S&C Fault Fiter® Electronic Power Fuses

Indoor Distribution 4.16 kV through 25 kV

- *Continuous current ratings to 1200 A*
- *Interrupting ratings to 40,000 A RMS symmetrical*
- *Three families of TCCs for every coordination need*

Descriptive Bulletin 441-30
April 30, 2007
Supersedes Descriptive Bulletin 441-30 dated 3-31-03

GENERAL

S&C Fault Fiter Electronic Power Fuses represent a major advancement in circuit-interruption technology through integration of state-of-the-art electronics with an advanced-design high-current fuse. The electronic componentry provides current-sensing, time-current characteristics (TCCs), and control power for the fuse. Unsurpassed high-speed interruption of fault currents to 40,000 amperes RMS symmetrical is provided by the high-current fuse section. These advanced-design electronic fuses are available in S&C Metal-Enclosed Switchgear, S&C Pad-Mounted Gear, and S&C Metal-Enclosed Fuses, and are offered with continuous current ratings to 1200 amperes. S&C Fault Fiter Electronic Power Fuses fit in the same space as conventional solid-material power fuses or current-limiting fuses and are completely self-contained, so they don't require remote relaying or an external source of control power.

S&C Fault Fiter Electronic Power Fuses are offered in two mounting styles; Disconnect, and Disconnect with Uni-Rupter®. The Disconnect Style Mounting is rated 600 or 1200 amperes continuous and is available in voltage ratings of 4.16 kV through 25 kV. The Disconnect with Uni-Rupter Style Mounting is available in voltage ratings of 13.8 kV and 25 kV, and provides 400-ampere or 200-ampere continuous and single-pole live-switching ratings for single-phase and three-phase circuits at 13.8 kV and 25 kV, respectively.

APPLICATION

S&C Fault Fiter Electronic Power Fuses are available with a selection of *electronically derived* TCCs, providing unique performance characteristics ideally suited for a wide variety of applications—including many for which no fully satisfactory protective device has been previously available. As shown in Figure 1, time-current characteristics are offered in three types: inverse, time-delayed compound, and underground subloop.

Inverse-curve-type TCCs are ideal for service-entrance and feeder protection in industrial, commercial, institutional, and utility substations. See Figure 2. Time-delayed compound-curve-type TCCs are specially designed for primary-side protection of larger-size transformers—and include the unique shape required to coordinate with secondary-side protective-device operating characteristics. Underground-subloop-curve-type TCCs are expressly designed for application in pad-mounted gear to provide protection for load-side cables and elbow connectors, as well as current-limiting backup protection for transformers with "weak-link" fuses. Families of curves within each type of TCC permit selection of the best Fault Fiter for each application.

Here are some examples of the superior protection and coordination provided by Fault Fiter in key applications.

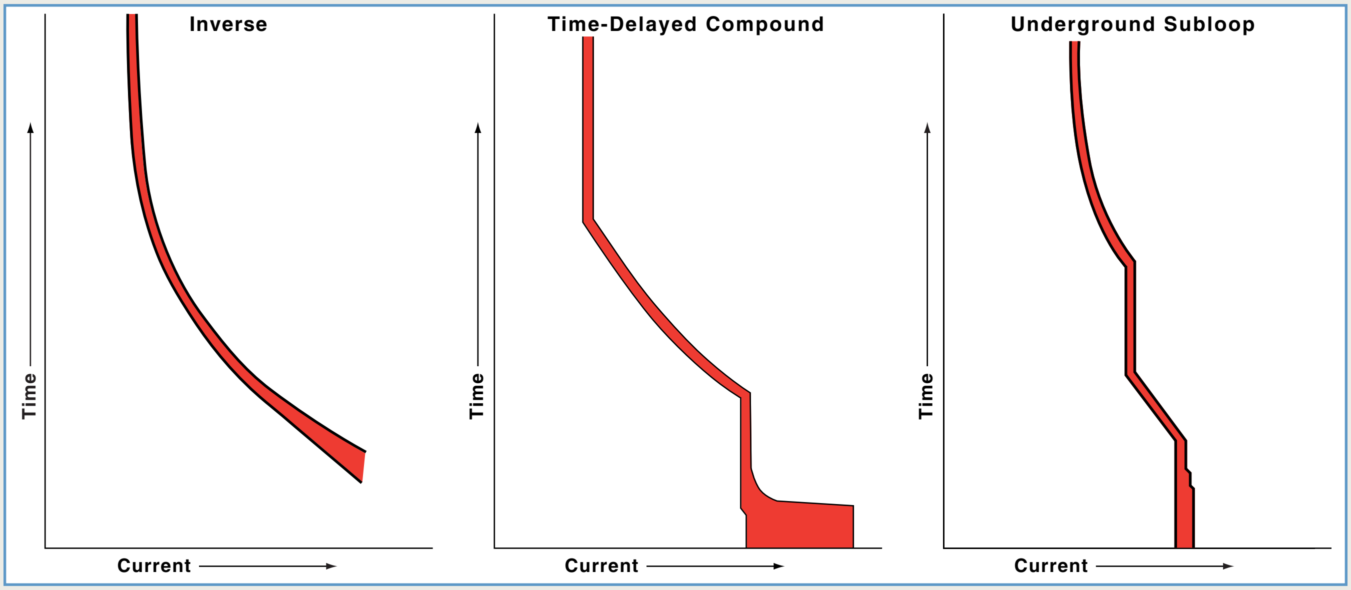


Figure 1. S&C Fault Fiter Electronic Power Fuse time-current characteristic curves.

