GE Digital Energy
Multilin

GE Multilin technical note

GE Multilin releases fast and dependable short circuit protection enhanced for performance under CT saturation

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Dependability of protection under heavy saturation

Short circuit protection in industrial applications by means of instantaneous overcurrent function (IOC) has gained significant interest in the last few years.

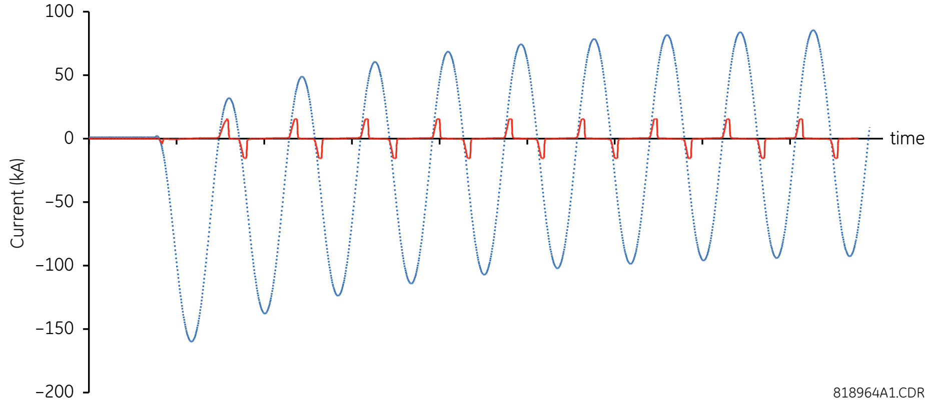
It is possible that relatively low-ratio current transformers (CTs) are applied for protective relaying of small loads fed from switchgear or motor controllers of relatively high short-circuit capacity. Assume the worst-case scenario of 64 kA available fault current from bus feeding a small motor load rated below 50 A. In theory, CTs rated as lows as 50:5 and relay class C10 may be applied for protection purposes. Recognizing that 64 kA of fault current is more than a thousand times the rated current of the 50:5 CT, the magnitude of the problem is evident.

Protection class CTs are designed to work in the linear range, with reasonable errors and waveform distortions only up to 20 times the rated nominal current. Well-established practices have been developed for engineering CT/relay installations under such conditions.

This engineering practice is of little help here: A CT fed with a primary current hundreds of times its rated current will saturate severely - only relatively short duration peaks of limited current will be observed from the secondary of the CT. These peaks can be as low as 5 to 10% of the ratio current, and will last for short times, down to 1 to 2 ms in extreme cases. As a result, only a very small portion of the actual ratio current is presented to protective relays fed from such severely saturated CTs. In terms of the true RMS value, the secondary current may be as low as 1 to 2% of the ratio RMS current.

The following concern arises – the fault current is so high compared with the CT rated that it virtually stops the CT from passing the signal to the relay. The relay does not see enough proportional secondary current during severe faults to operate its short circuit protection, and fails to trip. The upstream relays, using CTs of a much higher ratio, measure the same fault current more accurately and trip. Zone selectivity is lost because the low-ratio CT “blinded” the relay. In practical terms, however, the problem is not frequent as CTs are being selected reasonably well, and most relays – especially those responding to the true RMS value – retain ability to trip on heavily saturated waveforms.

Figure 1: Example of a current waveform as seen by a typical microprocessor-based relay – short lasting peaks of current do not carry enough energy to activate a high-set IOC function.



Users demand deterministic and guaranteed response from protective relays. Application of IOC functions under heavy CT saturation is beyond the standard engineering practice that normally predicts the worst-case performance by utilizing relay and CT specifications. Therefore, help is needed from relay manufacturers to quantify the problem better by educating users on relay performance during CT saturation, or by enhancing relays to ensure dependable and fast operation under such extreme conditions.

Relay design for heavily saturated CTs

The goal is to provide short circuit protection via an IOC function that is both dependable and secure.

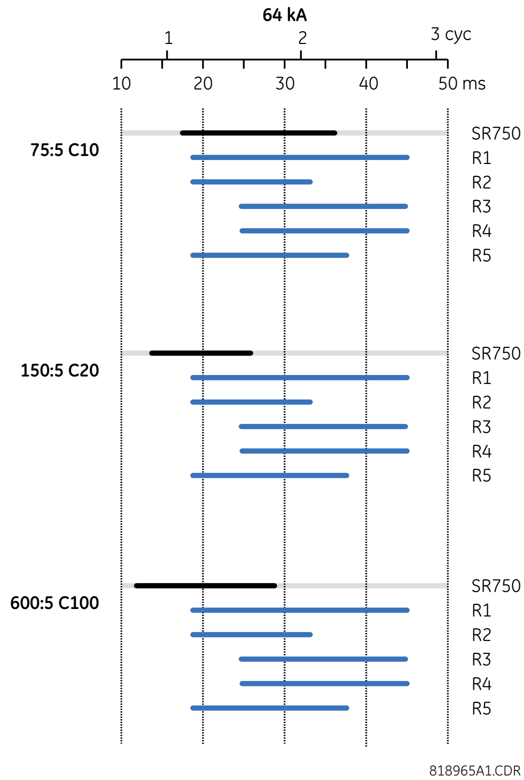
Dependability is defined as ability to respond to faults even under severe CT saturation within a specified period of time. Failure to trip or a slow trip would cause mis-coordination of the protection system. From this perspective the relay algorithm needs to respond to waveforms as illustrated in figure 1 - short lasting peaks of current are measured and must be interpreted through the intelligence of a microprocessor-based relay as a legitimate fault condition.

