Capacitor Switching

Southern States

The Power of Ideas

Southern States' Power Switching Division is committed to providing purpose specific devices that solve the most challenging issues facing the transmission and distribution utility markets. The ***CapSwitcher***® was created in response to the demand for improved power quality and voltage control when adding reactive loads via shunt capacitor banks. This bulletin highlights this unique application as well as the most appropriate design approach for ***mitigating voltage and current transients.***

Southern States

The Quality Name in High Voltage Switching

CATALOG BULLETIN

INTRODUCTION

The increasing requirement for improved power quality, a desire to maximize power transfer efficiency of lines, and greater focus on renewable energy generation has resulted in the need for improved voltage control. For utilities, the application of shunt capacitor banks has become a proven and favored tool for supplying reactive power to maintain voltage control on heavily loaded transmission and distribution systems. As one might expect, it is not unusual for shunt capacitors to be switched daily as the system load fluctuates. Connecting and disconnecting shunt capacitor banks from the system presents some unique challenges since the voltage across the capacitor cannot change instantaneously. This switching causes unwanted, high frequency voltage and current transients that may cause equipment damage, nuisance equipment operation, or disruption to the customer processes. Several technologies have been utilized to mitigate these transients including application of arrestors, inrush reactors, controlled voltage switching devices, pre-insertion resistors, and pre-insertion inductors.

Because switching shunt capacitors places stress on the system, the capacitors, and the switching device, a utility should look for a reliable, cost effective, and long-life device that ***mitigates re-strikes, voltage transients, and current transients***. This requirement exposes many weaknesses of the existing switching methodologies mentioned above. Switching designs that are general purpose in design may ultimately reduce their intrinsic performance when switching capacitor banks. It is therefore important to select a specific purpose device that includes closing resistor technology.

The Southern States ***CapSwitcher®***, a high voltage capacitor switching device ***specifically designed for re-strike free switching of capacitor banks***, is a reliable, long-life SF_6 capacitor switch that addresses this utility need, offering significant improvements in product life and overall reliability.

CapSwitcher®

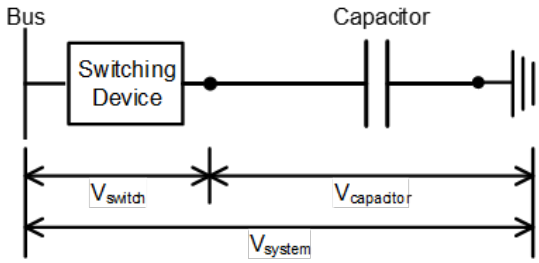
Application Specific Devices For Shunt Capacitor Switching

APPLICATION

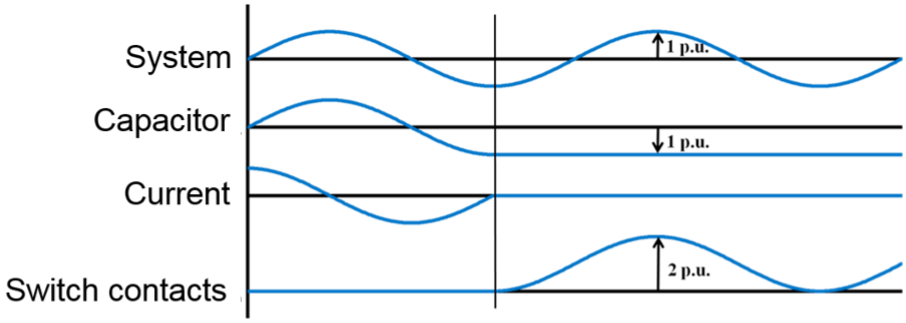
Considerations When Switching Capacitor Banks:

Minimize or Eliminate Re-strikes when De-Energizing Capacitor Banks

Re-strikes or re-ignitions occur when the dielectric strength of the open gap, during contact parting, is not great enough to withstand the recovery voltage across the open gap. With a capacitive load, the current waveform leads the voltage waveform by 90°. The current is interrupted close to the zero crossing when the voltage is at its maximum value. The supply side voltage is relatively unaffected following the interruption, but the voltage of the capacitor bank becomes trapped maintaining the peak voltage level (very low rate of decay) that was present at the time of current interruption. The initial low rate of rise of the recovery voltage and the low level of current being switched make it easy for the switching device to interrupt.



