CAPACITOR SWITCHING DEVICE

Zero-Crossing Breaker

vs

Pre-Insertion Resistor

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Method of Transient Control

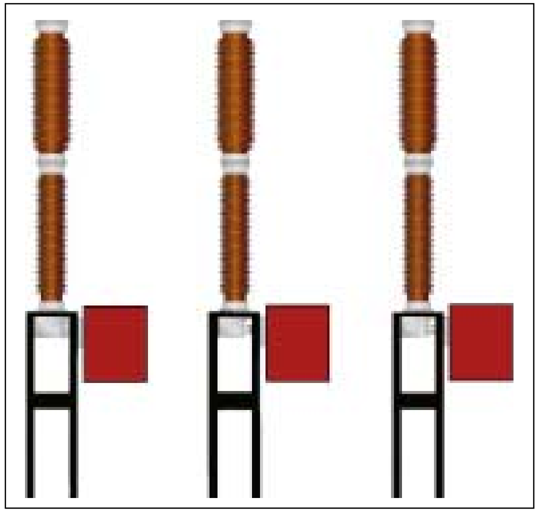
1.1. Zero-Crossing Breaker

1.2. Pre-Insertion Resistor

Method of Transient Control

Zero–Crossing Breaker

1.1



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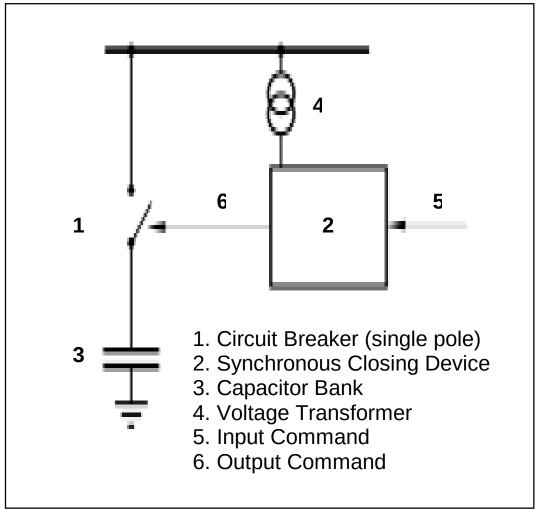
Synchronous Closing Device



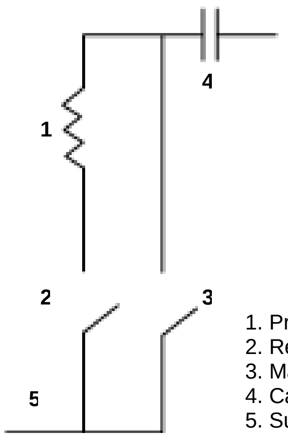
THREE "MUST" CONDITIONS :

1. CLOSING of ALL 3 PHASES at a ZERO VOLTAGE is a MUST
2. PRECISE TUNING and CONTROL of the 3 INDIVIDUAL POLES is a MUST
3. NO DRIFT of TIMING CALIBRATION is a MUST

Method of Transient Control

Pre-Insertion Resistor

1. Pre-Insertion Resistor
2. Resistor Contact
3. Main Contact
4. Capacitor Bank
5. Substation



1. Pre-Insertion Resistor
2. Resistor Contact
3. Main Contact
4. Capacitor Bank
5. Substation

“RESISTORS” (1) are typically inserted into the capacitive-energizing circuit through the closing of “RESISTOR CONTACT” (2) for 5 ms to 15 ms, prior to the closing of the “MAIN CONTACT” (3).

Design & Reliability

2.1. Zero-Crossing Breaker vs Pre-Insertion Resistor

Design & Reliability

Zero-Crossing Breaker vs Pre-Insertion Resistor

2.1

	Description	ZERO-CROSSING BREAKER	PRE-INSERTION RESISTOR
1.	Specifically Designed and Tested for Capacitor Switching	No	Yes
2.	Number of Operating Mechanisms (spring loaded systems, shunt trips, motor operators)	3 (one per phase)	1 (one for 3 phases)
3.	Allows Two or One Phase Closing of the Capacitor Bank (if one operating mechanism fails to operate)	Yes	No
4.	Key Factor for Successful Transient Suppression	• Capacitor Bank must be switched exactly when the voltage is crossing ZERO. • Electronic circuitry must successfully detect when the voltage wave is crossing ZERO and order the mechanical mechanism that drives the interrupter to close. • Complicated calculation are required to offset effects of external conditions, mechanical wear, etc.	• Simple electrical principle of a resistor in the circuit. • Key factor is simple physics.
5.	Reliability Factors	• Synchronous closing system is hard to maintain within required precision. • A highly precise electronic system tied to a mechanical device (interrupter) is not a guarantee for performance.	• Highly reliable

