



S&C Circuit-Switchers — Mark VI

Outdoor Transmission (69 kV through 138 kV)

Mark VI Circuit-Switcher with Pre-insertion Inductors . . . the most reliable way to switch and protect substation capacitor banks

Capacitor banks are a vital source of voltage support during peak periods, when the demand for electricity is high. Capacitor bank switching and protection requires a dependable switch—one that's able to function reliably several times a day, year after year. Such a switch should require little maintenance beyond routine inspections.

A capacitor switch must also be able to provide transient control to ensure high-quality power to customers. For many industrial customers, transient conditions at the substation capacitor-bank bus can cause nuisance tripping of adjustable-speed drives within their facility. Transient overvoltages can also cause wear on substation insulation, degrade control wiring, and cause extra operating duty for surge arresters.

S&C's Mark V Circuit-Switcher has been the best choice for capacitor bank switching and protection . . . its robust design and repeatable, consistent performance has given it an industry-wide reputation for excellence.

S&C has again advanced the state of circuit-switcher technology with the Mark VI Circuit-Switcher. Mark VI provides the same dependable performance you've come to expect from S&C . . . but with added features and benefits to meet today's demanding system and operational requirements.

Mark VI Circuit-Switcher Features:

- **Higher-than-ever 31.5-kA fault-interrupting rating and 3-cycle interrupting time.**
- **Three-phase tripping by electrically linked interrupters**—provides tripping simultaneity of less than $\frac{1}{4}$ cycle.
- **Hermetically sealed interrupters**—eliminates the hassle of field-filling with SF₆ gas. Interrupters provide full dielectric ratings when open.
- **Reliable performance**—Mark VI uses the same robust high-speed disconnect as Mark V Circuit-Switcher and the heavy-duty Mark VI CS-1A Switch Operator.

Mark VI Circuit-Switcher — switch and protect single and back-to-back capacitor banks . . . locally

The Mark VI Circuit-Switcher, with its 31.5-kA fault interrupting capability and 3-cycle interrupting time, can protect against faults on the capacitor bank bus, as well as bolted faults across a series group of capacitors. There is no need for a circuit breaker . . . either locally or downstream to interrupt fault current. Add S&C's pre-insertion inductors and the Mark VI Circuit-Switcher can switch, provide fault protection, *and* mitigate transient overvoltages . . . all with one device.

Mark VI Circuit-Switcher for Single Shunt Capacitor Banks

In single shunt capacitor-bank applications, like the one shown in Figure 1, Mark VI Circuit-Switcher offers an economical solution for switching and protection. Current transformers can be mounted directly on the Mark VI mounting pedestals. Add pre-insertion inductors and Mark VI becomes an effective and economical means to combine switching, protection at full available fault current, and transient overvoltage control in one device.

Mark VI Circuit-Switcher for Back-to-Back Shunt Capacitor Banks

Mark VI Circuit-Switcher can also be used in back-to-back applications—on both banks, as shown in Figure 2. In the past, a device with higher protective interrupting capability might have been required for such applications: Figure 3 illustrates a circuit breaker applied upstream of the circuit-switchers to provide full-fault-current protection. With its 31.5 kA interrupting performance, Mark VI Circuit-Switcher allows a single type of device to switch and protect both banks eliminating the breaker. The Mark VI eliminates the timing and adjustment problems inherent to using controlled-closing circuit breakers for transient control, as well as the extra cost and maintenance associated with these special-purpose breakers.

Adding pre-insertion inductors to the Mark VI Circuit-Switcher provides transient control without the need for a complicated operating scheme—as is required for a controlled-closing breaker.

