

Adaptive Sequential Controller Description and Operation

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What is ASC

- A power electronic circuit designed to close and open a circuit breaker or load breaker at the time of minimum stress
- ASC can be programmed to trigger the magnetic mechanism at a precise time, taking into account the breaker's speed.
- The triggering angle of the ASC is calculated so that when the breaker contacts are about to be closed, the voltage across the contacts is at or near zero.

ASC opens the breaker at zero current or minimum arc energy for any power factor.

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Switching characteristics of Breakers

- A breaker interrupts rated, or lower currents at the zero points of the instantaneous current waveform.
- While the breaker's contacts travel, the withstanding voltage v_s of the gap changes.
- The arc voltage is always in phase with the arc current.
- For a vacuum breaker, the arc voltage is constant (about 20V) regardless to the current.
- The rating of a breaker is based on the tolerable arc energy.

The gap dynamics is a quadratic function of time.

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Closing Dynamics of CB

- As the contacts gap decreases, the withstanding voltage, $v_s(t)$, decreases.
- The arc will not exist if the voltage across the contacts' terminals, $v_t(t)$, is always less than $v_s(t)$ except at the zero crossing.

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Closing Dynamics of CB

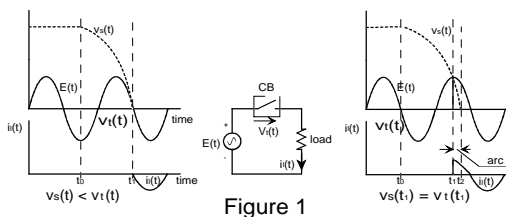


Figure 1

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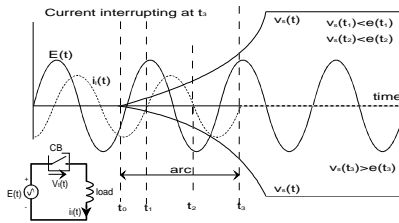
Opening Dynamics of CB

- After the initiation of breaker opening, arc will exist until the current crosses its zero point (at t_1).
- If $v_t(t_1) > v_s(t_1)$ at the zero current crossing, the gap dielectric strength is still small causing the arc to continue to the next zero crossing of the current.
- Arc will be extinguished only if the current goes to zero and the terminal voltage of the breaker is less than the breaker's withstanding voltage.

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Opening Dynamics of CB



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Switching of Capacitive Load

- **Capacitive loads:** Capacitors, lightly loaded transmission lines or energizing loaded or unloaded transmission lines
- **Switching on:** At the instantaneous zero voltage.
- **Switching off:** arc is extinguished after $v_s(t)$ is greater than twice the source voltage.

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Switching of Capacitive Load

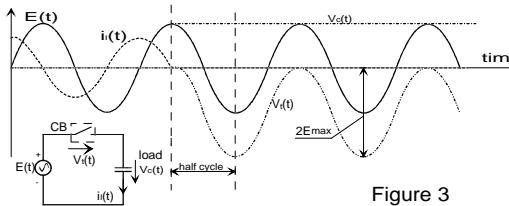


Figure 3

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Switching of Inductive Load

- **Inductive loads:** Inductors, short-circuit, energizing a transformer, lightly loaded transformers, motors startups
- **Switching on:** to minimize the transient component, and to prevent transformers from saturation, contacts are preferred to be closed at 75 to 85 degrees.
- **Switching off:** arc is extinguished after $v_s(t)$ is greater than the source voltage.

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Switching of Inductive Load

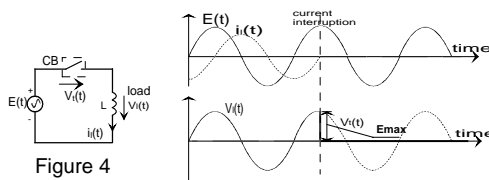


Figure 4

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Closing CB at Minimum Energy

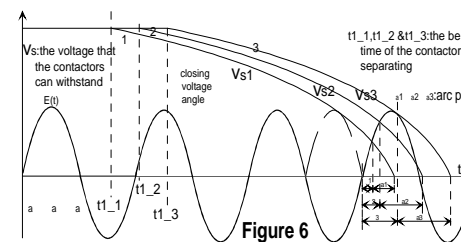


Figure 6

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Closing CB at Minimum Energy

