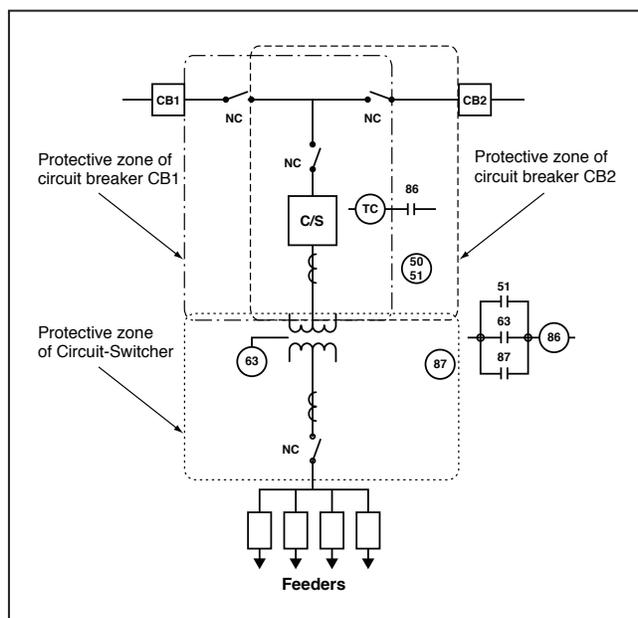


# Selection Guide for S&C Substation Transformer Protective Devices (34.5 kV through 230 kV)

## Transformer Protection

The selector table on page 2 of this publication compares the features and capabilities of S&C's substation transformer protective devices, enabling users to select the appropriate device for their application.

Best practice dictates *an individual protective device for each transformer*, thereby eliminating the need to take all transformers connected to the transmission line offline when only one transformer has experienced a fault. S&C Circuit-Switchers, Trans-Rupter II® Transformer Protectors, and Power Fuses are designed and tested for use in coordinated transformer-protection plans. They're widely applied at load-tap transformers where available fault current exceeds their primary-fault interrupting ratings.



Overlapping protection from rare high-current primary faults is afforded by the line-terminal circuit breakers and first-zone phase- and ground-fault line-protective relays. Circuit interruption following a high-current primary fault is typically accomplished in three cycles. The local primary-side transformer protective device responds to faults internal to the transformer and to faults on the secondary bus in its zone of protection. It also provides backup protection for the secondary-side protective device(s). Properly applied transformer protection will overlap the protection provided by the line-terminal circuit breakers and supplement the protection afforded by the secondary-side protective device(s).

## Secondary-Side Faults

Secondary-side bus faults, or "through-faults," are the most common type of fault a local primary-side transformer protective device must interrupt. Such faults are limited by the impedance of the transformer, so they are of modest magnitude. But they're difficult to interrupt due to the high-frequency transient recovery voltage (TRV) seen by the protective device. The TRV frequency is high because the bushing and winding capacitances of the transformer are small. S&C has specifically tested Circuit-Switchers and Trans-Rupter II Transformer Protectors for this duty.

Assuming an infinite (zero-impedance) source, the secondary-fault current as reflected on the primary side of the transformer can be calculated using the equation  $I = (57.8P) / [(\%Z) E]$ , where

$I$  = Inherent secondary-fault current, A

$P$  = Transformer self-cooled three-phase rating, kVA

$E$  = System phase-to-phase voltage, kV

$\%Z$  = Percent transformer primary-to-secondary impedance, referred to transformer self-cooled three-phase kVA rating

For example, a 37.5/50/62.5-MVA, 115-kV, 8% impedance transformer will provide an inherent secondary-fault current of 2,356 amperes, calculated as follows:  
 $I = [(57.8) (37,500 \text{ kVA})] / [(8) (115 \text{ kV})] = 2,356 \text{ amperes}$ .

A 115-kV Mark V or Series 2000 Circuit-Switcher or Trans-Rupter II Transformer Protector would be appropriate for this application. Mark V and Series 2000 Circuit-Switchers have a secondary fault interrupting rating of 4000 amperes. Trans-Rupter II Transformer Protectors have a secondary-fault interrupting rating of 2600 amperes.

A secondary-side fault current calculator is available at [sandc.com](http://sandc.com).



Supersedes Data Bulletin 710-50 dated May 10, 2010.