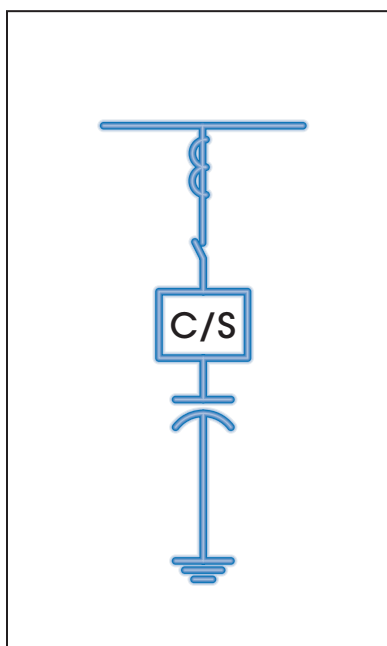


Figure 1. Single shunt capacitor bank.

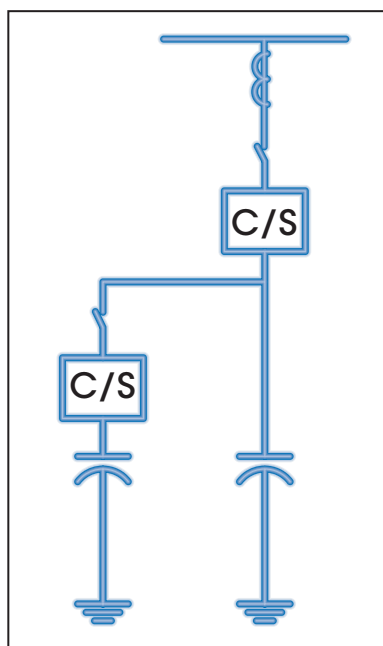


Figure 2. Back-to-back shunt capacitor banks.

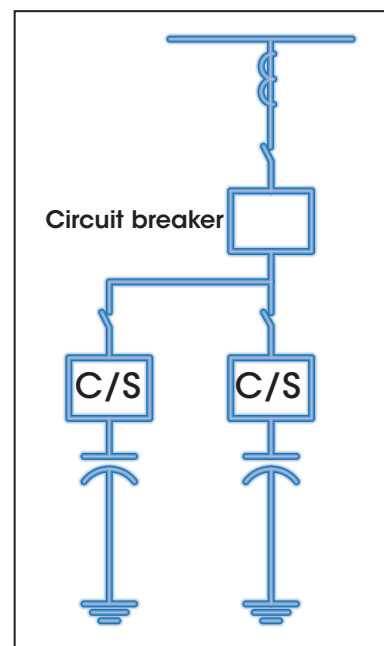


Figure 3. Back-to-back shunt capacitor banks with upstream circuit breaker.

A Design Built on Tradition— Enhanced by Innovation

Mark VI Circuit-Switcher combines the robust vertical-break disconnect of the Mark V Circuit-Switcher with the innovative new interrupting technology of the Trans-Rupter II® Transformer Protector—providing 31.5-kA fault-interrupting ratings and increased installation flexibility.

Integral Disconnect

The integral disconnect is factory-assembled—saving valuable installation time. The circuit-making and isolating disconnect, powered by the Mark VI CS-1A Switch Operator, is capable of opening and closing without hesitation under ¾-inch ice formation.

The disconnect features aluminum blades with silver-inlaid, hot-tin-dipped (except over silver inlay), high-conductivity cast-copper tongue contacts. The jaw contacts are of multi-finger, spring-loaded, silver-inlaid, hard-drawn-copper reverse-loop construction—to grip firmly against the tongue contact. The built-in blade-wiping action ensures a clean current-carrying surface and low-resistance current path—all arcing

associated with switching is confined to the fault-closing contacts. The disconnect blade is positively toggled in the fully-closed position.