Service-Entrance Protection and Coordination

S&C Fault Fiter Electronic Power Fuses equipped with inverse-curve-type TCCs are ideally suited for service-entrance protection. They provide superior coordination with source-side overcurrent relays and in-plant load-side feeder fuses. Fault Fiter provides an important "buffer" to prevent in-plant problems on the *customer's* system from affecting service on the utility system. Fault Fiter also provides unsurpassed protection for the switchgear bus against damage from high-current bus faults, as well as *backup protection* for the load-side feeder fuses. The unique capabilities provided by Fault Fiter make it a superior alternative to traditional protection schemes involving conventional power fuses or circuit breakers.

Fault Fiter is a better choice than conventional power fuses because its 600- or 1200-ampere continuous-current ratings and 40,000 ampere RMS symmetrical interrupting rating are especially well suited to the heavier duties of service-entrance applications. And Fault Fiter Electronic Power Fuses equipped with inverse-curve-type TCCs provide substantially better coordination with load-side feeder fuses. As shown in Figure 3, power fuses can sometimes be difficult to coordinate for high-current faults. But with the unique shape of its inverse-curve-type TCC, Fault Fiter can be coordinated with a broad selection of load-side power fuses over the full range of available fault currents. See Figure 4 on page 4.

Fault Fiter Electronic Power Fuses equipped with inverse-curve-type TCCs are also a better choice than circuit breakers. In the past, circuit breakers have been applied for service-entrance protection to provide the higher continuous-current capability required to serve multiple in-plant feeders. But, circuit breakers are costly and often difficult or impossible to coordinate with the serving utility's overcurrent relays. A principal difficulty encountered in circuit breaker-to-circuit breaker coordination results from the adjustments which must be made to published relay curves to allow for overtravel and tolerances in relay response characteristics, plus fault-interrupting time for the load-side circuit breaker. These adjustments create a coordinating time interval (CTI) that can result in extensive miscoordination between the serving utility and in-plant circuit breakers.

With Fault Fiter, the CTI is substantially reduced because Fault Fiter's total clearing time is defined by its total-clearing TCC and—unlike relay operating characteristic curves—requires no adjustment to reflect operating time. As a consequence, Fault Fiter can be readily coordinated with the serving utility's overcurrent relays while still maintaining complete coordination with load-side feeder fuses. See Figure 4 on page 4. As such, Fault Fiter is the first economically practical protective device to simultaneously satisfy the continuous-current, fault-interrupting, and source- and load-side coordination requirements of this application,

Figure 2. Typical installation of S&C Metal-Enclosed Switchgear with Fault Fiter Electronic Power Fuses.

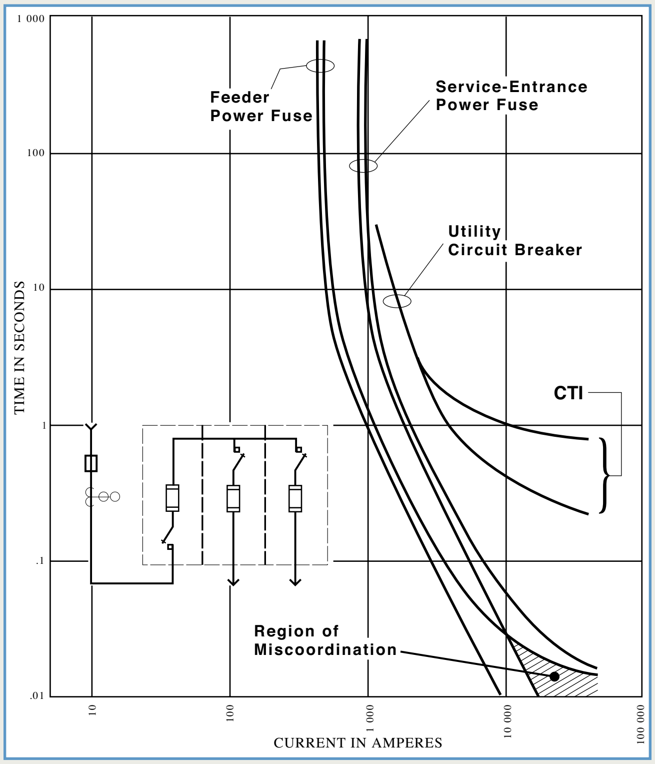


Figure 3. Miscoordination of service-entrance power fuse and feeder fuse for high-current faults.

APPLICATION—Continued

thereby meeting today's demand for maximum protection with minimum interruption of service. Refer to S&C Information Bulletin 441-450 for additional details.

Feeder Protection

Fault Fiter Electronic Power Fuses with inverse-curve TCCs are also well suited for protection of in-plant feeders involving relatively high continuous load currents—such as are common on circuits feeding multiple downstream transformers. Fault Fiter has the high continuous current rating to handle such loads, and a selection of inverse-curve-type TCCs that can be coordinated with a broad selection of load-side transformer fuses. In addition, feeder protection provided by Fault Fiter can readily be coordinated with service-entrance protection, as illustrated in Figure 5. Refer to S&C Information Bulletin 441-460 for additional details.

Transformer Protection

Primary-side transformer protection has traditionally been difficult to address due to conflicting protection and coordination criteria: the primary-side protective device is required to operate as quickly as possible in the event of a transformer fault but still coordinate with secondary-side protective equipment such as main-secondary circuit breakers. Fault Fiter's time-delayed compound-curve-type TCCs provide specialized features designed especially for coordination with secondary-side equipment and superior protection of larger-size transformers installed in high-load industrial, commercial, and institutional applications. As shown in Figure 6, the unique shape of the time-delayed compound-curve-type TCC provides maximum protection for the transformer in accordance with the through-fault protection curve and, at the same time, maintains coordination with the main-secondary circuit breaker. Refer to S&C Information Bulletin 441-470 for additional details.