3

Computer Simulation of Capacitor Switching Transients

3.1. Zero-Crossing Breaker vs Pre-Insertion Resistor

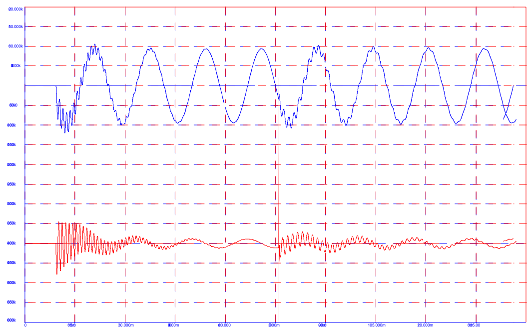
3.2. Summary & Conclusion

3.3. Reference : "Pre-Insertion Resistors in HV Capacitor Bank Switching"

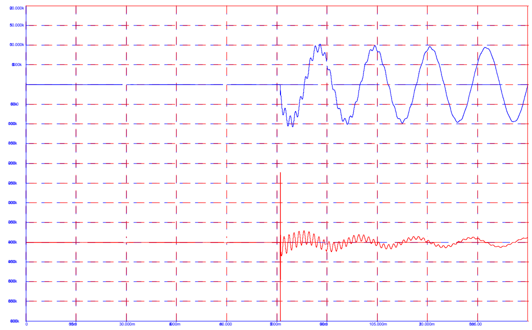
Computer Simulation of Capacitor Switching Transients

3.1

Zero-Crossing Breaker



Voltage and Current for Energization of 1st Bank

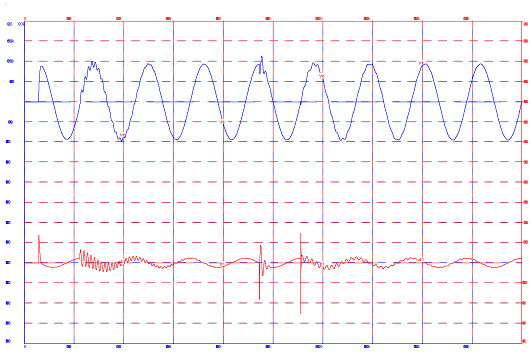


Voltage and Current for Energization of 2nd Bank

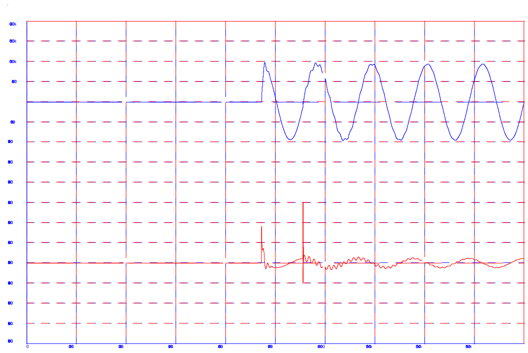
Zero-crossing Breaker	Peak Current	Frequency	Peak Voltage
Bank 1 Energization	**942A**	**944Hz**	**120kV (1.28pu)**
Bank 2 Transient	**5021A**	**16,807Hz**	108kV (1.15pu)
Bank 2 Ringing	419A	672Hz	

Zero-crossing Breaker	Peak Current	Frequency	Peak Voltage
Bank 2 Energization	5228A	16,667Hz	108kV (1.15pu)
Bank 2 Ringing	420A	670Hz	

Pre-Insertion Resistor



Voltage and Current for Energization of 1st Bank at 80 Ohms



Voltage and Current for Energization of 2nd Bank at 80 Ohms

Pre-insertion Resistor	Peak Current	Frequency	Peak Voltage
Bank 1 Energization	**835A**	NA	97kV (1.03pu)
Bank 1 Transient	404A	**948Hz**	101kV (1.07pu)
Bank 2 Energization	1100A	809Hz	**114kV (1.21pu)**
Bank 2 Transient	1520A	16,400Hz	
Bank 2 Ringing	235A	670Hz	97kV (1.03pu)

Pre-insertion Resistor	Peak Current	Frequency	Peak Voltage
Bank 2 Energization	1100A	892Hz	98.7kV (1.05pu)
Bank 2 Transient	**1820A**	**16,529Hz**	
Bank 2 Ringing	235A	672Hz	98.3kV (1.05pu)

In addition, the I^2t for the 80 ohm pre-insertion resistor is $330A^2s$.

Computer Simulation of Capacitor Switching Transients

3.2

Summary

Simulation Case	Single-Bank		Back-to-Back		PEAK VOLTAGE
	PEAK CURRENT	FREQUENCY	PEAK CURRENT	FREQUENCY	
ZERO-CROSSING BREAKER (1 ms error)	**942 A**	**944 Hz**	**5021 A**	**16.807 Hz**	**1.28 pu**
PRE-INSERTION RESISTOR (80Ω)	**835 A**	**948 Hz**	**1820 A**	**16.529 Hz**	**1.22 pu**

Remarks : All above values are summarized from the most significant data.

Conclusion

Simulation Case	Mitigation of CURRENT TRANSIENTS	Mitigation of VOLTAGE TRANSIENTS	Remarks
ZERO-CROSSING BREAKER (1 ms error)	**Successful**	**Good**	**TRANSIENTS will INCREASE, if "TIMING CALIBRATION" DRIFTS**
PRE-INSERTION RESISTOR (80 Ω)	**Successful**	**Significant**	

3.3

"Pre-Insertion Resistor in HV Capacitor Bank Switching"

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