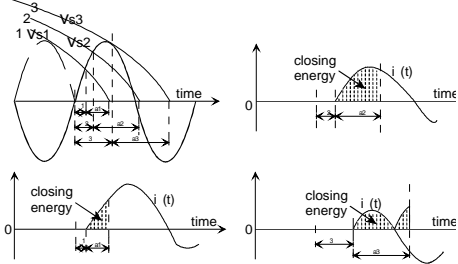


Figure 7

Arc Energy

- The arc energy can be reduced to zero for fast breakers. This is because of the large slope of the withstanding voltage
- Slower breaker will always have arc energy. The energy, however, can be reduced by selecting α .

Opening CB at Minimum Energy

- 1) inductive load

⇒ Arc is extinguished when at the zero current the withstanding voltage $v_s(t) \geq v_{max} + \Delta v$

⇒ Δv is called margin opening voltage

- 2) Capacitive load

• Arc is extinguished when at the zero current the withstanding voltage $v_s(t) \geq 2v_{max} + \Delta v$

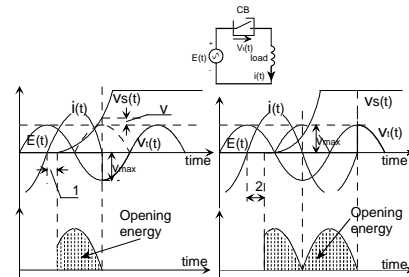


Figure 8

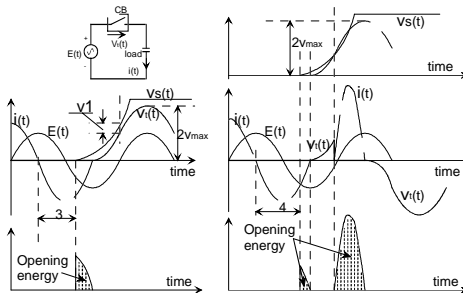
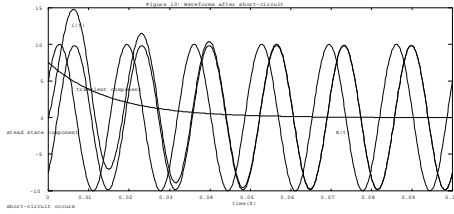


Figure 9

Interrupting a Fault

- Due to the dc component of the transient current, it is not possible to interrupt the CB at zero arc energy
- If the dc component can be anticipated, a triggering angle can be computed to reduce the arc energy.

Interrupting a Fault



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Current Source Control Circuit (CSCC): Why?

- Travelling trajectory of a breaker is affected by the variations of the secondary voltage. Switching time and withstanding voltage characteristics are also affected.
- Circuit components (especially the storage capacitors) may drift due to temperature variations.

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Current Source Control Circuit (CSCC): Purpose?

- CSCC provides a constant current to the switch solenoids to ensure constant switching time.

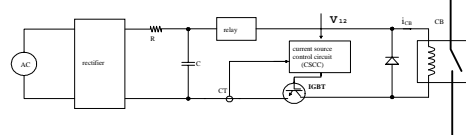
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Driving Circuit of ASC

Block Diagram of CB Driving Circuit

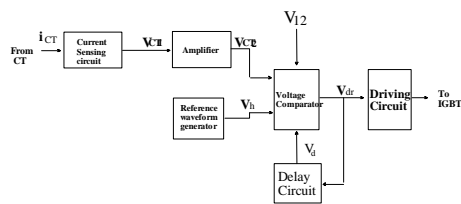
(Design #2)



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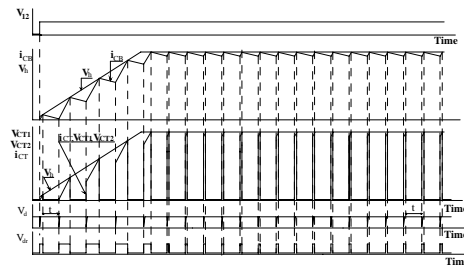
Current Source Driving Circuit