Undergrounded-Subloop Protection

Pad-mounted transformers installed on underground-distribution systems usually incorporate "weak-link" fuses for protection against internal faults. Because of the limited interrupting capability of such fuses, and concern for the momentary and fault-closing capabilities of the elbow connectors typically used on underground loops, transformers on systems with higher fault currents are sometimes equipped with expensive internal backup current-limiting fuses. S&C Fault Fiter Electronic Power Fuses installed in pad-mounted gear feeding the loop, and equipped with the underground-

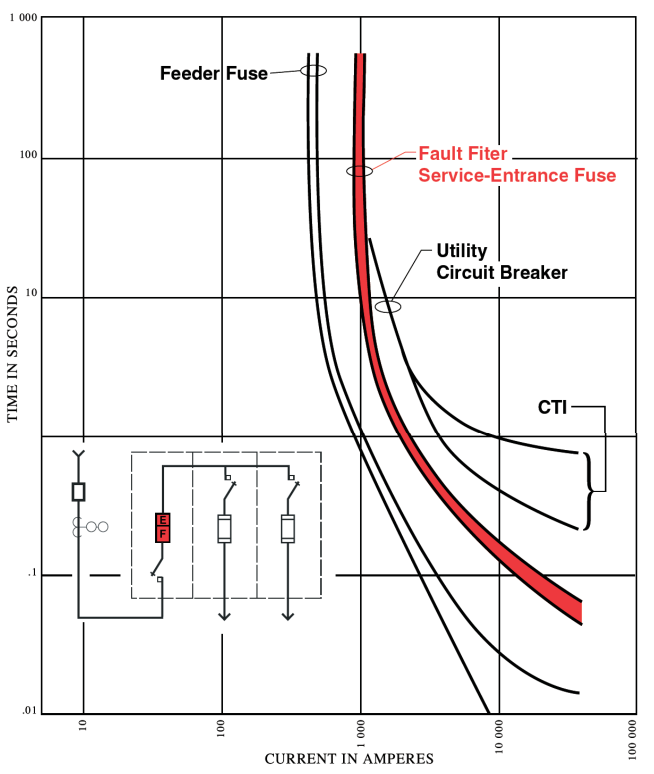


Figure 4. S&C Fault Fiter with inverse-curve-type TCC applied for service-entrance protection and coordination.

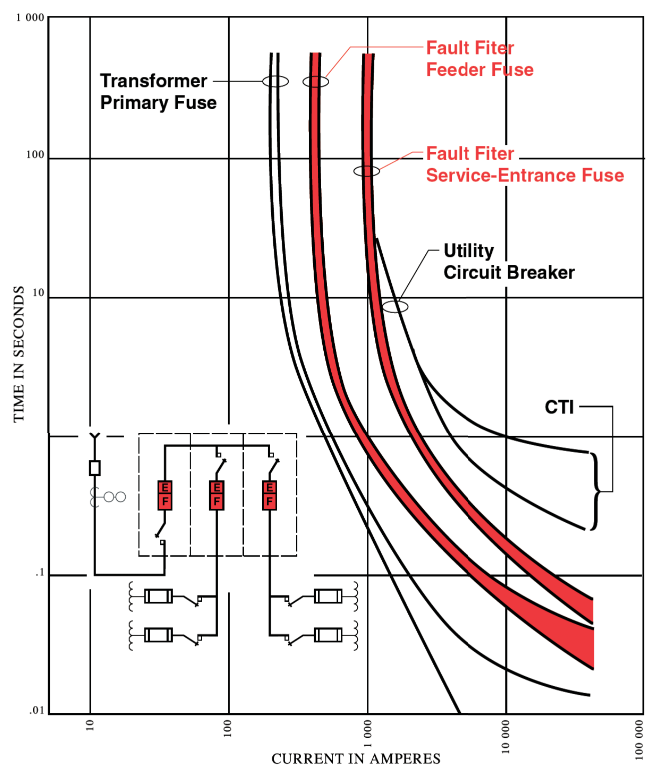


Figure 5. S&C Fault Fiter with inverse-curve-type TCC applied for in-plant feeder protection.

subloop-curve-type TCC, provide a much more effective and economical solution. Fault Fiter provides current-limiting protection for individual transformers feeding the loop (without any need for backup current-limiting fuses installed in the transformer), *plus* unsurpassed backup protection for elbow connectors—whether the fault is inside the transformer or on the downstream cable. And, as shown in Figure 7, Fault Fiter also provides complete protection for the load-side cable in accordance with the cable short-circuit characteristic curve.

The underground-subloop-curve-type TCC coordinates with weak-link fuses and accommodates the continuous current and the inrush current associated with energizing the entire loop. Refer to S&C Information Bulletin 441-480 for additional details.