Since the level of the currents being switched are low, the switching device, which is often a general purpose device such as a power circuit breaker or vacuum interrupter, may interrupt the current at a point where the contact separation and parting speed is not sufficient to withstand the voltage difference across the contacts leading to a re-strike and the resumption of current flow. Single re-strike over-voltages can approach 3 PU.



Neutral Grounding	Pole Discrepancy	Recovery Voltage (p.u.)
Solidly Grounded	N/A	2.0
Ungrounded	≤ 90 electrical degrees (simultaneous operation)	2.5
Ungrounded	Both of the other 2 poles delay opening	3.0
Ungrounded	One of the other 2 pole delays opening	4.1

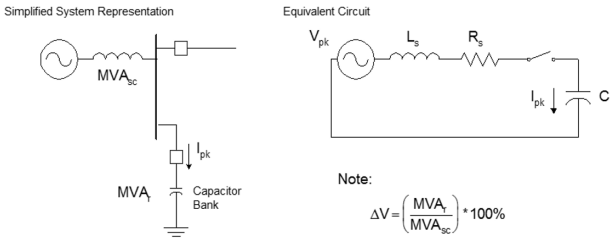
Recovery Voltage Across First Pole to Clear

Re-strikes cause cascading over-voltages that can lead to: Ruptured capacitor cans, Blown Fuses, Failed Arrestors, External equipment flash-overs, and contact wear that may lead to interrupter dielectric failures.

APPLICATION

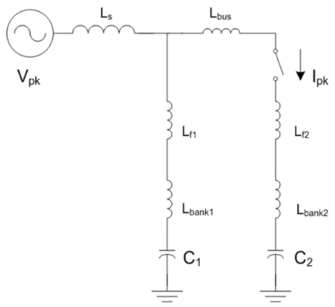
Minimize Voltage and Current Transients when Energizing Capacitor Banks

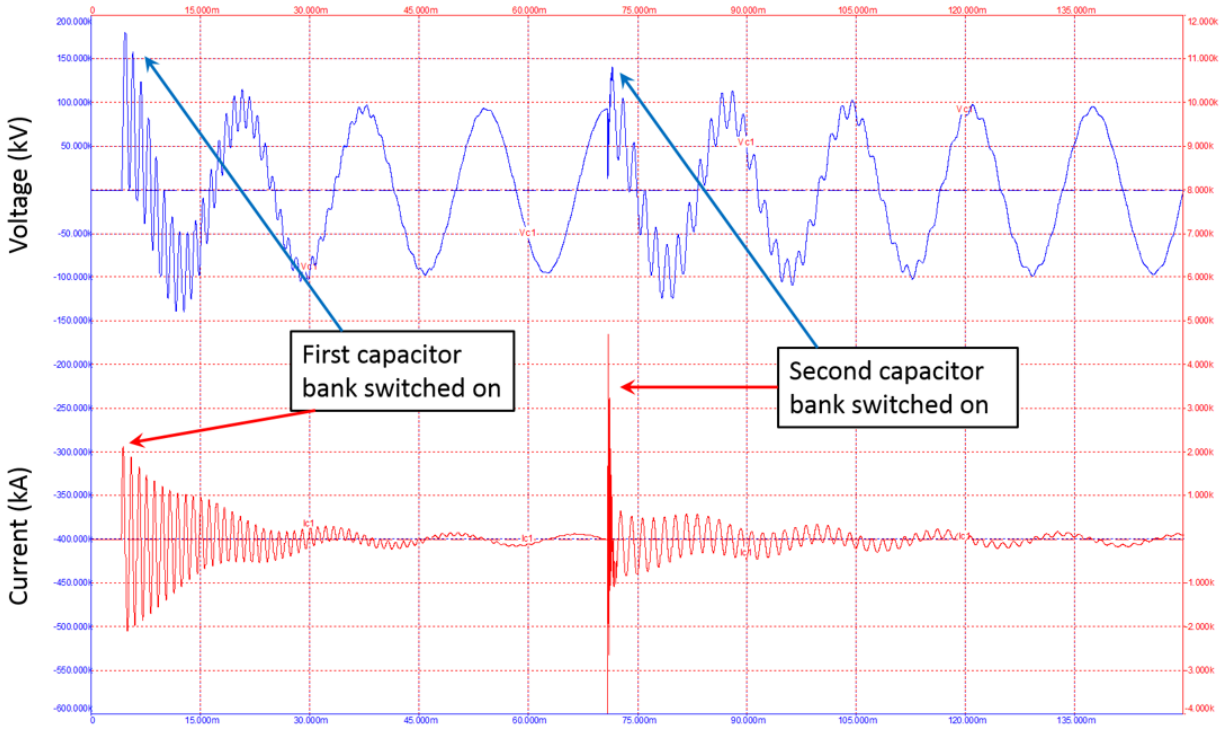
When a capacitor bank is energized, there is an immediate drop in system voltage toward zero, followed by a fast voltage recovery that is superimposed on the system 60 Hz fundamental waveform. This recovery voltage can reach a peak of 2.0 p.u. at frequencies between 300 Hz and 1000 Hz.