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Driving Circuit of ASC



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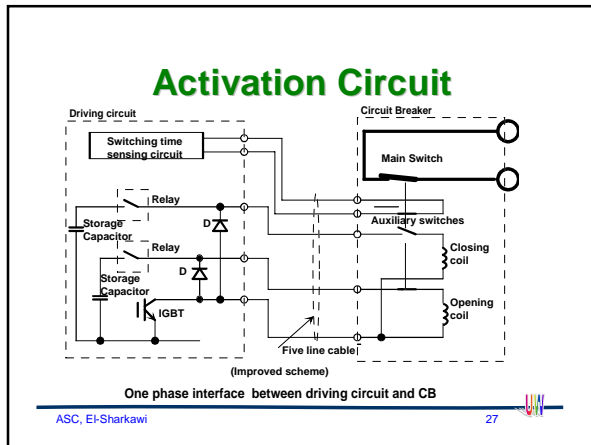
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DC voltage (V)	Closing time (ms)		Opening time (ms)	
	With CCDC	Without CCDC	With CCDC	Without CCDC
120V	36.79	33.10	34.57	28.75
140V	36.55	31.17	34.70	27.01
155V	36.69	30.24	34.42	25.92
175V	36.49	29.08	34.26	24.67
195V	36.34	27.93	34.10	23.89

Capacitance (F)	Closing time (ms)		
	DC voltage: 140V	DC voltage: 155V	DC voltage: 175V
0.0189	36.27	36.53	36.36
0.0246	36.55	36.69	36.49
0.0295	36.30	36.61	36.53

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- ## Adaptive Compensation of Breaker Speed Variation
- o Speed of the breaker may change due to weather conditions or normal wear and tear
 - o ASC detects the speed variation and compensates for it without human intervention.
 - o No current sensing is needed if the load power factor is not widely varying.
 - o The voltage of one phase must be sensed.
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- ### Main Features of ASC
- Closes electrically actuated CBs or load breakers at zero voltage across the breaker terminals
 - Opens the breaker at zero current or at minimum arc energy.
 - Capable of closing at voltage zero or at any other time in the voltage cycle.
 - Constant current source is used to drive the breaker so that switching time is kept almost constant
 - Eliminates damaging transients especially
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- ### Main Features of ASC
- Extends the lifetime of the breaker
 - Reduces maintenance of breaker
 - Breakers can be switched as often as desired
 - Adaptive: When the speed of the breaker changes, the ASC automatically compensates for it without human intervention.
 - The ASC can be used with any size of electrically controlled breaker at any voltage level.
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- ### Main Features of ASC
- It can operate grounded and ungrounded Y, delta, open delta and open Y loads.
 - It is also suitable for unbalanced loads with different PFs.
 - Only voltage sensing of one phase is needed if the load power factor is not widely varying
 - ASC is designed for any single pole breaker
 - Ganged three phase breakers must be modified before the ASC can be used
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Main Features of ASC

- Has back up switch in case of ASC malfunction.
- Suitable for different system configuration
- Switching command can be produced manually and locally.
- Switching command can be generated through a communication link.
- Switching command can be created through a Status/Control Radio.



Main Features of ASC

- ASC can also be used for var/voltage/current control.
- ASC can interface with PC for remote monitoring.
- The switching time of the breaker can be calculated from the switching time of the auxiliary switch, this makes adaptive control work more reliably.
- The controller can use one step switching time adjustment.



Other Options

- Switching Counters.
- Storage capacitor charge relay:
 - To regulate the charged voltage of the storage capacitors. When the charge reaches the desired value, the relay opens. Site overvoltage problems at night can thus be avoided.
 - Disconnection of cap charging loop while switching requires only one power supply



Other Options

- The storage capacitors with the minimum capacitance are mounted in print circuit board. Additional capacitance can be added if needed.
- Small jumps or dip switches are used to able or disable options beyond the basic functions and features.



Sensing requirements

	Three VTs			One VT	
	3 CTs	1 CT	No CT	1 CT	No CT
Grounded Y	X	X	X	X	X
Ungrounded Y	X	X	X	X	X

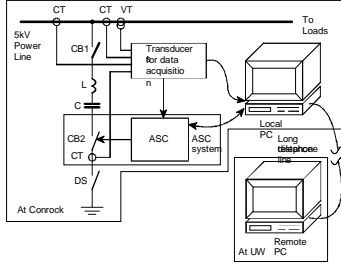


ASC Field Installation

- ASC was installed at Conrock rock crushing plant, located in LA area, on Sept. 12, 1994.
- ASC is working in the automatic Var compensation mode at 5 KV voltage level.
- ASC switches a capacitor bank rated 600 Kvar, 5-kV. This corresponds to about 90 A per phase.