November 19, 2018

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Information Bulletin 710-50

# Selection Guide

## Substation Transformer Protective Device Selector Table

|  | Trans-Rupter II Transformer Protector, Model EX   | Trans-Rupter II Transformer Protector, Model SE  | Series 2000 Circuit-Switcher   |
|--|---|--|--|
| Voltage Rating, kV   | 69 through 138  | 69 through 138   | 69 through 230   |
| Base Transformer Rating, MVA <sup>①</sup>                                  | 69 kV: 30; 115 kV: 36; 138 kV: 43   | 69 kV: 30; 115 kV: 36; 138 kV: 43  | 69 kV: 33; 115 kV: 55; 138 kV: 66; 161 kV: 77; 230 kV: 111   |
| Continuous Current Rating, Amperes   | 420   | 420  | 69 through 138 kV: 1200, 2000◆<br>161 and 230 kV: 1200   |
| Primary-Fault Interrupting Rating, kA, RMS, Sym.                           | 31.5  | 31.5   | 69 through 138 kV: 25 or 40◆;<br>161 and 230 kV: 20  |
| Secondary-Fault Interrupting Rating, kA, RMS, Sym.                         | 69 kV: 4.2;<br>115 and 138 kV: 2.6  | 69 kV: 4.2;<br>115 and 138 kV: 2.6   | 4  |
| Three-Phase Fault Interruption   | Yes   | Yes  | Yes  |
| Mounting Configurations  | Vertical interrupter  | Vertical interrupter   | Vertical or horizontal interrupter   |
| Phase Spacings and S&C Mounting Pedestal Heights, Inches (cm) <sup>②</sup> | Phase spacings: 48, 84, and 102 (122, 213, 259);<br>Pedestal heights: 96, 120, and 144 (244, 305, and 366)  | Phase spacings: 48, 84, and 102 (122, 213, and 259);<br>Pedestal heights: 96, 120, and 144 (244, 305, and 366) | Phase spacings: 48, 84, 102, and 120 (122, 213, and 259);<br>Pedestal heights: 96▼, 120, 144, 168, 192, 216, and 240 (244, 305, 366, 427, 488, 549, and 610) |
| Integral Disconnect  | Optional vertical-break disconnect  | Optional vertical-break disconnect   | Model 2010 includes vertical-break disconnect;<br>Model 2020 includes side-break disconnect  |
| Installable on User-Furnished Structure                                    | Yes   | Yes  | S&C Mounting Pedestals included as standard. Modifiable for use on user-furnished structure  |
| Control Power Source   | User-furnished substation batteries   | Self-powered from transformer primary bushing CTs  | User-furnished substation batteries  |
| Interrupting Time, Cycles  | 3   | 5 (including relay power-up time for high-current faults)  | 5 to 6   |
| Duty Cycle (O=open, C=closed)  | O   | O  | O or CO  |
| Resetting Method   | Manual, using tool furnished. Motor operators optionally available for remote "hands-free" resetting        | Manual, using tool furnished   | Switch operator furnished  |
| Transformer Magnetizing Current Picked-Up By                               | User-furnished disconnect or optional S&C-furnished disconnect  | User-furnished disconnect or optional S&C-furnished disconnect   | Interrupter contacts   |
| Relay Compatible   | Yes   | Self-contained overcurrent relays. Compatible with some sudden-pressure relays▲                                | Yes  |
| Operate/Monitor via SCADA  | Remote open. Remote close with optional motor operators.● Contacts available for monitoring pole-unit state | Remote open. Contacts available for monitoring pole-unit state●  | Fully SCADA compatible○  |
| Scheduled Maintenance  | Visual inspection during regular transformer maintenance cycle■   | Visual inspection during regular transformer maintenance cycle■  | Mechanically-linked interrupters and disconnect require inspection on approximate 5-year cycle   |

① Based on 7%-impedance transformer. Base transformer rating can vary at temperatures lower than -35°C. See protective device specification bulletin for details.

② Special phase spacings and pedestal heights are available. Contact your nearest S&C Sales Office for details.

● Remote gas-density indicator optionally available.

■ Silicone-polymer insulation and electrically-linked pole-units require no regular maintenance. Periodic testing of the protective relay circuit is recommended.

▲ User-furnished relays and monitoring equipment must not draw power from the control circuit. Contact your nearest S&C Sales Office for details.

◆ Models rated 2000 A continuous are not available with 40-kA primary-fault interrupting rating, and vice versa.

▼ 96-inch height mounting pedestals furnished as standard.

○ Remote gas-density monitor optionally available.