On the other hand the relay must be immune to sporadic current spikes that may be induced by transients and other non-fault events such as contactor bounce and arcing in vicinity of the relay and its wiring.

As a result the algorithm design is a challenging task. GE Multilin is introducing an enhanced algorithm that provides dependability for conditions as severe as 64 kA of short circuit current with a 75:5 C10 CT with settings as high as a typical 16 times rated IOC pickup, without jeopardizing security of protection.

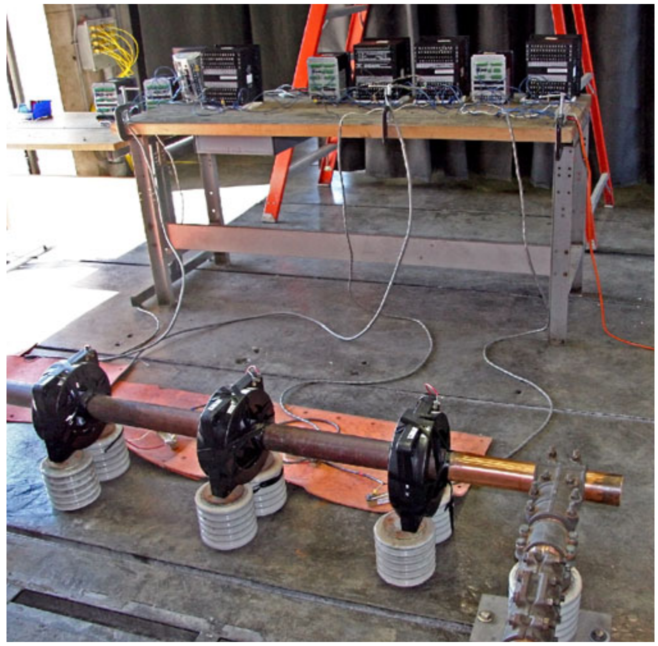
With reference to figure 2, three typical CTs have been exposed to 64 kA of short circuit current. A number of relays have been tested for dependability and speed with a common pickup setting of 16 times rated. The SR750 relay performed exceptionally well even when fed from a 75:5 C10 CT. The relay is dependable and responds within 25 ms in most cases.

Figure 2: Trip times for a set of tested relays fed from three typical CTs under 64 kA of fault current. The IOC functions were set at 16 times rated.



Performance verification of IOC functions under extreme fault conditions is not a trivial task either. The secondary CT currents reach hundreds of Amperes, well above capabilities of a typical test set. In addition accurate modeling of CTs can be a challenging exercise for a typical engineering staff rendering testing via waveform playback impractical. High power testing with actual CTs and relays is, therefore, a necessity. Figure 3 depicts a typical test setup for such type tests. It is prudent to contact a relay manufacturer regarding high power tests for applications with low-ratio CTs and extremely high fault current.

Figure 3: Typical test setup in a high power lab



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Short-circuit protection – speed considerations

Historically, overcurrent protection responding to faults in the range of 50 ms was sufficient in industrial applications. Recently, however, expectations for faster operating times have risen, driven by arc flash considerations, impact of fault current on primary equipment such as generators, and overall protection coordination.

Speed of operation without security and dynamic accuracy is problematic, and relay designs need to balance speed, security and accuracy.

With this in mind GE Multilin has enhanced IOC algorithms further in order to provide for ultra fast operation under typical fault currents with no or mild CT saturation. Figure 4 presents the IOC trip times – from fault inception till closure of a trip rated output – of the SR750 relay. The response time depends on the ratio between the fault current and the applied setting and varies from 16 ms for high multiples of pickup to 25 ms for a multiple of pickup of 1.2. For comparison, figure 5 provides trip times for other brands of relays tested under identical conditions.