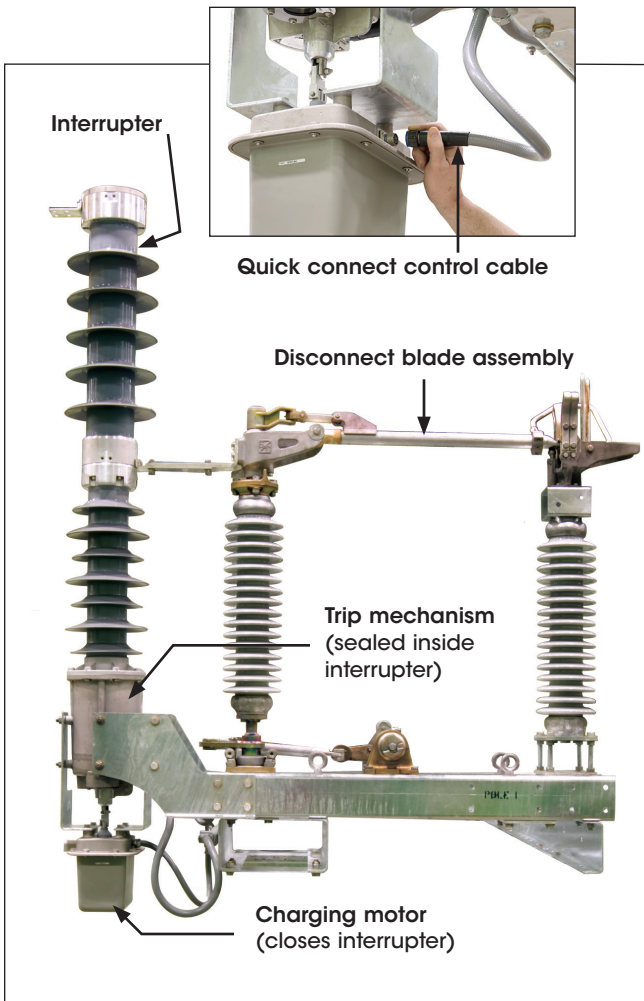
The rigid galvanized steel bases simplify installation on steel structures or S&C Mounting Pedestals.

Enhanced 31.5-kA Interrupters

The SF₆-gas-filled, single-gap, puffer-type interrupters are factory-filled to 75 PSIG, tested and permanently sealed. Field-filling is never needed, eliminating the risk of contaminating the interrupting medium and the need for gas-handling equipment—saving installation time. The interrupters use lightweight, shatterproof, composite-polymer silicone insulation—providing outstanding performance, even in contaminated environments. Each interrupter has its own permanently sealed stored-energy trip mechanism and charging motor. After the Circuit-Switcher has been called upon to trip and the disconnect has opened to establish a visible air gap, the charging motors close and charge the interrupters for coordinated operation.

Each interrupter includes a built-in limit switch that prevents overcharging the trip mechanism, and ensures that the interrupter is either open or closed.

Local indication of interrupter state—“closed” or “open”—is provided at the base of each interrupter and the interrupter position can also be monitored by SCADA Systems. Each interrupter also includes a temperature-compensated SF₆ gas-pressure gauge, with two gas-indicator levels. A remote gas-density indicator, which provides indication of the two alarms, is optionally available.



One pole-unit of 69-kV Mark VI Circuit-Switcher.

A wide variety of options are available:

- **Interrupter pole-unit quick-connect control cable**—plug-style connector replaces butt-splice electrical connection at interrupter junction box
- **Complete quick-connect control cable**—plug-style connector replaces conduit between the interrupter, interrupter charging motor, and Mark VI CS-1A Switch Operator
- **Grounding switch**—grounds jaw-contact terminal pads of Circuit-Switcher. Includes manual operating handle
- **Remote gas-density indicator**—for remote indication of two-level low-gas-density alarms.

Mark VI Type CS-1A Switch Operator

The operator's heavy-duty motor enables high-speed, high-torque closing and opening of the disconnect—providing close interphase simultaneity and long life of closing contacts, and avoiding excessive switching transients due to prolonged or unstable pre-strike arcing. All interrupter and relay wiring connections are made within the operator enclosure.

The operator includes external trip and close pushbuttons, and a decoupling mechanism that allows decoupling and locking of the disconnect-blade power train in the open position. A non-resettable operation counter and mechanical position indicator are also included. The Mark VI CS-1A Switch Operator includes eight-pole auxiliary adjustable switch contacts, coupled to the motor.