Many other applications can be addressed using Fault Fiter's unique capabilities. Contact your local S&C Sales Office for details

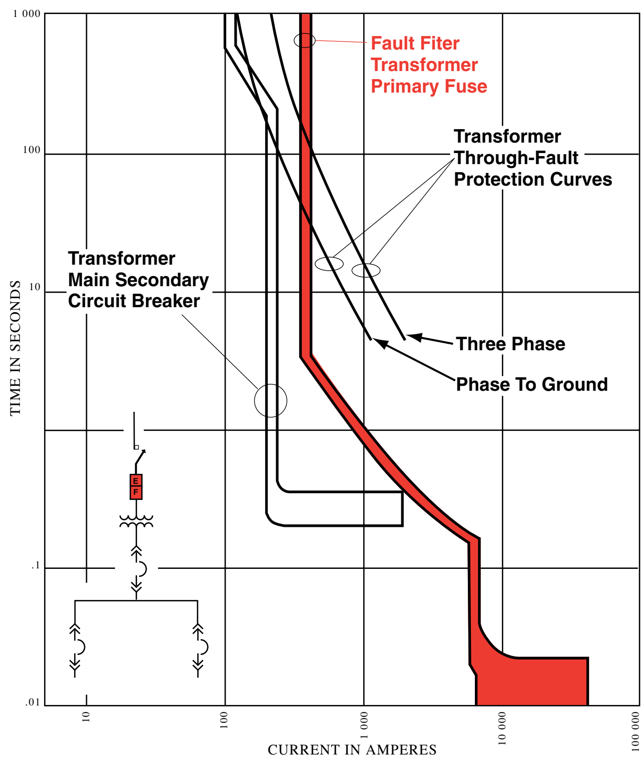


Figure 6. S&C Fault Fiter with time-delayed compound-curve-type TCC applied for transformer protection.

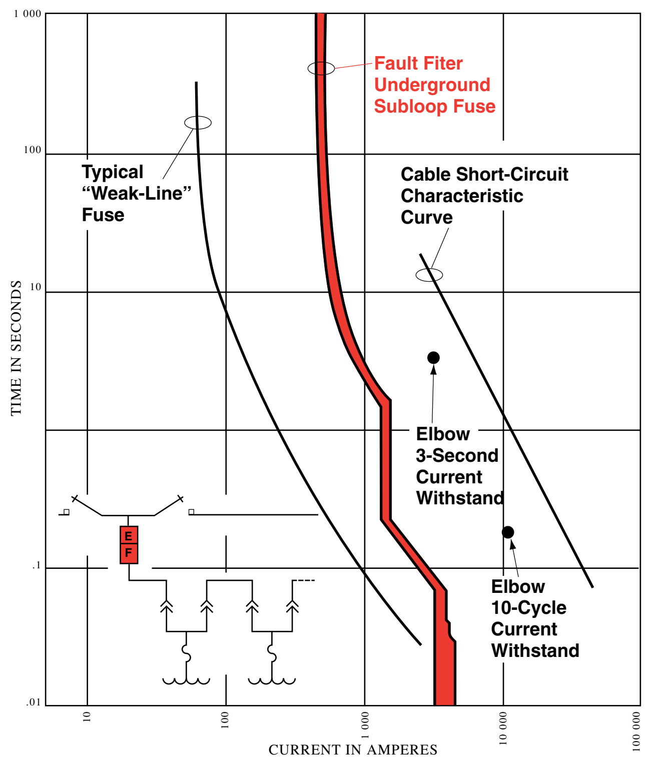


Figure 7. S&C Fault Fiter with underground-subloop-curve-type TCC applied for backup protection of elbow connectors and "weak-link" transformers.

S&C Fault Fiter Electronic Power Fuses

. . . In S&C Metal-Enclosed Switchgear

. . . In S&C Pad-Mounted Gear

. . . In S&C Metal-Enclosed Fuses

CONSTRUCTION

S&C Fault Fiter Electronic Power Fuses consist of four components: mounting, holder, control module, and interrupting module. See Figure 8. The mounting incorporates heavy-duty construction to provide sure guidance for the holder during opening and closing operations, and to resist the substantial magnetic forces resulting from high-current faults. The control module provides the current sensing and time-current characteristics for the fuse, as well as the energy to initiate operation of the interrupting module in the event of a fault. The interrupting module carries load current continuously and operates to interrupt a fault after receiving a trip signal from the control module. Following a fault-clearing operation, the interrupting module is replaced. The control module is unaffected by the fuse operation and is reused.

The Control Module

The S&C Fault Fiter Control Module employs one or more integral toroidal current transformers (CTs) which provide line-current sensing and control power for the electronic circuitry. See Figure 9. The CTs also provide the energy to operate the interrupting module in the event of a fault. Electrical output from the CTs is processed by the electronics located inside the factory-sealed cast-aluminum control-module housing, which serves both as a path for continuous current and as a Faraday cage to shield the sensing circuits against interference from external electric fields. When a fault occurs, the electronics within the control module initiate a "trip" signal in accordance with its electronically derived time-current characteristics. The signal to "trip" is delivered to the interrupting module through a low-resistance gold-plated contact.