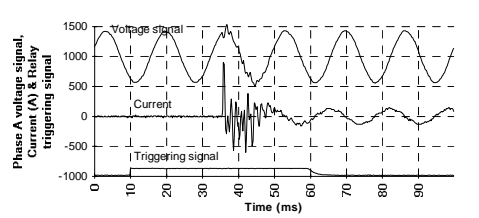
ASC Field Installation



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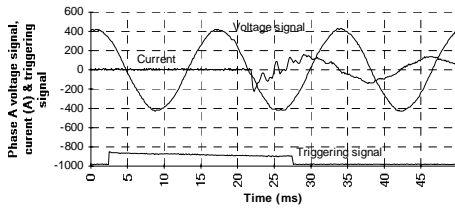
Random Closing of Caps without ASC



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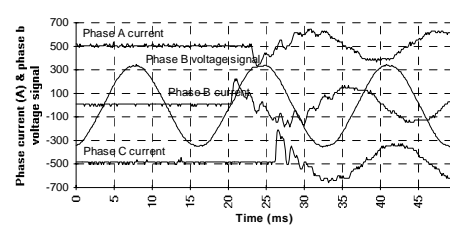
Manual Closing of Caps with ASC



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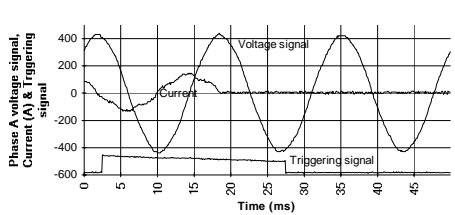
Automatic Closing of Caps with ASC



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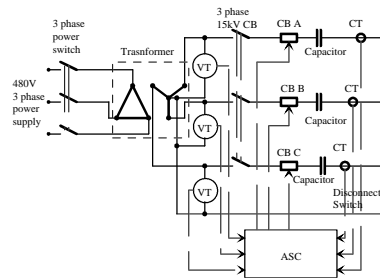
Manual Opening of Caps with ASC



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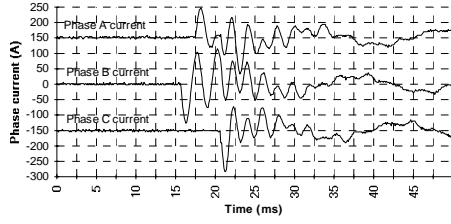
15 KV Lab Test



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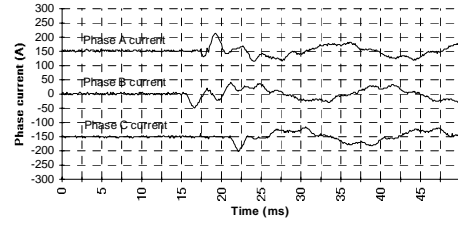
Closing Caps without ASC



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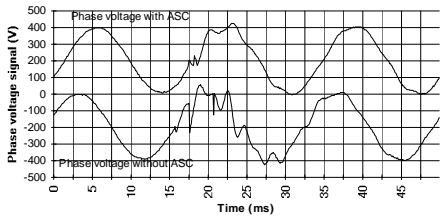
Closing Caps with ASC



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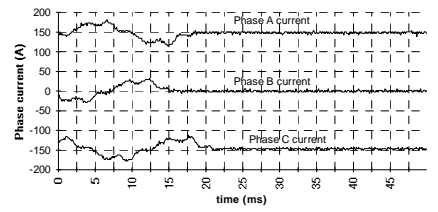
Closing Caps with/without ASC



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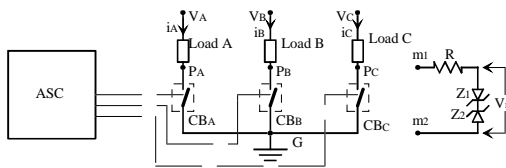
Opening of Caps with ASC



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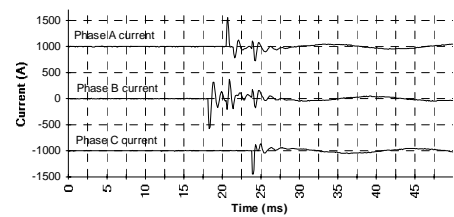
Test of ASC at 480 V



