

Development and Operational Advantages of a Solid State Circuit Breaker with Current Limiting

- Breaker Technology
- Operational Advantages
- Development Schedule

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Powell Industries Overview

We design, manufacture and package equipment and systems for the generation, transmission, distribution and control of electrical power.

- Traded on the NASDAQ
- 2000 Revenues > \$ 2 20 Million

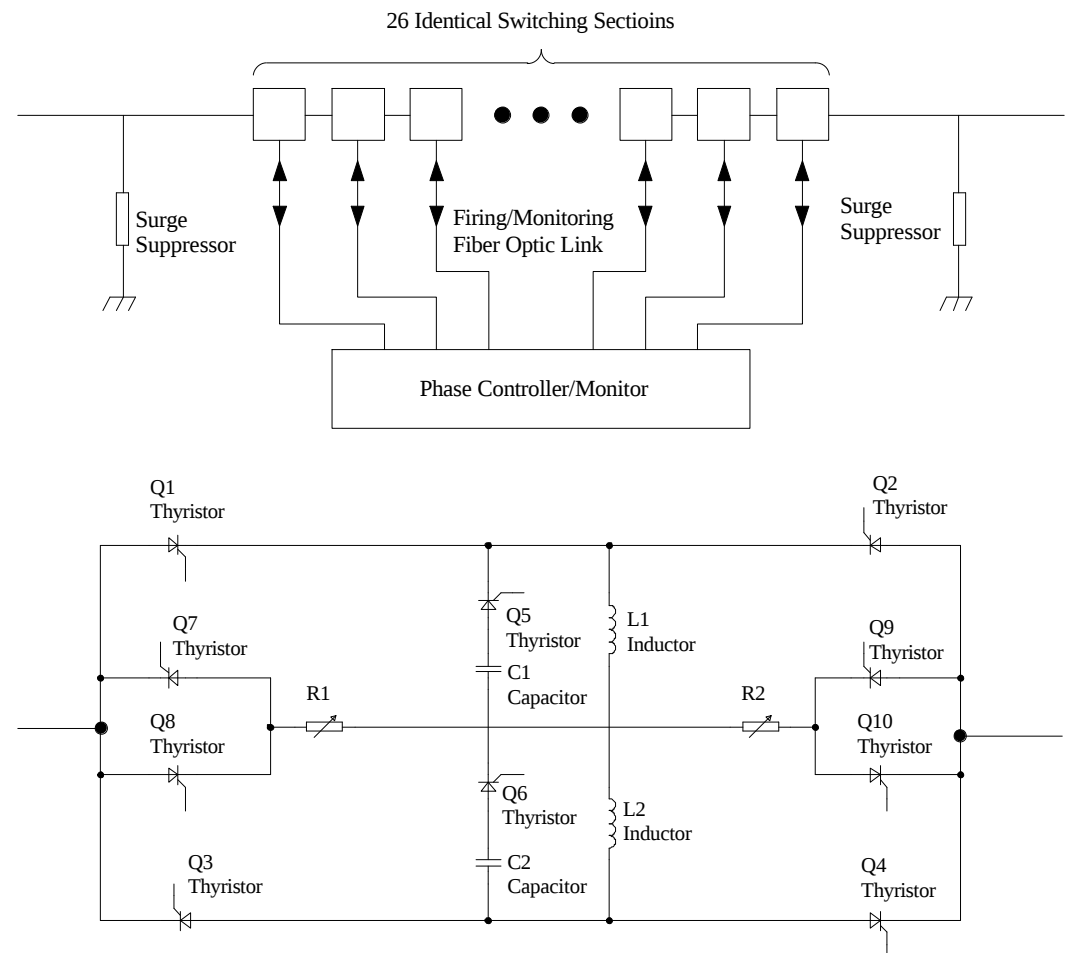
ConEd-EPRI Transmission Class Power Electronic Circuit Breaker Project

■ Specification

- System Voltage 138,000 V rms
- L-N Voltage (peak Volts+10%) 123,944 V
- Transient Voltage capability 247,888 V
(2 times peak L-N Voltage)
- Peak available asymmetrical fault current 63,000 A
- Peak fault current limit < 5,000 A
- Cost? Approximately 2.5 times cost of conventional transmission breaker