While these transients are not typically harmful to utility equipment, they may be troublesome to some customers' sensitive equipment. The transients often show up a significant distance from the capacitor bus as the high frequency transients pass through transformers and are magnified by capacitor banks located on the distribution system or the at the customers location. The resulting over-voltages can cause nuisance tripping of adjustable speed drives, computer network problems, as well as customer equipment damage or failure. It is generally accepted that transients maintained below about 1.2 p.u. will not impact the customer. Some form of control is necessary to achieve this performance.

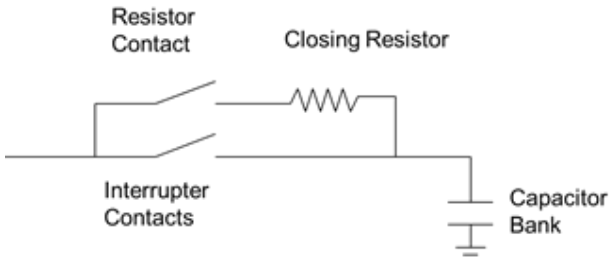
When capacitor banks are installed in a back-to-back arrangement (two or more capacitors close to each other), the energization of the second bank looks like a short circuit to the first bank. This causes the first capacitor bank to discharge into the second capacitor bank resulting in high inrush currents. These in-rush currents can reduce the life of the capacitor switching device. On grounded capacitor banks, transient currents may flow in the ground mat causing potential problems with electronic equipment in the substation because of induced voltage in the control voltage supply.

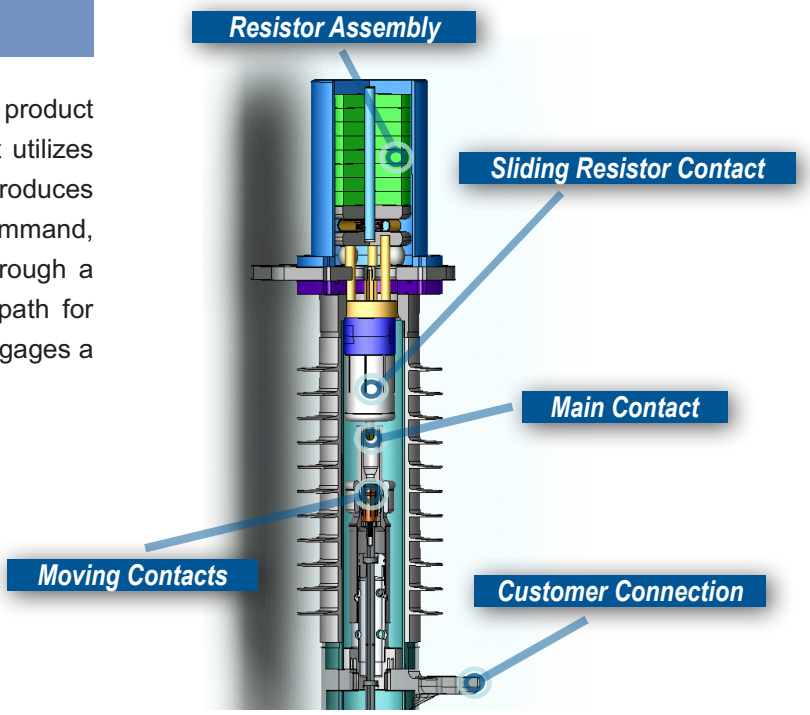




SOUTHERN STATES SOLUTION

The Southern States solution is a special purpose product designed specifically for switching capacitor banks. It utilizes a two-stage switching device that momentarily introduces a resistance into the circuit. On receiving a close command, the moving contact, energizes the capacitor bank through a closing resistor, which is the main current carrying path for approximately 5-10 msec. The moving contact then engages a fixed main contact, shunting the closing resistor



