GE Energy Connections

DET - 1004 Application and Technical Guide

# Energy-Reducing Maintenance Switch

## RELT Function in GE Circuit Breaker Trip Units & Power Switch Control Relays

## Introduction

The energy-reducing maintenance switch is almost ubiquitous in discussions about how to implement overcurrent protection for low- and medium-voltage systems. This energy-reducing maintenance switch is often called simply a maintenance switch, or an arc flash switch; GE calls it the reduced energy let-through (RELT) function in applicable products. Similar functionality may be achieved by using the alternate setting group capability in protection relays typically used in medium-voltage systems.

However, the need for an alternate low-voltage setting group became evident since the publication of IEEE 1584-2002 - IEEE Guide for Performing Arc Flash Hazard Calculations. The requirement for an energy-reducing maintenance switch became mandatory in jurisdictions that have adopted the 2014 National Electrical Code (NEC). That alternate low-voltage setting group is now known as the maintenance switch, and it is offered by most manufacturers in at least some portion of their low-voltage circuit breaker product portfolio.

## Evaluating the Maintenance Switch and Other Hazard Control Methods

Today's electrical system designer should consider how to improve the safety of their designs.

The safety of operation and maintenance personnel is the main element to embed in power distribution systems, and will be for years to come; and it needs to be evaluated against concrete criteria.

Alternatives may be evaluated for various performance factors, including:

- Efficacy
- Complexity
- Cost
- Regulatory compliance
- Maintainability

Although some of these factors lend themselves to intuitive reasoning, this paper will describe the concrete criteria consistent with consensus standards to use.

## Efficacy: The Hierarchy of Hazard Control Methods

Within the body of standards available to the industry, there is a method to evaluate the efficacy of solutions called the "Hierarchy of Hazard Control Methods", described in NFPA 70E[1] and ANSI Z10[2].

The hierarchy divides the methods into 6 categories, shown in order of most effective to least effective in the following list:

(1) Elimination
(2) Substitution
(3) Engineered controls
(4) Awareness
(5) Administrative controls
(6) Personal Protection Equipment (PPE)

The first three hazard control methods provide consistent continuous value for controlling the hazard to some extent. However, it is important to note that the personnel responsible for operating the equipment and receiving direct benefit from these methods are not active participants in the decision-making in any of these cases.

*Elimination* means the hazard is eliminated completely. In electrical terms, it would usually mean a shutdown of the power or putting the hazard in an electrically-safe condition. In this context, elimination is difficult to achieve unless electrical power is no longer needed. Elimination could also mean to remove the operator from the hazard area.

*Substitution* means that equipment, methodology or an alternate design is used to lower the perceived risk associated with the hazard. Arc resistant (AR) equipment is an example of this type of solution. However, AR equipment is also a good example of how evaluating a solution by only one of the methods in the hierarchy criteria could ultimately be insufficient, as it provides additional hazard control under some situations, but not in other situations.

*Engineered controls* refers to methods that implement safety-related controls, protection or other characteristics that lessen the hazard. An example of this type of method would be improvements that speed up protection under arcing current conditions and therefore deliver less arc flash incident energy in the case of an event.

The last three methods are dependent on some action, behavior or understanding by the party being protected. The introduction of human interaction adds the possibility of human error, and hence the latter three methods are considered inferior to the former.

*Awareness* describes training, labelling, signage or any other practice that intends to help personnel recognize, avoid, or work around a hazard.

*Administrative control*s are procedures that must be used to ensure a greater level of safety. The energy-reducing maintenance switch is considered an administrative procedure because personnel must act to enable the protection at the correct device at the correct time.

*Personal Protection Equipment* is well-known and is referred to as the last line of defense.

## Regulatory compliance: The National Electrical Code[3]

The energy-reducing maintenance switch is described in two sections of the 2017 National Electrical Code: article 240.87 for circuit breaker-protected circuits; and article 240.67 for fuse-protected circuits. In both cases, the function is identified as a method to reduce incident energy in circuits 1200A and larger.