The Mark VI CS-1A Switch Operator features sturdy welded-aluminum enclosure construction, with baffled louvers that allow air circulation while keeping out rain. It has a gasketed, flanged door design with cam-action latch for easy opening . . . and a clear, safety-plate glass window that allows visual inspection of the decoupling mechanism, mechanical position indicator, and the operation counter without opening the door. The Mark VI CS-1A Switch Operator can be padlocked for safety.

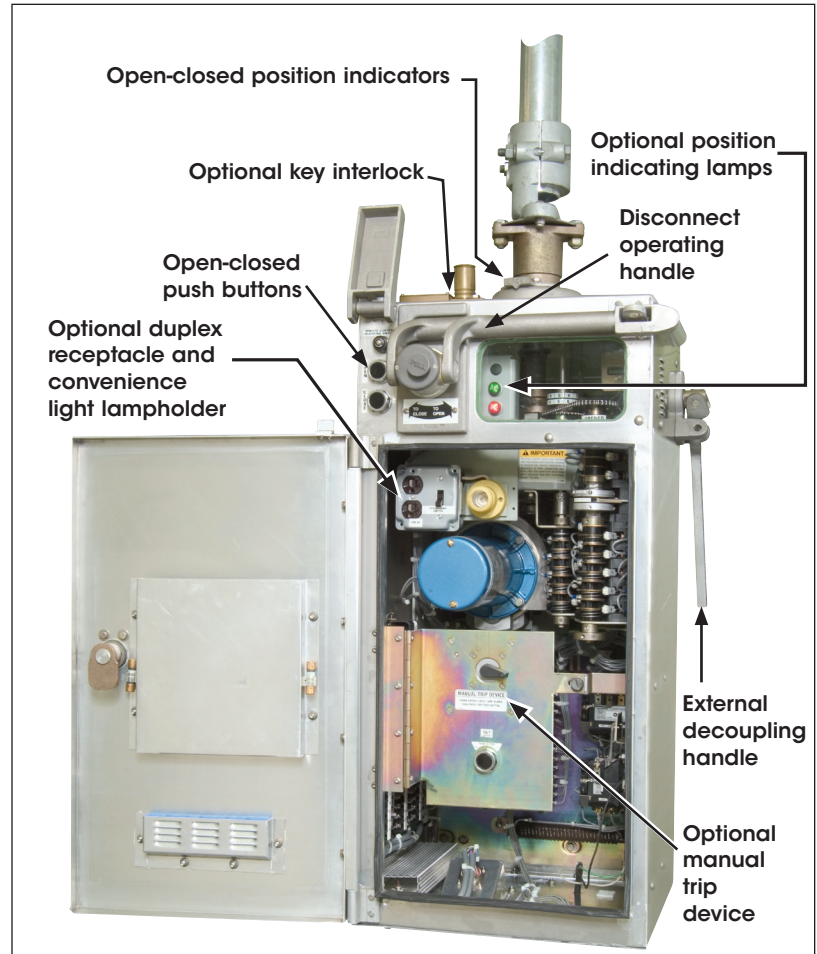
Available options include:

- Space heater thermostat,
- Long-lasting LED position-indicating lamps,
- Manual trip device, and
- Duplex receptacle and convenience-light lamp holder.

An assortment of auxiliary contacts are available to suit any control scheme or SCADA requirements.

S&C Mounting Pedestals Make Installation Easy

S&C Mounting Pedestals include all necessary interphase wiring and conduit, for a simplifying installation. They're available in heights of 96, 120, or 144 inches, with phase spacings of 51 or 84 inches at 69 kV, and 84, 96, or 102 inches at 115 kV and 138 kV.



Interior of Mark VI CS-1A Switch Operator.



