The pickup and time-multiplier settings are as before (600 and 900 amperes, with time-multipliers of 1.0 and roughly 4.8 respectively).

The TCC response tolerances for the upstream (crosshatched) relay and breaker or recloser TCC reflected in the plot of Figure 4 are:

- +/–8% current (includes +/–5% primary-current sensing-device error)
- +/–4% time
- +/–0.025 seconds fixed-time error
- +3 cycles fault-clearing time

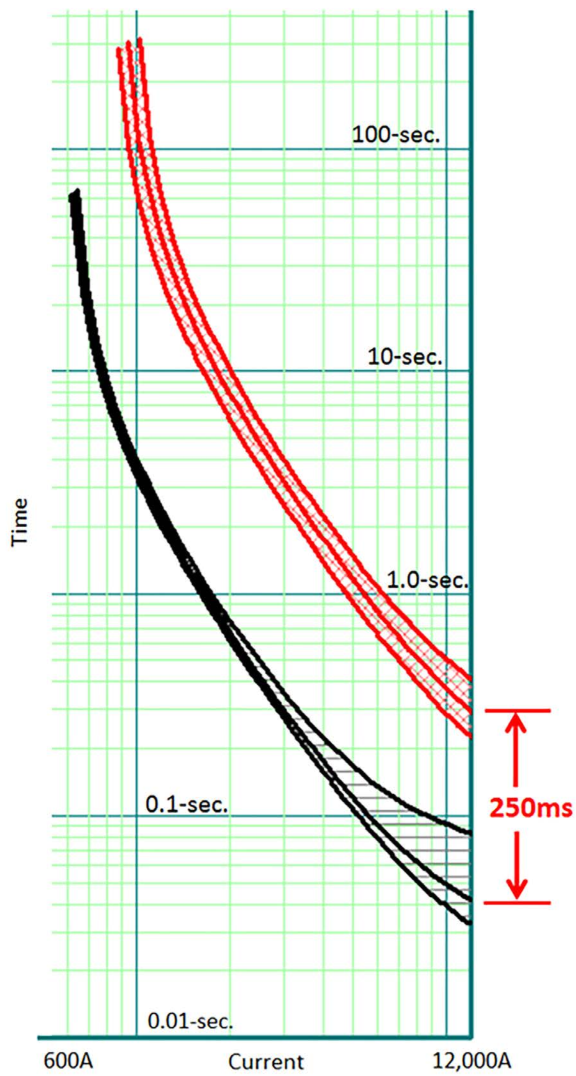

Figure 4. IEEE Extremely Inverse TCC tolerance-response bands for an IntelliRupter fault interrupter (lower TCC band) and a relay-based recloser or breaker (upper TCC band).

Unlike the results produced by the precision of the IntelliRupter fault interrupter, there is only about a 140-millisecond separation between the top and bottom TCC tolerance-response bands plotted in Figure 4 on page 6. However, Figure 5 demonstrates there is still enough separation margin to enable the addition of another relay-based recloser control.

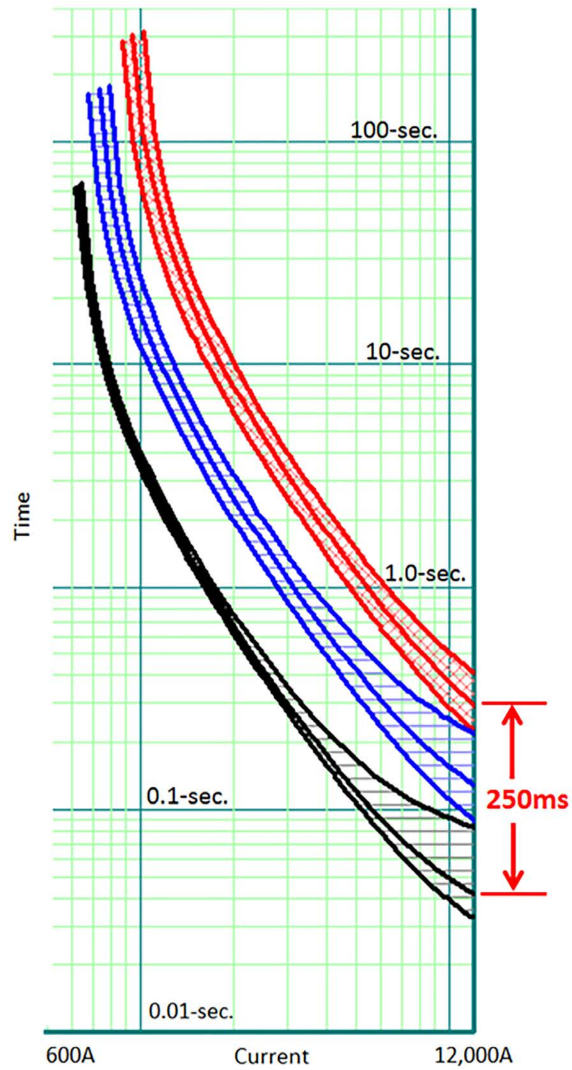

Figure 5. One more competitor's IEEE Extremely Inverse TCC relay-based recloser is added (middle TCC band).