The requirement in the 2017 NEC 240.87 is that if the normal instantaneous protection by the circuit breaker is not able to operate at the estimated arcing current, one of several additional protection methods must be included in the circuit. The energy-reducing maintenance switch is one of these prescribed methods. An additional requirement is that the function be provided with local status indication, though the code is not clear if local means the circuit breaker, or the load at the end of the conductors protected by the circuit breaker.

In the 2017 NEC 240.67, additional protection is described for fusible switches 1200A or larger where the fuse does not clear the available arcing current in 70 milliseconds or less. Since the arcing current ($I_a$) for a circuit is not known until a comprehensive fault study and arc flash study are performed, it would be extremely difficult for the authority having jurisdiction (AHJ) to evaluate if the protection provided by the fuse is sufficient. It may therefore be a better solution to include the additional protection in every switch rated 1200A or larger, such as the High Pressure Contact (HPC) power switch by GE, which offers optional control relay able to provide ground fault protection and instantaneous protection, or the RELT function, which meets the energy-reducing maintenance switch requirements.

Shown in figure - 1, the time-current curve (TCC) for a 1200A class L fuse in a system with 15kA-18.25kA (85%-100%) arcing current ($I_a$) and a RELT function implemented with a 1200A GE HPC power switch set at 4X the switch rating, 4800A. The arcing current crosses the fuse time-current curve at 0.07 seconds as required per the 2017 NEC 240.67. However, notice that the RELT function provides better protection in at least two ways. First, the pickup is much more sensitive than that at which the fuse curve clears in 0.07 seconds. Second, the clearing time is 0.05 for a three-phase bolted fault at 600V rather than 0.07 seconds, providing for at least 40% less incident energy per the published curve and the IEEE 1584 model equations. However; let us examine the fuse versus energy-reducing maintenance switch comparison a little further.

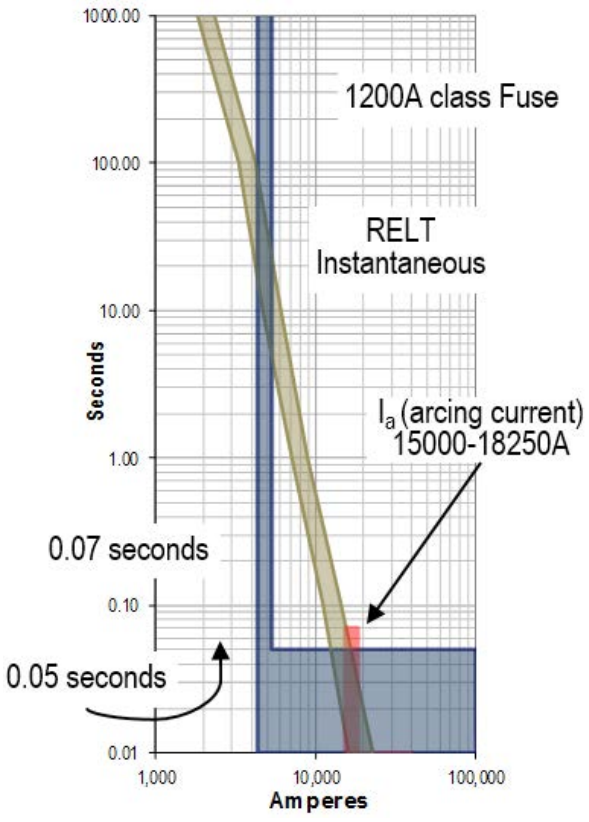


Figure - 1: 1200A class L fuse shown with GE HPC RELT instantaneous set at 4800A with 15kA-18kA arcing current.

IEEE 1584-2002 has two models that could be used with fuses. The first model may be used with any time-current curve[5], and the second model provides the fuse equation that could be used as an alternative[6]. The fuse equations are usually based on tests at 600V and for a working distance of 455mm (18 inches) with an unidentified arcing gap and the available bolted fault current ($I_{bf}$) as a single independent variable.