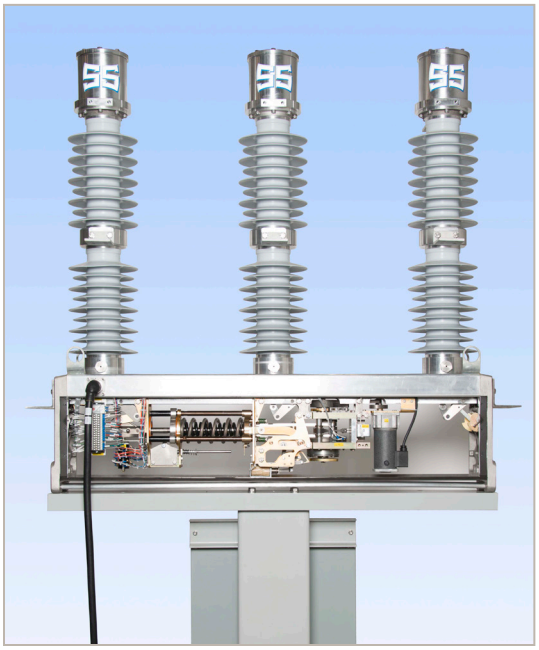


The closing resistor is chosen to reduce the initial transient upon energizing the voltage-less capacitor bank and to balance the inrush events between this initial inrush and the inrush from shunting the resistor. With properly sized closing resistors, the voltage transients and current inrush levels are reduced to minimize system disturbances and equipment exposure to damaging transients.

Another key feature of the Southern States CapSwitcher solution is the patented interrupter design that first opens the closing resistor contacts allowing the circuit interruption to take place within the specially designed nozzle minimizing the possibility of potentially damaging re-strikes. Reliability is enhanced by mechanical design that does not require electronically controlled point-on-wave switching.

DESIGN ADVANTAGES

- Mechanical design does not require point-on-wave switching
- Closing resistors for mitigation of voltage and current transients
- Resistor sizes to allow optimization for best results
- Long Life (10,000 operations)
- Eliminates need for inrush reactors
- Interrupting capability on most designs
- Fault close ratings on all designs
- Making and breaking the circuit in SF6
- Design virtually eliminates re-strikes



PRODUCT OFFERINGS

CapSwitcher® 15 kV - 38 kV *(TYPE 38M)*

RATINGS			
Maximum Voltage Rating	**15.5 kV**	**27 kV**	**38 kV**
BIL	110 kV	150 kV	200 kV
Rated Power Frequency	50/60 Hz		
Continuous Current	600 A (800 A optional)		
Capacitive Switching Current	600 A (800 A optional)		
Short-Time Symmetrical Withstand	40 kA RMS (2 sec)		
Rated High-Frequency Transient-Making Current	42 kA peak at 8100 Hz		
Endurance Life	10,000 operations		
Ambient Temperature Rating	-35° C to +50° C (standard) -50 ° C to +50° C (optional)		
Capacitor Switching Ratings (IEEE C37.09a-2005)			
High Freq. Transient Making Current	23 kA peak at 5400 Hz		

CapSwitcher® 38 kV - 72.5 kV

RATINGS			
Maximum Voltage Rating	**38 kV**	**48.3 kV**	**72.5 kV**
BIL	200 kV	250 kV	350 kV
Continuous Current	600 A		
Primary Fault Interrupting Rating	25 kA RMS * 18 kA (optional -50° C)**		
Short-Time Symmetrical Withstand	50 kA RMS (1 sec)		
Endurance Life	10,000 operations		
Ambient Temperature Rating	-40° C to +50° C (standard) -50° C to +50° C (optional)		
Capacitor Switching Ratings (IEEE C37.09a-2005)			
High Freq. Transient Making Current	18 kA peak at 4630 Hz		

*31.5 kA rating available (max 3 full fault interruptions)
** Design has SF_6 / N_2 mixture