| Mark V Circuit-Switcher   | Mark VI Circuit-Switcher  | Type SMD® Power Fuses   |
|---|---|---|
| 34.5 through 230  | 69 through 138  | 34.5 through 138  |
| 34.5 kV: 15; 46 kV: 22; 69 kV: 33; 115 kV: 55□; 138 kV: 66; 161 kV: 77; 230 kV: 111   | 69 kV: 30; 115 kV: 36; 138 kV: 43   | 34.5 kV: 12; 46 kV: 15; 69 kV: 18; 115 kV: 25; 138 kV: 30   |
| 1200  | 420   | 250E and 300E   |
| 7 or 8  | 31.5  | 34.5 kV: 6.7, 17.5, or 33.5; 46 kV: 5, 13.1, or 31.5; 69 kV: 3.35, 8.75, 17.5 or 25; 115 kV: 10.5; 138 kV: 8.75 |
| 4   | 69 kV: 4.2; 115 and 138 kV: 2.6   | Depends on fuse-unit ampere rating and speed selected   |
| Yes   | Yes   | No, single phase only   |
| Horizontal interrupter  | Vertical interrupter  | Vertical, vertical-offset, upright, inverted, and right-angle   |
| Phase spacings: 41, 51, 96, 108, and 123△ (104, 130, 244, 274, and 312); Pedestal heights: 96, 108, 120, 132, and 144 (244, 274, 305, 335, and 366) | Phase spacings: 51, 84, and 102 (130, 213, and 259); Pedestal heights: 96, 120, and 144 (244, 205, and 366) | Phase spacings vary according to mounting arrangement and voltage rating  |
| Vertical-break or center-break disconnect   | Vertical-break disconnect   | Not applicable  |
| Yes◇△   | Yes ◇   | Yes   |
| User-furnished substation batteries   | User-furnished substation batteries   | Not required  |
| 8 with shunt-trip option; 30 without shunt-trip option  | 3   | Depends on fuse-unit ampere rating and speed selected, and level of fault current                               |
| O or CO   | O or CO   | O (Fuse will operate if fault current is present when circuit is energized)                                     |
| CS-1A Switch Operator available separately. Manual operating handle available at some voltages  | Disconnect operated by CS-1A Switch Operator furnished. Interrupters reset by motor operators furnished●    | Manual, following fuse unit replacement   |
| Integral high-speed disconnect▲   | Integral high-speed disconnect  | User-furnished disconnect   |
| Yes   | Yes   | Not applicable  |
| Fully SCADA compatible  | Fully SCADA compatible●   | Not applicable  |
| Mechanically-linked interrupters and disconnect require inspection on approximate 5-year cycle  | Mechanically-linked disconnect requires inspection on approximate 5-year cycle                              | Visual inspection during regular transformer maintenance cycle. Refinishing of fuse units if necessary▲         |

□ 40 MVA for 115-kV single-gap Mark V Circuit-Switchers.

△ Phase spacing of Integer Style Circuit-Switchers is fixed by the dimensions of the mounting frame. For Circuit-Switchers rated 34.5 kV and 46 kV: 41 inches (140 cm); for Circuit-Switchers rated 69 kV: 51 inches (130 cm).

◇ An as-built drawing of the user-furnished structure is required at the time of order.

▽ CS-1A Switch Operator is required to obtain high-speed disconnect operation.

● Two-minute interrupter resetting time is required between opening operations.

■ User must stock spare fuse units. Fuse unit end fittings are reusable.

### Transformer Protective Device Overview

**S&C Series 2000, Mark V, and Mark VI Circuit-Switchers** use stored-energy operating mechanisms to drive the interrupters open and have trip-free operating capability. In the event the Circuit-Switcher is closed into a fault, it will open immediately to interrupt the fault. Mark V and Mark VI Circuit-Switchers, as well as some styles of Series 2000 Circuit-Switchers, are equipped with an integral disconnect that provides visual indication of the device's state in addition to working clearance for transformer maintenance or repair.

Circuit-Switchers are available in ratings from 34.5 through 230 kV, with primary-fault interrupting ratings up to 40 kA, secondary-fault interrupting ratings up to 4200 amperes, and interrupting times as low as three cycles.

Additional information on Series 2000 Circuit-Switchers is available in S&C Descriptive Bulletin 716-30 and S&C Specification Bulletin 716-31. Information on Mark V Circuit-Switcher is available in S&C Specification Bulletin 711-31. Information on the Mark VI Circuit-Switcher is available in S&C Specification Bulletin 712-31.

**S&C Trans-Rupter II Transformer Protector, Models EX and Model SE**, feature puffer-type interrupters similar to those used in Series 2000 Circuit-Switchers. These interrupters provide a 31.5-kA fault-interrupting

rating and three-cycle interrupting time. Trans-Rupter II Transformer Protectors have been tested to confirm their ability to interrupt fast TRVs and have been assigned a secondary-fault interrupting rating similar to Circuit-Switchers. Each pole-unit has its own operating mechanism; the pole-units are filled with SF<sub>6</sub> and sealed.

Model EX Trans-Rupter II Transformer Protectors are tripped by user-furnished relaying; they require an external power source. Model SE Trans-Rupter II Transformer Protectors feature a self-contained overcurrent protection relay system and require no external power source. Additional information on the Trans-Rupter II Transformer Protector is available in S&C Descriptive Bulletin 731-30 and S&C Specification Bulletin 731-31.

**S&C Type SMD Power Fuses** provide reliable, economical protection of small to mid-sized transformers. The savings can be considerable because power fuses are less costly than other types of protective equipment. They also require no costly auxiliary equipment, such as station batteries, motor-driven switch operators, or protective relays.

S&C Power Fuses are included in the selector table to help contrast their capabilities with those of S&C Circuit-Switchers and the Trans-Rupter II Transformer Protector. Detailed information on the application of S&C Power Fuses for transformer protection can be found in S&C Information Bulletin 210-110.