The scenario in figure - 2 shows the incident energy in calories per square centimeter, calculated for the formulas created with 600V. Data are transposed to 480V and 208V applications by adjusting the formulas 5/4 and 5/2, respectively, to account for the expected lower arcing current at each driving voltage. The main driver of fuse performance is the prospective bolted fault current, which is also the arcing current for an arcing fault. Conservative multipliers for arc current for mid-range bolted fault currents could be 20% for 208V, 40% for 480V and 50% for 600V. In other words, everything else being equal, to get an equivalent fuse performance at 208V the prospective bolted fault current would need to be more than twice as high as it would need to be at 600V.

A cursory inspection of figure - 2 shows that at 208V, even the 1200A fuse requires very high bolted fault current to operate quickly. Even 480V applications would seem to require $I_{bf}$ = 40kA or higher to achieve low levels of incident energy. At 600V, rarely used in the US but common in Canada, the 1200A fuse seems to be driving incident energy to a low level at 30kA or higher.

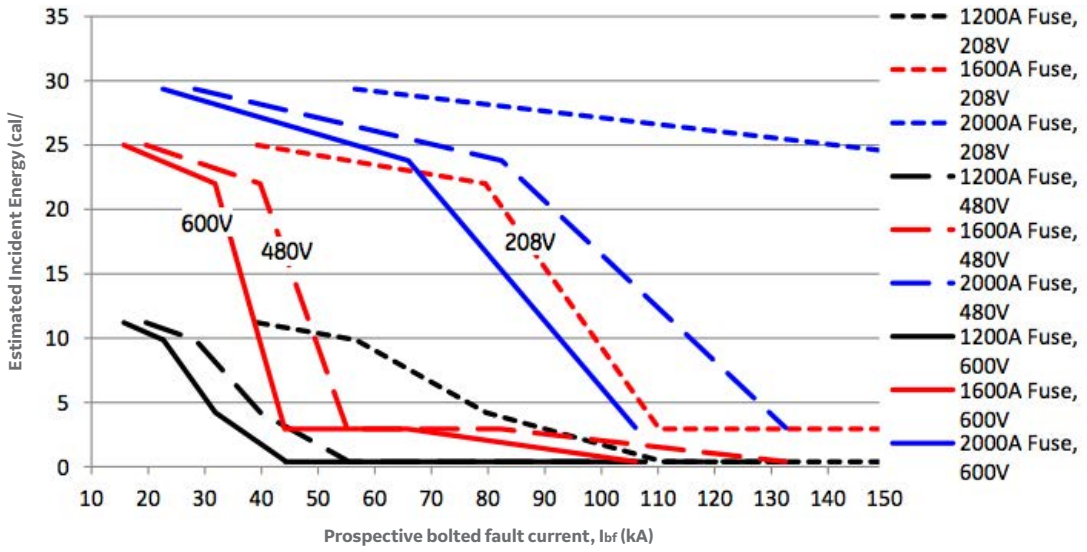


Figure - 2: Plot of IEEE 1584 fuse equations at 600V. Transposed for 480V and 208V arcing current.

## Complexity: A Simple Solution That Always Works

The concept behind the RELT function is not complex. In addition to the circuit breaker's normal protection functions, there is a second instantaneous protection function with a dedicated threshold and algorithm optimized for speed and sensitivity. The user sets the threshold as needed, enables the function when required, and simply disables it when not required. Enabling or disabling the RELT function within any GE circuit breaker trip unit does not turn off or alter any other function; it enables or disables the faster instantaneous protection as seen in figure - 1. In every system, it should be possible to adjust this protection to be sensitive enough to meet the letter and intent of the code, regardless of the system's electrical parameters.

The RELT function itself may be simple to understand, but there are other considerations for employing this method of protection, such as:

1. What kind of control to use?
2. How to verify it's working?
3. Where to put the control?
4. How to ensure it's not forgotten in the "ON" position?
5. How to set the threshold settings?