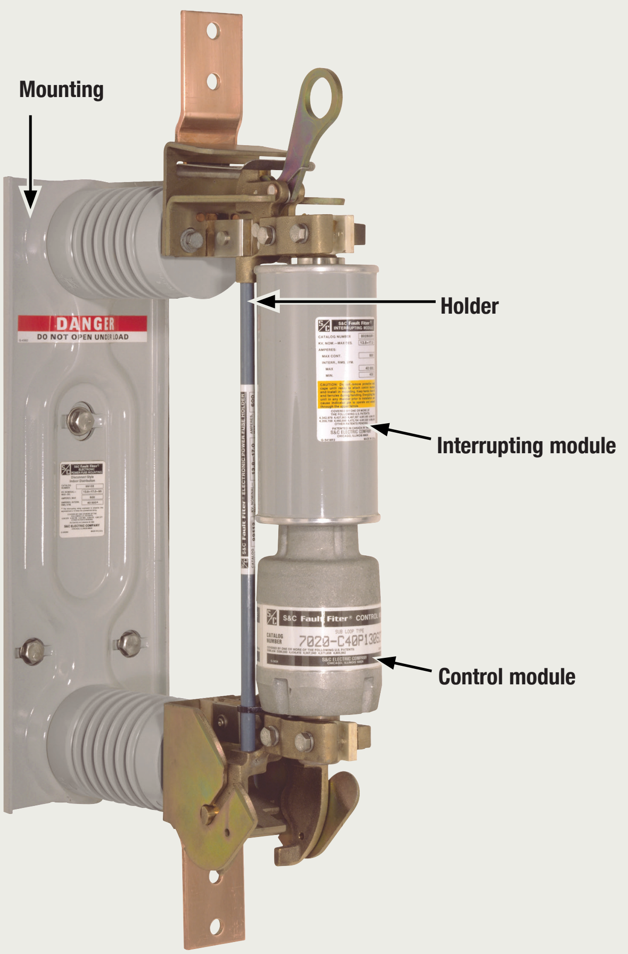


Figure 8. S&C Fault Fiter Electronic Power Fuse (600-ampere Disconnect Style Mounting shown).

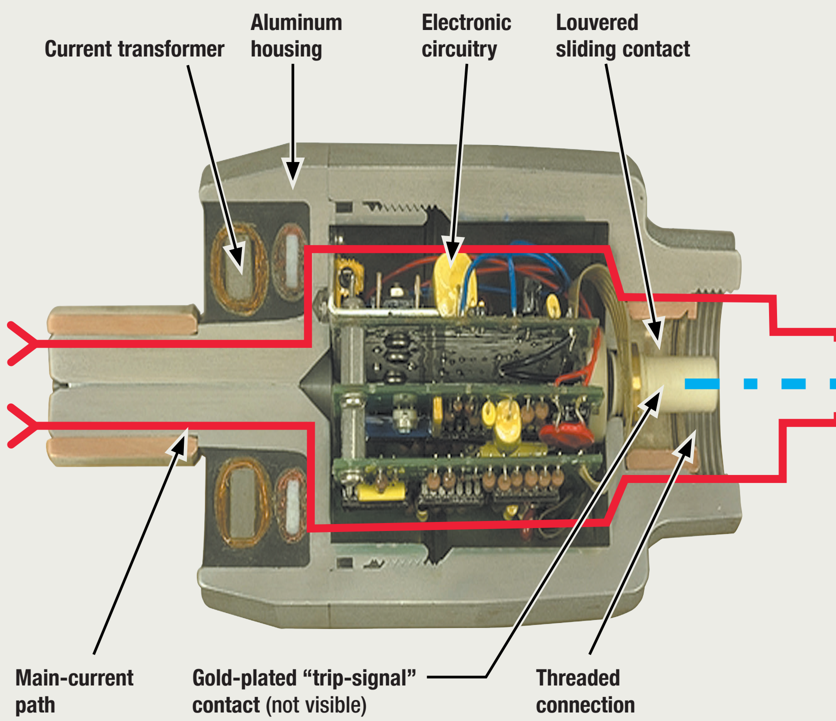


Figure 9. Cross-sectional view of control module.

The interrupting module and control module are mechanically attached to one another by means of a threaded connection. Trouble-free, operator-independent electrical connection of the control module and the interrupting module is assured by means of a louvered ring-type sliding contact of the type widely used in circuit breakers and elbow connectors. Complete electrical coupling is automatically achieved when the two modules are joined at the threaded connection.

The Interrupting Module

The S&C Fault Fiter Interrupting Module includes a specially designed main-current section centrally positioned within the interrupting module. See Figure 10. The main-current section carries load current under normal operating conditions and is rapidly opened—in the event of a fault—by the action of a gas-generating power cartridge and associated insulating piston. After the main-current section is opened, fault current is shunted into the circuit-interrupting section and the coaxially wound fusible elements.

The circuit-interrupting section—which is electrically in parallel with the main-current section—consists of helically wound copper-ribbon fusible elements embedded in highly refined silica sand. Unlike conventional power fuses or current-limiting fuses, the fusible elements in the Fault Fiter Interrupting Module do not carry load current and do not determine the time-current characteristics of the fuse (TCCs are provided by the control module). Consequently, the S&C Fault Fiter Electronic Power Fuse is not subject to the protection vagaries that can be introduced to conventional current-limiting fuses, for example, when the current-limiting fusible elements are subjected to load cycling or repeated current surges that may alter the time-current characteristics of the element. In addition, Fault Fiter's fusible-element design has been optimized through the use of special, patented features (related to the current-carrying cross-section of the element) that provide unmatched high-speed circuit-interrupting performance without producing voltage surges that could damage surge arresters, transformers, or other equipment.