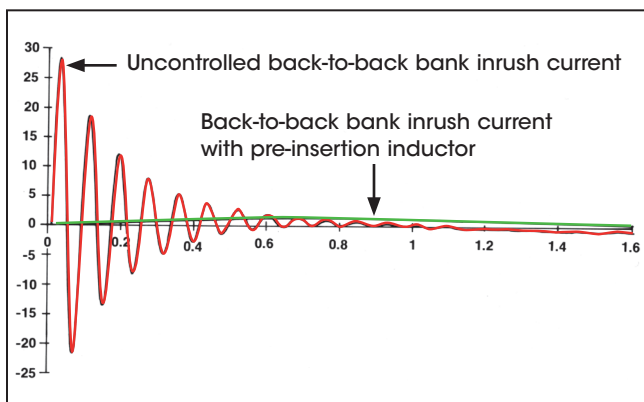
138-kV Mark VI Circuit-Switcher on S&C Mounting Pedestals.

Pre-insertion Inductors . . . Reliable Transient Control

Mark VI Circuit-Switchers are available with optional pre-insertion inductors for use in shunt capacitor-bank switching and protection applications. Pre-insertion inductors offer excellent performance compared to controlled-closing schemes and pre-insertion resistors for:

- **Limiting inrush current and overvoltage at the capacitor bank bus**—and thus induced transient voltage disturbances in substation low-voltage control circuits, which can cause spurious signals, insulation puncture, and component damage.
- **Limiting phase-to-phase switching-surge overvoltages produced at remote transformers as a result of energizing a capacitor bank . . .** a phenomenon which can lead to decreased transformer life, or even transformer failure, because of the high voltage-stress concentrations which are imposed across the transformer windings.
- **Limiting overvoltages on long open-ended lines.** Such overvoltages can cause nuisance operation of surge arresters.

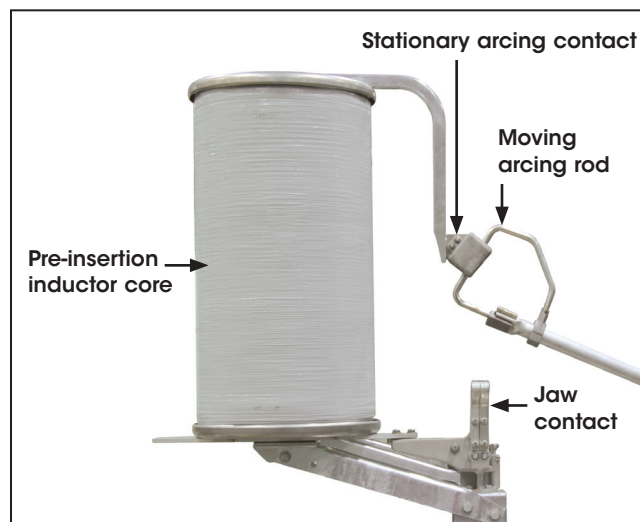
Transient control has become increasingly important as utility customers require higher levels of power quality for sensitive process-related equipment, such as adjustable-speed drives. Transient control is also important for minimizing the stresses that surges cause on utility system equipment. Pre-insertion inductors are especially suited for limiting transient overvoltages which, through voltage magnification, can result in nuisance tripping of adjustable-speed drives and other sensitive electronic devices. Voltage magnification can occur where power-factor correction capacitors and/or voltage control capacitors are applied on the utility distribution system or on a utility customer's low-voltage bus, and is caused by a near-resonant condition between the switched capacitor bus and the capacitances at lower voltage.



Inrush current during switching of back-to-back capacitor bank, with and without pre-insertion inductors.

Pre-insertion inductors offer distinct advantages over circuit breakers using a controlled-closing relay scheme. Controlled-closing breakers are set to close each phase at voltage zero—adding significant mechanical complexity and extra cost. When commissioning a controlled-closing breaker, the installer must perform many switching operations to “train” the adaptive control relay system—all the while putting transients on the system. And controlled-closing breakers must be periodically inspected to verify that the control system is indeed closing each phase at zero voltage and hasn’t “drifted” . . . if most breakers don’t close within 1.5 ms of the “zero” setting, damaging transients can still appear on the system.