There are three types of controls: automatic, mechanical, or from an HMI. The RELT function can be used with all three types. Regardless of which type of control, it is important the user sees affirmatively that the control signal has been received by the trip unit and is processed appropriately so that the protection is enabled. The RELT function may be wired to receive a 24V signal initiated by a switch or contact closure. When the trip unit receives the signal to enable the RELT protection, it then provides a contact closure for external use to indicate the signal has been received and processed by the CPU in the trip unit. In addition, the standard control provided by GE is a three-position switch, figure - 3, that allows the user to test the control power circuit prior to enabling the RELT protection.

It is important for the user to understand that when the switch is enabled and then illuminates “blue”, this notification is not simply an indication that the switch was activated. More importantly, it indicates that the circuit breaker trip unit or switch relay received the signal that the 24V power supply was activated, and the trip unit has responded with a contact closure to indicate activation. Figure - 4 is a simplified schematic for the wiring of the RELT hard wired signal into a trip unit.


Figure - 3: Three-position lockable RELT control switch with built-in indicating light.

## OUTLINE DRAWING

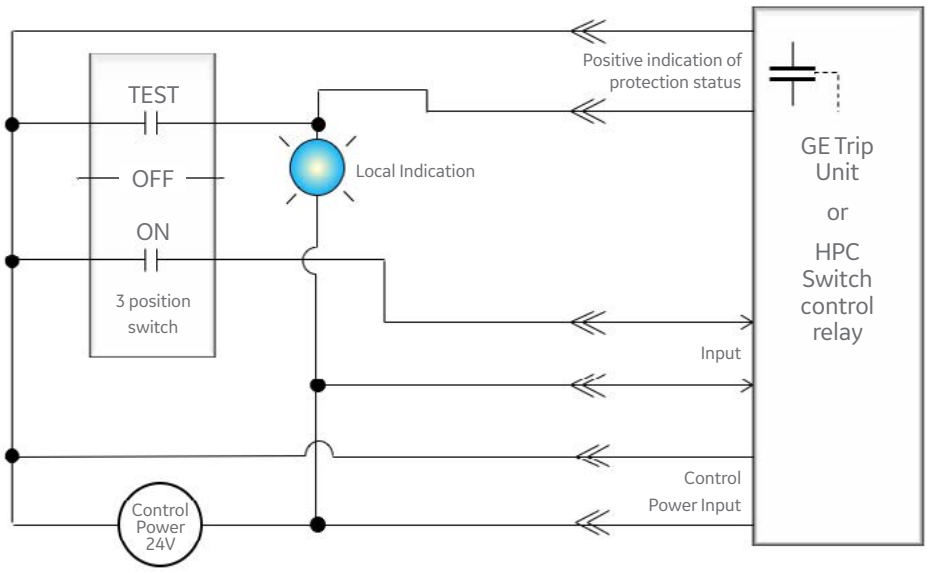


Figure - 4: RELT control circuit showing switch and blue indicating light.

The control switch for the energy-reducing maintenance switch should be able to be locked and tagged when in the enabled position so operation and maintenance personnel can maintain control of the protection status as required in standard safe work practices.

The indicating light should provide very clear and easy to understand indication of the status. A user or OEM could substitute their own control device if desired. The RELT switch provides the ability to padlock the switch cover.

The RELT control also provides an additional function not included in other energy-reducing maintenance switches. In trip units, and in the GE HPC control relay, when the RELT switch is turned off, there is a 15-second delay before the function reverts to normal protection. This extra time allows the operator, who may be wearing less PPE due to the improved protection provided by the RELT function, to step away before the RELT protection is deactivated and more PPE is needed.

The RELT function may also be enabled via an HMI or serial communications using the Modbus communication capabilities of the various circuit breaker trip units and switch control relays. The RELT function may be activated via the hardwired control or the serial communications, but both must command the RELT function OFF before it turns ON.

A common question is, how should the threshold for the RELT function be determined? The main consideration is that the threshold be lower than the expected arcing current. However, the lower the threshold, the more robust or reliable the operation. The IEEE model for arcing current does not include sources of variance that may exist in a real-world situation, so using a lower setting is more reliable from a protection perspective. If the setting is high enough to allow normal current transients that may occur while the RELT function is enabled, and simultaneously well below the calculated 85% arcing current, it is likely a good setting. Figure - 5 through figure - 7 show the scenarios with and without RELT functions activated.