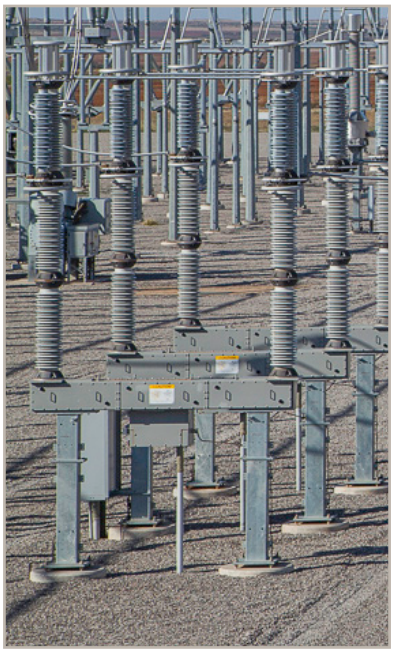
PRODUCT OFFERINGS

CapSwitcher® 123 kV - 170 kV

RATINGS			
Maximum Voltage Rating	**123 kV**	**145 kV**	**170 kV***
BIL	550 kV	650 kV	750 kV
Continuous Current	650 A		
Primary Fault Interrupting Rating	40 kA RMS (standard) 25 kA RMS (optional -50° C)**		
Short-Time Symmetrical Withstand	40 kA RMS (3 sec) 63 kA RMS (18 cycles)		
Endurance Life	10,000 operations		
Ambient Temperature Rating	-40° C to +50° C (standard) -50° C to +50° C (optional)		
Capacitor Switching Ratings (IEEE C37.09a-2005)			
High Freq. Transient Making Current	20 kA peak at 4600 Hz		

*Suitable for use on grounded capacitor banks only
** Design has SF_6 / N_2 mixture

CapSwitcher® 245 / 362 kV



362 kV pictured above

RATINGS	
Maximum Voltage Rating*	**362 kV**
BIL	1300
Continuous Current	810 A
Power Frequency Withstand Voltage	555 kV
Chopped Wave Voltage *(Optional)*	1680 kV
Power Frequency	50 / 60 Hz
Short-Time Withstand Current	40 kA RMS 1 sec *(63 kA 18 cy)*
Peak Withstand Current	40 kA RMS - 104 kA peak
Ambient Temperature Rating	-30° C to +50° C (standard)
Capacitor Switching Ratings (IEEE C37.09a-2005)	
High Freq. Transient Making Current	20 kA at 4600 Hz

* Consult factory for 245 kV applications

CLOSING RESISTOR SELECTION CHART

Applied Voltage (kV)	Bank Size (MVAR)	Closing Resistor Size
15.5	1 to 2	45 ohm[1]
	2.1 to 4.0	24 ohm[2]
	4.1 to 7.5	12 ohm
	7.6 to 15.0	6 ohm
27	1.5 to 3	90 ohm
	3.1 to 6	45 ohm[1]
	6.1 to 11	24 ohm[2]
	11.1 to 22	12 ohm
	22.1 to 30	10 ohm[3]
38	3 to 5	90 ohm
	5.1 TO 9	60 ohm
	9.1 to 15	30 ohm
	15.1 to 25	20 ohm
	25.1 to 40	12 ohm
48.3	4 to 18	40 ohm
	18.1 to 48	20 ohm
72.5	5 to 20	80 ohm
	20.1 to 72	40 ohm
123	15 to 40	150 ohm
	40.1 to 75	75 ohm
	75.1 to 130	37.5 ohm
145	10 to 25	300 ohm
	25.1 to 60	150 ohm
	60.1 to 120	75 ohm
	120.1 to 155	37.5 ohm
170	18 to 30	300 ohm
	30.1 to 75	150 ohm
	75.1 to 181	75 ohm

Notes:

1. 40 ohm resistor supplied on CAP38M and CAP72 design platforms.
2. 30 ohm resistor supplied on CAP38M and CAP72 design platforms.
3. Only available with the CAP38M and CAP72 design platforms.
4. If you have a capacitor bank size not shown in the table above for one of these kV ratings please contact Southern States for closing resistor values and provide the bank size in MVAR adn the kV rating of the installation.
5. Additionally, if desired Southern States can analyze a customer's specific installation and recommend a resistor size based upon that installation specific requirements (i.e. kV rating of the installation, single bank switching or back-to-back switching,bank size, sequence in which banks are added - for back to back applications-, etc.)

Southern States increases utility systems reliability by delivering next generation switching, automation and protection solutions built on a century of service and customer care.

Southern States

30 Georgia Avenue, Hampton, GA 30228
P 770.946.4562 F 770.946.8106
sales@southernstatesllc.com www.southernstatesllc.com
24/7 emergency support line: 770.946.4565

Publication Number CB807-Capacitor Switching Bulletin R6 04112022 Printed in USA April 2022