Circuit-breakers equipped with pre-insertion resistors operate similarly to Circuit-Switchers with pre-insertion inductors—but are mechanically complex—and prone to overheating. The resistor and main contacts of the breaker must be synchronized. Synchronization is usually achieved by connecting the resistor contact rod to the breaker main-contact control rod; this arrangement requires periodic adjustment of the contacts. Pre-insertion resistors also tend to have a much-shorter electrical life. Pre-insertion inductors, with their lower resistance and hollow core, offer greater durability and heat-dissipating capability than resistors . . . providing longer operating life and enhanced reliability. More information on S&C Pre-insertion Inductors can be found in S&C Data Bulletin 711-95, “S&C Circuit-Switchers—Mark V: Pre-insertion Inductor Application Guide, 34.5 kV through 230 kV.”



Each pre-insertion inductor is comprised of two or more close-coupled layers of stainless-steel or aluminum conductor, wound along with a resin-impregnated filament-fiberglass roving, to form a hollow glass-reinforced tube. An integral counterwound stainless-steel damping winding limits voltage across the Circuit-Switcher during opening. A layer of roving separates the layers of conductor; other layers of roving add mechanical strength and stability. The outer roving is finished with silicone-alkyd paint for all-weather durability.

MARK VI CIRCUIT-SWITCHER—50/60-HZ RATINGS

kV			Amperes, RMS				
Nom.	Max	BIL	Cont.	4-Hour	Peak Withstand	1-Sec.	Fault Closing, Duty-Cycle, Two-Time ¹
69	72.5	350	420	630	81 900	31 500	30 000
115	123	550	420	630	81 900	31 500	30 000
138	145	650	420	630	81 900	31 500	30 000

¹ For complete information, refer to S&C Specification Bulletin 712-31.

MARK VI CIRCUIT-SWITCHER—INTERRUPTING RATINGS

Application			Maximum Amperes, Interrupting, RMS, Symmetrical
Class	Qualifications		
Transformer Switching and Protection	Load Dropping ¹	–	630
	Duty-Cycle Fault Interrupting ^{2,3}	3-Time	31 500 ^f
		5-Time	18 900
		10-Time	9 450
		30-Time	3 150
	Secondary Faults ⁴	69 kV	4 200
		115 kV and 138 kV	2 600
Internal faults—see both primary and secondary faults, above			
Capacitor-Bank Switching and Protection	Bank Current Switching	Grounded capacitor banks applied on solidly grounded systems only, through 138 kV	420
		Ungrounded capacitor banks applied through 138 kV	420
	Fault Interrupting ^{2,3,f}	–	31 500

¹ Mark VI Circuit-Switchers can close, carry, and interrupt the magnetizing current of the protected transformer.

² Rating is based on transient-recovery voltage parameters defined in the following tables of IEC Standard 60056, Edition 4.0: 1987:

For Circuit-Switchers rated 69 kV: Tables IIa, XVa, and XVIa.

For Circuit-Switchers rated 115 kV and 138 kV: Tables IIc, XVC, XVIc, and XVII.

³ The interrupting ratings shown are applicable for the following duty-cycles: O or CO.

⁴ Mark VI Circuit-Switchers are suitable for transformer-primary applications where the inherent secondary-fault current—the secondary-side fault current as reflected on the primary side of the transformer, assuming an infinite (zero-impedance) source—does not exceed this value for a fault external to the transformer.

The *inherent* secondary-fault current may be calculated as follows:

$$I = \frac{57.8P}{(\%Z)E}$$

where I = Inherent secondary-fault current, amperes

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

E = Primary-side phase-to-phase voltage, kV

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

^f Mark VI Circuit-Switchers cannot be applied on systems with short-circuit currents in excess of this value.