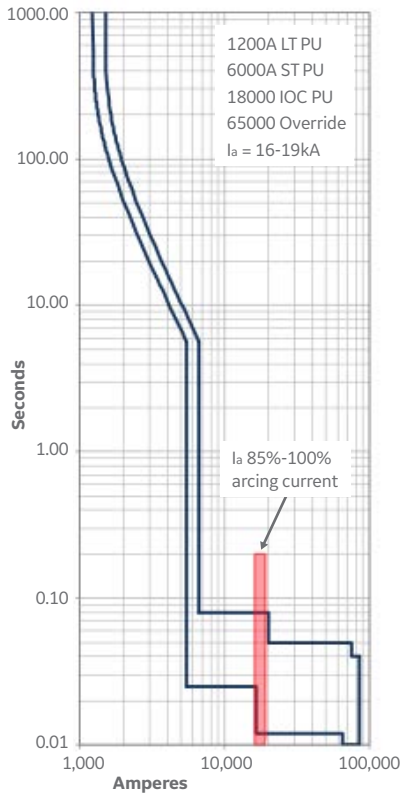


Figure - 5: Circuit breaker without RELT function and arcing current at ~16kA-19kA.

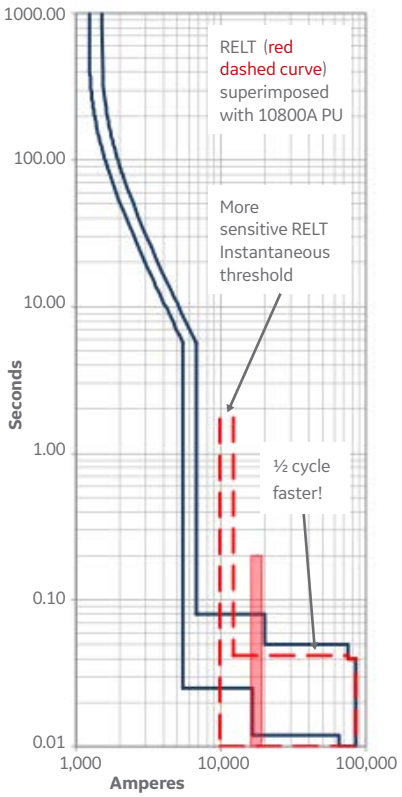


Figure - 6: Circuit breaker with RELT function added with at threshold well below the estimated arcing current and a clearing time of 42 milliseconds at estimated arcing current level.

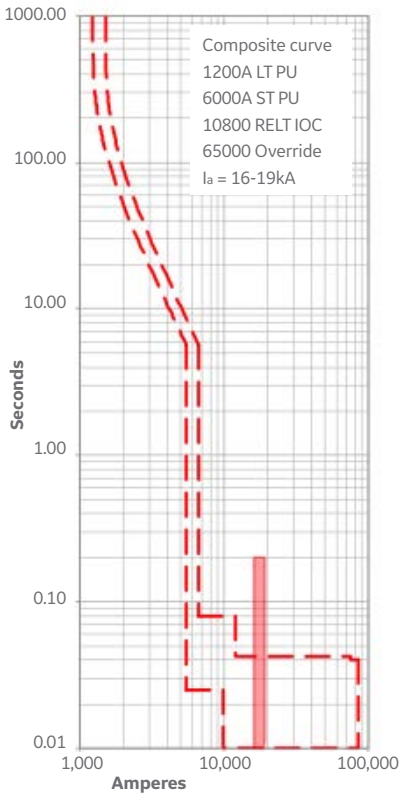


Figure - 7: Net composite curve of circuit breaker with fast RELT instantaneous protection well below extimated arcing current.

A concern for many users is forgetting an energy-reducing maintenance switch is enabled after it is no longer needed, thereby compromising system reliability. It is not unusual to connect the trip unit feedback signal to an audible alarm or light tower to provide more obvious indication of protection status. Some systems connected to a SCADA or Power Management System (PMS) may issue emails to supervisory personnel to communicate that a maintenance switch has been enabled for a certain number of hours.