Alternative TCC Representation Method

To better illustrate the contrast between the two previous tolerance-response coordination examples, Figure 6 not only highlights the superior performance and precision of the IntelliRupter fault interrupter versus the less precise behavior of a relay, but it also demonstrates the benefit of using tolerance-response coordination. Instead of coordinating only two series devices using the CTI method, where the time-value is 250 milliseconds, the tolerance-response technique enables three or four series devices to be well coordinated within the same time interval.

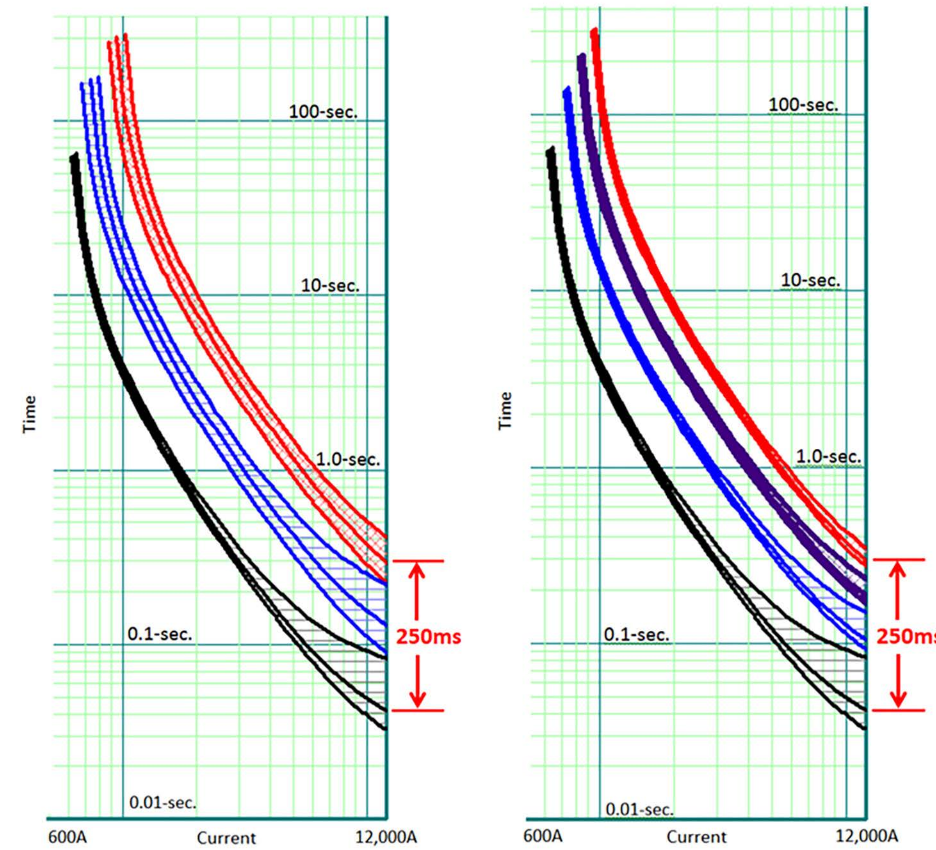

Figure 6. A side-by-side comparison of the IntelliRupter fault interrupter TCC tolerance-response bands (TCC plot on right) with those of an IntelliRupter fault interrupter and two of today's popular relay-based fault interrupters (TCC plot on left).

Conclusions

The illustration of TCC tolerance-based coordination conclusively demonstrates that time-overcurrent protection responses can be better modeled using cumulative response tolerances. Instead of simply relying on a single, nominal TCC line and a fixed CTI time value (which are overly conservative), graphically coordinating comprehensive TCC response bands results in more accurate TCC margins.

So, if increasing the number of series-coordinated, time-overcurrent devices is the ultimate objective, using the proposed TCC tolerance-response coordination technique (and ideally the IntelliRupter PulseCloser Fault Interrupter) can appreciably improve upon what can be achieved using the conventional CTI method.