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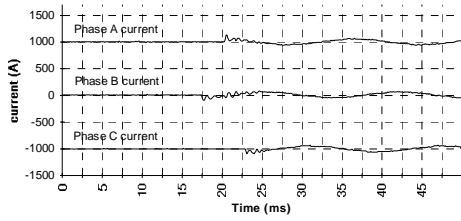
Closing without ASC



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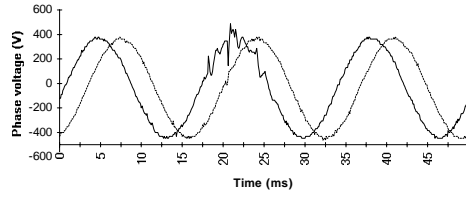
Closing with ASC



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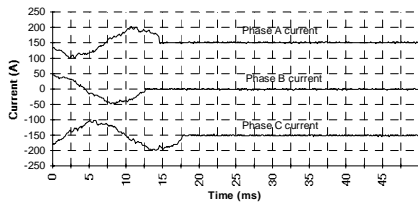
Closing Caps with/without ASC



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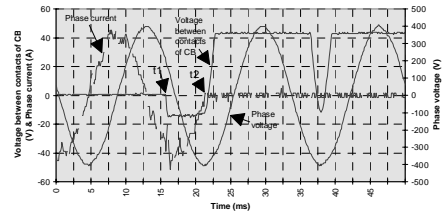
Closing Caps with ASC



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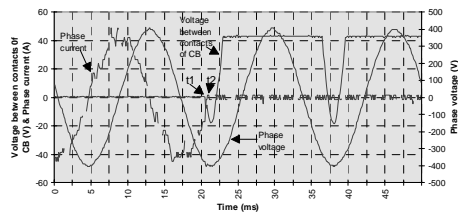
Arc Energy: Opening Caps without ASC



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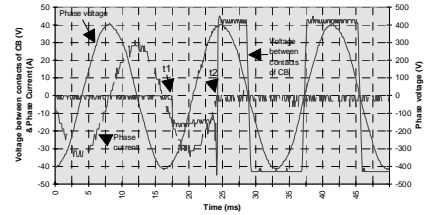
Arc Energy: Opening Caps with ASC



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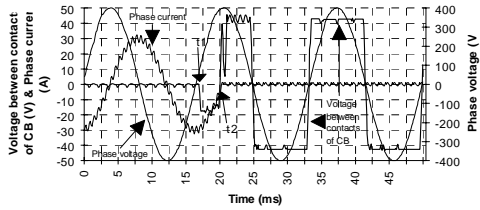
Arc Energy: Opening Inductors without ASC



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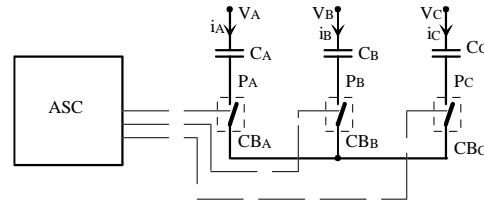
Arc Energy: Opening Inductors with ASC



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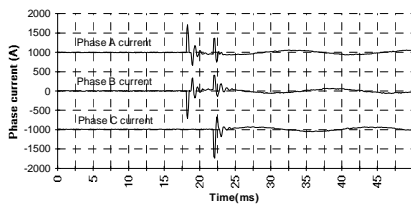
Ungrounded Y



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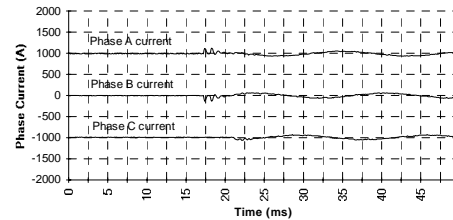
Closing Caps Without ASC



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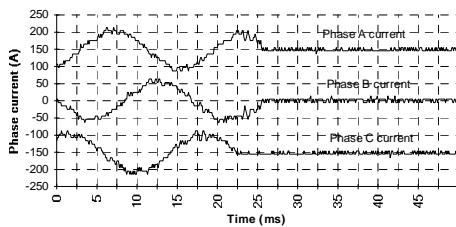
Closing Caps With ASC



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Opening Caps With ASC



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