When a device is furnished with RELT in GE equipment, the default mountings are:

- Switchgear (UL 1558): the three-position switch is illuminated for feedback and mounted in the instrument tray above each circuit breaker cubicle.
- Group mounted switchboards (UL891): the three-position switches will be mounted in a blank panel adjacent to the device furnished with the RELT function.

Both GE default locations meet the code requirements for local indication if local is interpreted as local to the circuit breaker or switch being controlled. But a user may want an indication closer to protected equipment, which may be in another room or some distance away. Remote switch or indication is possible, but considerations should be made when the distance from the switch to the device is significant, as an interposing relay may be required.

2017 NEC 240.87 and 240.67 require that the energy-reducing maintenance switch be mounted locally. The question then becomes, does it need to be local to the over current protection device (OCPD) being controlled, or local to the circuit or equipment being protected? It may be wise to check with the relevant AHJ to understand how they interpret the code requirement. Normally, a single switch is provided for each device requiring the RELT functionality. Therefore, a single device can be put into the RELT mode for work to be performed downstream of that device. However, some applications call for multiple overcurrent devices to be put into RELT mode simultaneously. That logic can be implemented with the use of interposing relays among other means.

It is imperative that the operator understand what is occurring when a RELT switch is activated. What device, circuit or end-use equipment is being affected by the change in protection? Appropriate signage, training, and task planning are required for optimal use of this functionality.

## Maintainability: An Easy-to-Maintain Solution

The RELT function is a trip unit capability with simple control. Proper operation can be verified during routine maintenance intervals for the equipment and circuit breakers requiring no special test equipment or skill. At any time, the control power circuit can be checked without affecting the operation of the circuit breaker.

## Cost: A Cost-Effective Solution

The three-position switch used with the RELT function is available with all advanced circuit breaker trip units and the HPC power switch control relay. It is a cost-effective solution that can also be installed in the field for equipment requiring an update to the latest National Electric Code revision.

## What Should the Arc Flash Label State?

Any equipment with an arc flash label received that label based on an arc flash study that should be available to the operation and maintenance personnel. The qualified personnel can determine the answers to the questions from information in that study. However, in some cases, the operation or maintenance personnel may have no more information than what is provided by the label on the equipment. In this case, consideration should be made to how the label can be interpreted. It is advisable to provide additional information on the equipment that can assist in properly evaluating the hazard presented.

There is some controversy in the industry as to whether a label should reflect the lower level of incident energy calculated when a maintenance switch is enabled. In some cases, two labels may be provided. If two labels are provided, or two values are provided on a single label, it should be clear to the reader to what situation each label applies and to what portion of the equipment.

In some cases, there may be a desire to apply one level of incident energy in one section and a different level in another section due to the protection provided by a local overcurrent protection device. That may be acceptable if there are barriers or other measures taken to ensure that the hazard presented by one section is sufficiently isolated from the hazard presented in the other section. However, there are currently no industry standards defining what barriers to implement, how to test them or how to qualify their performance.

## Arc Flash Protection Versus Selective Coordination: Don't Compromise

When a device is put into an arc reduction or RELT mode, the system coordination may be compromised. The fundamental concept of taking a reductive action is to ensure the circuit breaker or relay for the fuse switch opens in the possible arc fault current range. If the device can be set to clear instantaneously within the estimated arc fault current range continuously, while achieving the desired level of coordination, it should be set to that range. If traditional low voltage selectivity methods are being used, it is possible that achieving instantaneous protection at arcing current level might become difficult. However, if using GE ArcWatch* technology, it may be possible to achieve instantaneous protection at arcing current levels and selectivity simultaneously; even then, the RELT function still allows faster and more sensitive protection, which can help provide a greater margin of safety for the operation or maintenance personnel.