Figure 4: Operating speed of short-circuit protection – the SR750 relay

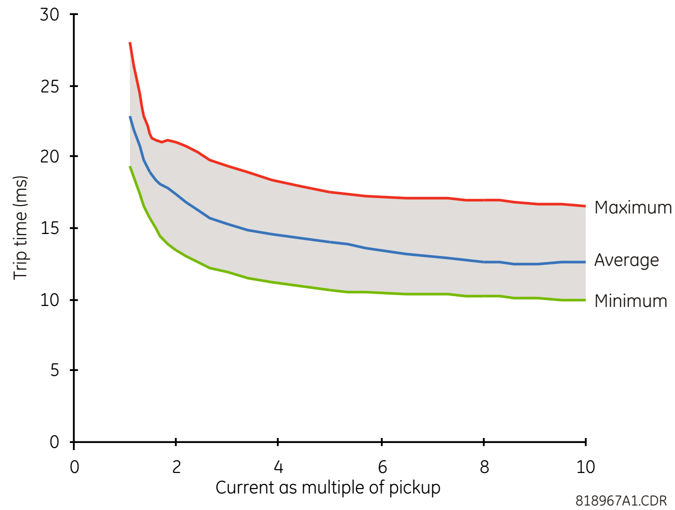
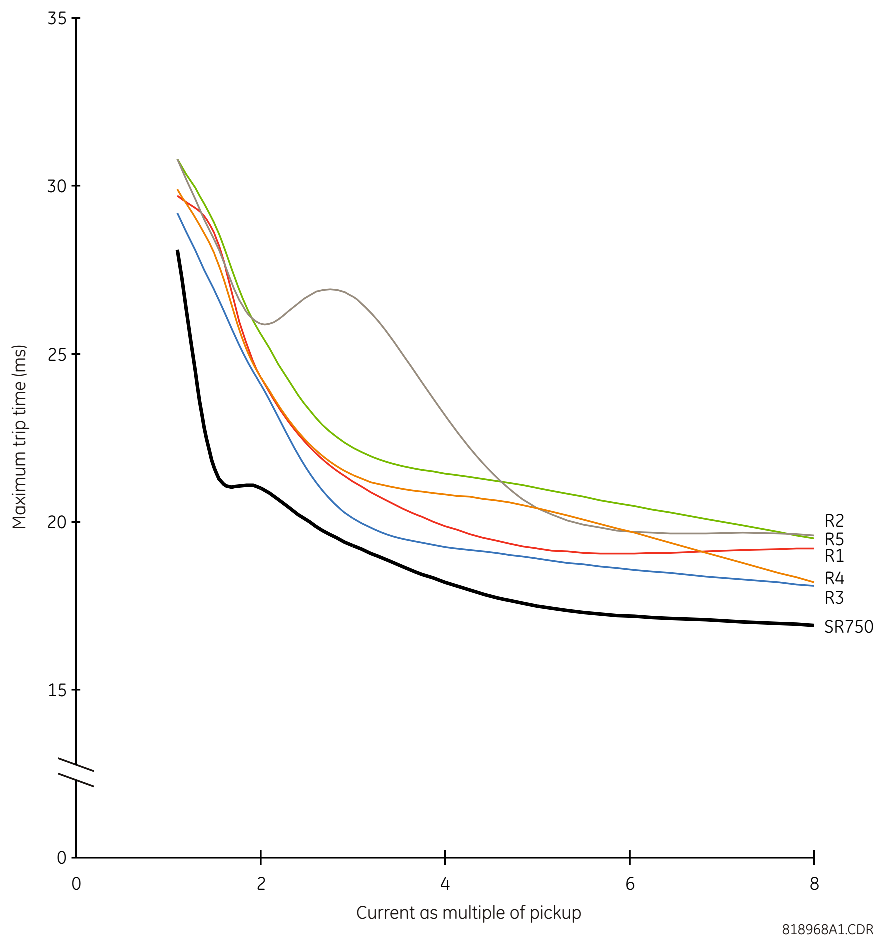


Figure 5: Operating speed of short-circuit protection – SR750 and reference



Summary

The computational capabilities of microprocessor-based relays allow the development of sophisticated overcurrent algorithms. These algorithms ensure dependable and fast operation of short circuit protection even under severe saturation of current transformers. This eliminates the need for impractical engineering of such applications, and increases confidence levels in cases with relatively well-rated CTs that do not experience extreme saturation but are exposed to currents much higher than the conventional 20 times rated.

Speeding up protection functions and improving their response to severely impaired input signals exposes them, however, to security concerns. The users are advised to inquire about rigorous relay type tests including high power tests with physical CTs and relays before deciding to shift toward greatly underrated CTs while relying on protective relays to work with impaired input signals.

The presented test results for the SR750 relay illustrate the level of performance in terms of speed and dependability under severe CT saturation that is safely achievable. The relay is dependable and fast under CT saturation conditions. In addition, in properly sized CT/relay applications it provides a 1-cycle trip time for fault current levels of 4 times the pickup, and a 1.5-cycle trip time at lower currents. This performance meets the present and future needs of industrial applications.