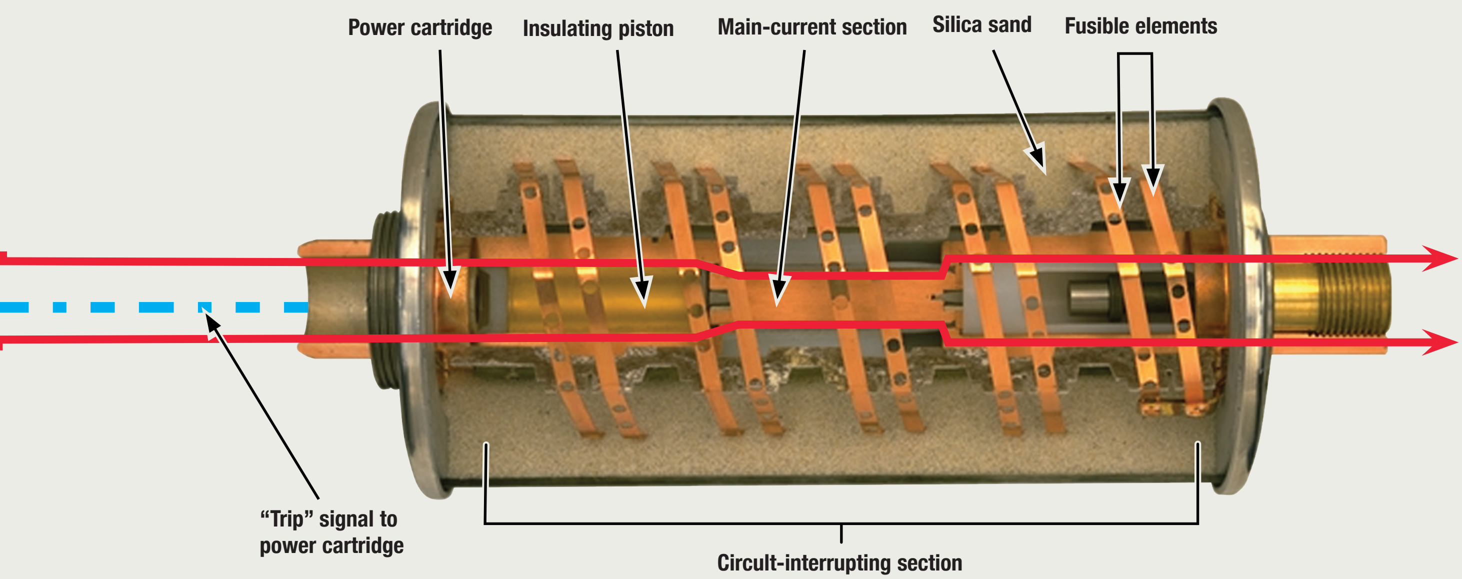


Figure 10. Cross-sectional view of interrupting module.

OPERATION

Modes of Operation

There are two fundamental modes of operation for Fault Fiter Electronic Power Fuses: the inverse-time mode, and the instantaneous mode that provides current-limiting protection for system equipment and conductors.

The inverse-time mode is employed in the inverse- and time-delayed compound-curve time-current characteristics, illustrated on page 2. This operating mode incorporates special electronic counters to provide the appropriate delayed response dependent upon fault-current magnitude. An advantage of electronically derived TCCs over conventional power fuse TCCs is the flexibility to tailor the TCC to meet the special coordination requirements of specific applications.

The instantaneous mode employed in the underground-subloop time-current characteristic (illustrated on page 2) is designed to provide "instantaneous" response whenever the *rate-of-rise* of line current exceeds a threshold value determined by electronics within the control module. The rate-of-rise criterion permits Fault Fiter to respond to prospective faults more quickly than conventional current-limiting fuses—and before the current magnitude reaches even a small fraction of the prospective peak current.

In addition to early response made possible by rate-of-rise current sensing, Fault Fiter's energy-limiting performance in the instantaneous mode is further enhanced by the unique, specialized fusible elements included in the Fault Fiter Interrupting Module. Fault Fiter fusible elements do not carry load current and, as a consequence, have been optimally sized *to minimize energy let-through to the fault*. The energy let-through characteristics of Fault Fiter's fusible elements, moreover, are unaffected by load current. Current-limiting fuses, in contrast, exhibit increasing let-through i^2t characteristics as the fuse ampere rating increases.

S&C Fault Fiter Electronic Power Fuses with underground-subloop time-current characteristics respond more quickly to high-current faults than conventional current-limiting fuses, and promote more efficient current-limiting action due to the special performance characteristics of the interrupting module. A step-by-step operating sequence for the Fault Fiter Interrupting Module is illustrated on the following page.

A. Fault Detection
Electronic circuitry inside the control module responds to fault current and sends a pulse of energy (derived from the fault current) to activate the power cartridge in the interrupting module.

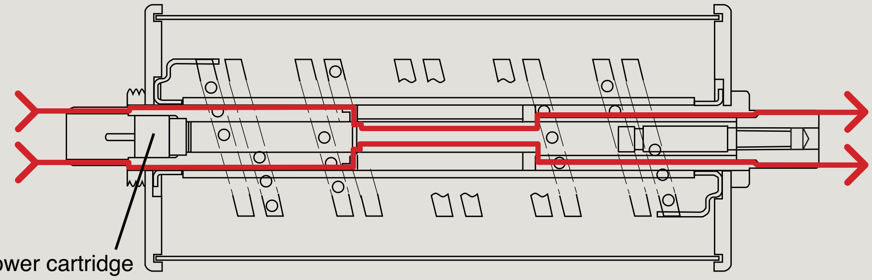
B. Current Transfer
The power cartridge drives an insulating piston which severs the main-current path at the points shown. The resultant arcing at these points is quickly extinguished by the ablative action of the arc-extinguishing materials of the piston and liner. Current is transferred from the axial main-current path to the circuit-interrupting fusible elements within 480 microseconds of fault initiation.

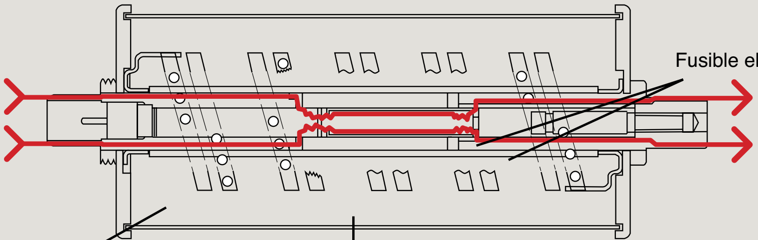
C. Fusible-Element Melting
The fusible elements simultaneously melt in multiple locations, creating multiple series arcs that promote an initial rapid increase in arc voltage. In the instantaneous mode of operation provided by the underground-subloop time-current characteristic, the increase in arc voltage provides efficient limitation of current to a small fraction of the prospective peak current. Unique, patented features of the fusible elements provide back emf "voltage control" to prevent excessive voltage buildup that could damage surge arresters or other equipment.