## Summary

An energy-reducing maintenance switch is part of an administrative procedure, but it provides robust protection due to the ability to set the protection at sensitive, low thresholds. An energy-reducing maintenance switch can also be used simultaneously with other hazard control methods. The RELT function is a simple way to ensure that any individual doing work on energized equipment can obtain the best protection the circuit breaker or switch can provide when needed and, in a cost-effective way, comply with 2017 NEC 240.87 and 240.67. The function is simple to understand and operate, and it fulfills the code sections where required.

For further reading, please see publication DET760D - GE Guide to Selectivity, or ask your GE representative about GE's ArcWatch technology.

## GE RELT Operating Characteristics

| CIRCUIT BREAKER, TRIP OR SWITCH TYPE | ADJUSTABILITY RANGE | CLEARING TIME | MODBUS CONTROL AVAILABLE | 24V CONTROL AVAILABLE | 15 SEC. DELAY ON OFF |
|---|---|---|---|---|---|
| EntelliGuard Low Voltage Power Circuit Breakers | 1.5-15X | 42ms | Yes | Yes | Yes |
| EntelliGuard Insulated Case Circuit Breakers | 1.5-15X | 42ms | Yes | Yes | Yes |
| PowerBreak II Insulated Case Circuit Breakers | 1.5-10X | 50ms | Yes | Yes | Yes |
| Spectra G MCCB | 1.5-10X | 25ms | Yes | Yes | Yes |
| Spectra K MCCB | 1.5-10X | 30ms | Yes | Yes | Yes |
| GuardEon E Frame MCCB | 1.5-10X | 25ms | Yes | Yes | Yes |
| GuardEon G Frame MCCB | 1.5-10X | 25ms | Yes | Yes | Yes |
| Low Voltage Power Circuit Breaker Trip Upgrades Kits | 1.5-10X | 50ms | Yes | Yes | Yes |
| UL 977 Power Switch, HPC II | 1.5-10X | 50ms | Yes | Yes | Yes |

Note: RELT instantaneous clears 1/2 cycle faster than the device's normal adjustable selective instantaneous function.

# Notes

## For more information please see the following recommended GE and IEEE publications:

**GE and IEEE publications on related subjects:**

- DET-760D – Guide to Instantaneous Selectivity
- DET -1002 – 2017 National Electric Code Updates, 240.87 Arc Energy Reduction for Circuit Breakers and 240.67 Arc Energy Reduction forFusible Switches
- Valdes, M.E.; Hansen, S.; Sutherland, P.; Optimized Instantaneous Protection Settings: Improving Selectivity and Arc-Flash Protection; Industry Applications Magazine, IEEE, Vol 18, Issue 3, Pgs. 66-73, yr. 2012
- Valdes, M.E.; Dougherty, J.J.; Advances in Protective Device Interlocking for Improved Protection and Selectivity; Industry Applications, IEEE Transactions on; Vol 50, Issue 3, Pgs. 1639-1648, yr. 2014

For additional product data see:
www.geindustrial.com/arcwatch
www.geindustrial.com/arcflash
www.geindustrial.com/lv-circuit-breaker-line

GE
4200 Wildwood Parkway
Atlanta, GA. 30339 USA
www.geindustrial.com

**Citations**

[1]Article 110.1(G), pg. 70E-16 ; NFPA 70E-2015, Standard for Electrical Safety in the Workplace; 2015 Edition; National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471

[2]Section 5.1.2, pg. 15, ANSI/AHA Z10-2012, Occupational Health and Safety Management Systems; 2012 Edition; By the ANSI/AIHA Z10 Committee; A publication of the American Industrial Hygiene Association; 3131 Fairview Park Drive, Suite 777, Falls Church, Virginia 22042

[3]NFPA 70-2017; National Electrical Code; 2017 Edition; National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471

[4]In the 2014 code the function was only mentioned in 240.87. Article 240.67, covering fuse protected circuits, was added in its entirety to the 2017 code for the first time

[5]IEEE 1584. IEEE Guide for Performing Arc-Flash Calculations, sect. 5 through 5.5, pgs. 10-12

[6]Ibid, sect. 5.6, pg. 13



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