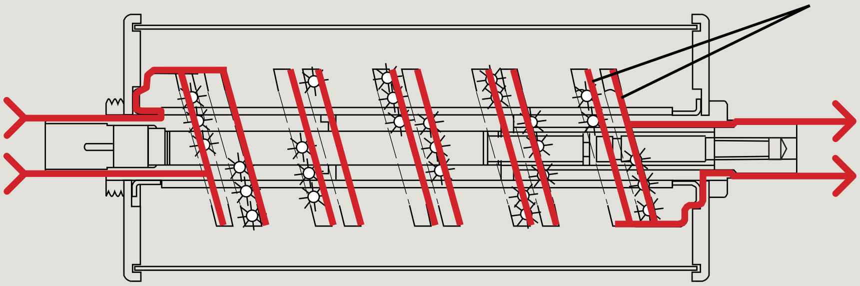
Fusible-element melting characteristics are similar in the inverse-time mode of operation, except that operation of the interrupting module and fusible-element melting occurs *after* the appropriate time delay dictated by the inverse- or time-delayed compound curve TCC.

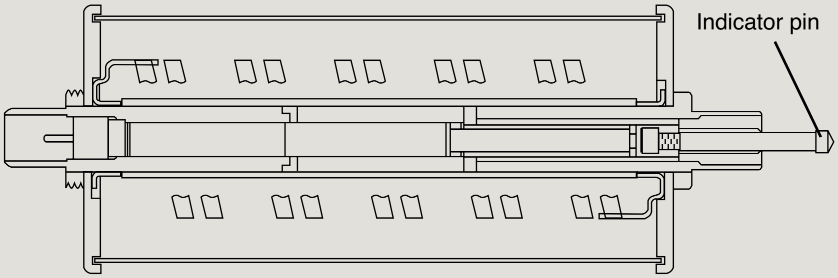
D. Circuit Interruption
Fault current is driven to zero in a controlled fashion as the fusible elements burn back and the arc energy is absorbed by the surrounding sand. The integral indicator pin—driven by the action of the insulating piston—pierces the end of the interrupting module to provide visual indication that the Fault Fiter has operated.

Fault Fiter Electronic Power Fuse Operating Sequence









FUSE MOUNTINGS

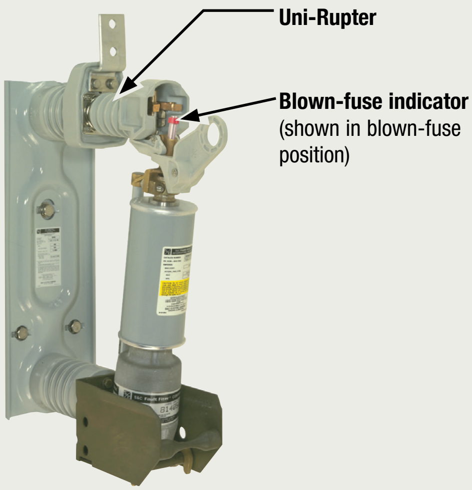
Mounting Styles

Fault Fiter Electronic Power Fuses are available in Disconnect Style and Disconnect with Uni-Rupter Style.

The Disconnect Style Mounting is available in ratings of 4.16 kV through 25 kV, 600 or 1200 amperes continuous, 40,000 amperes RMS symmetrical interrupting. It is designed for use in conjunction with an interrupter switch and, therefore, is not equipped for live-switching duty.

The Disconnect with Uni-Rupter Style Mounting provides 400-ampere single-pole *live switching* of single-phase or three-phase circuits rated 13.8 kV, and 200-ampere single-pole live switching of circuits rated 25 kV. Uni-Rupter offers the ultimate in live-switching simplicity: a firm, steady opening pull on the fuse with a hookstick is all that's required. Since circuit interruption is internal to Uni-Rupter, there's no external arc or flame. Uni-Rupter is self-resetting; a swift, unhesitating stroke with a hookstick is all that's needed to move the fuse back to the closed position. The Disconnect Style with Uni-Rupter Mounting provides a one-time duty-cycle fault-closing capability of 14,000 amperes RMS symmetrical.

A blown-fuse indicator pin, common to both styles, provides ready indication of a blown-fuse condition. See Uni-Rupter Style Mounting below.



Disconnect with Uni-Rupter Style

Disconnect Style (600-ampere)

Disconnect Style (1200-ampere)

RATINGS

Style	Rating						Catalog Number	
	kV			Amperes, RMS			Mounting (less Holder)	Holder
	Nom.	Max	BIL	Cont.	Load Dropping	Interr., Sym.		
Disconnect with Uni-Rupter	13.8	17.0	95	400	400★	14 000	99402	99412
	25	29	125	200	200★	14 000	99403	99413
Disconnect	4.16	5.5	60	600	—	40 000	99100	99110
	4.16	5.5	60	1200	—	40 000	99150	99110▲
	13.8	17.0	95	600	—	40 000	99102	99112
	13.8	17.0	95	1200	—	40 000	99152	99112▲
	25	29	150	600	—	40 000	99103	99113
	25	29	150	1200	—	40 000	99153	99113▲

★ The Disconnect with Uni-Rupter Style Mounting has a one-time duty-cycle fault-closing capability of 22,400 amperes RMS asymmetrical, and a two-time duty-cycle fault-closing capability of 13,000 amperes RMS asymmetrical. The duty-cycle fault-closing capability defines the level of available fault current into which the fuse can be closed the specified number of times (once or twice), when operated vigorously through its full travel without hesitation at any point, with the Uni-Rupter remaining operable and able to carry and interrupt the rated continuous and load-dropping current specified above.

▲ Two holders are required.

FUSE HANDLING

Installing (or Removing) Fault Fiter

S&C Fault Fiter Electronic Power Fuses rated 4.16 kV and 13.8 kV are easily handled using a universal pole equipped either with the S&C Grappler or the S&C Extra-Large Clamp. The specific handling-tool selection depends on the operation to be performed.

The S&C Grappler, Catalog Number 4423, is ideally suited for opening and closing Fault Fiter, as well as for installing or removing the fuse. The S&C Extra-Large Clamp, Catalog Number 4424, may be used in lieu of the S&C Grappler for installing or removing Fault Fiter. See Figure 11. This handling tool is particularly useful for fuse handling when the mounting is located at waist height or higher.

Fault Fiter Electronic Power Fuses rated 25 kV should be opened and closed using Grappler, and the fuse should be removed from the mounting by hand after the mounting has been de-energized and properly grounded in accordance with local operating procedures.

For more information on S&C Fault Fiter Electronic Power Fuses, refer to your nearest S&C Sales Office.

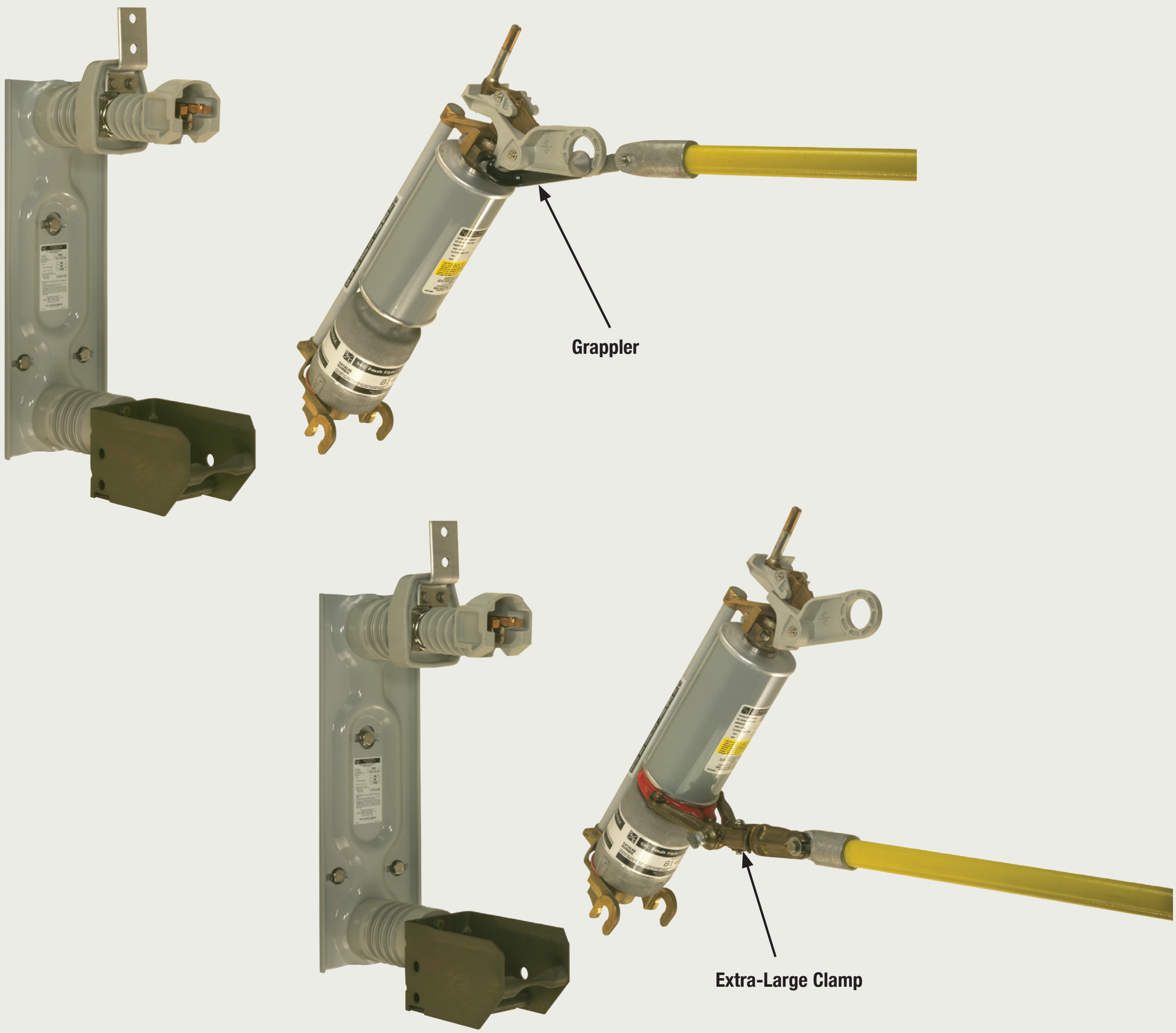


Figure 11. Installing (or removing) Fault Fiter using the S&C Grappler or S&C Extra-Large Clamp.