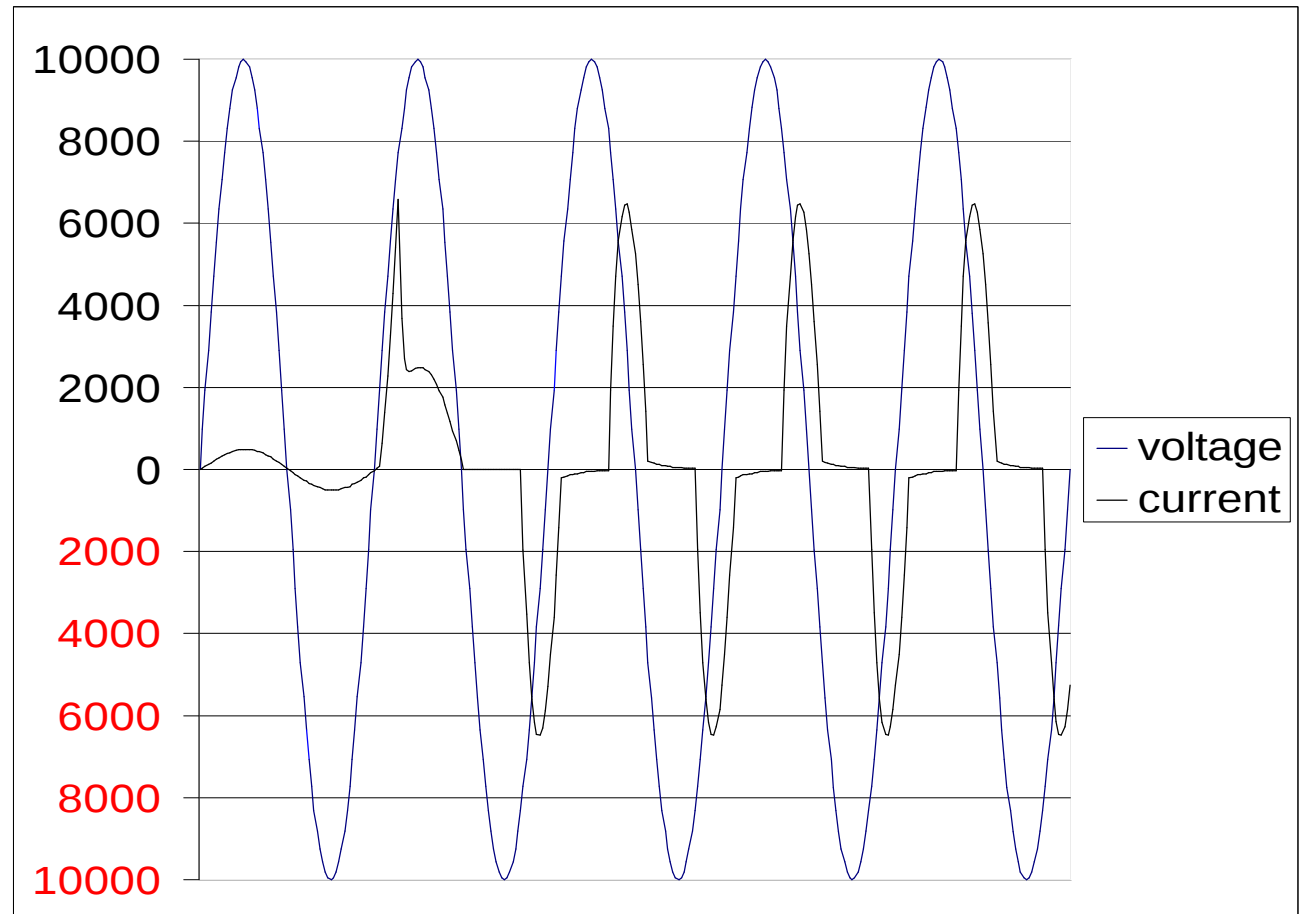
Powell Power Electronic Transmission Circuit Breaker

- 26 modules in series per phase
- 10 kV per module
- 250 kV rating for N+1 reliability
- Soft switching
- Current limiting
- No SF6 gas

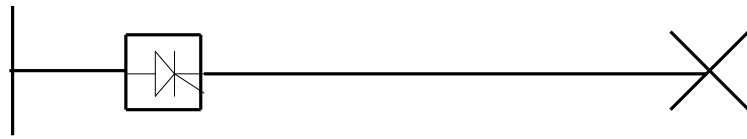


Powell Current Limiting Power Electronic Circuit Breaker

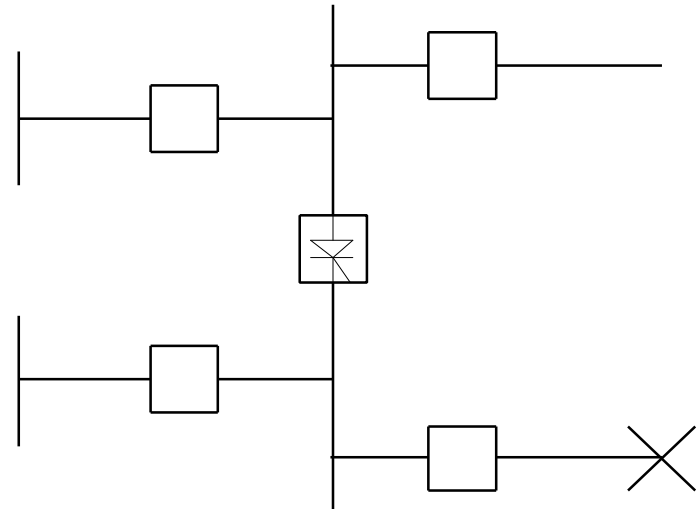
- Fault current commutates thru resistors
- Current limiting by phase controlling the SCRs



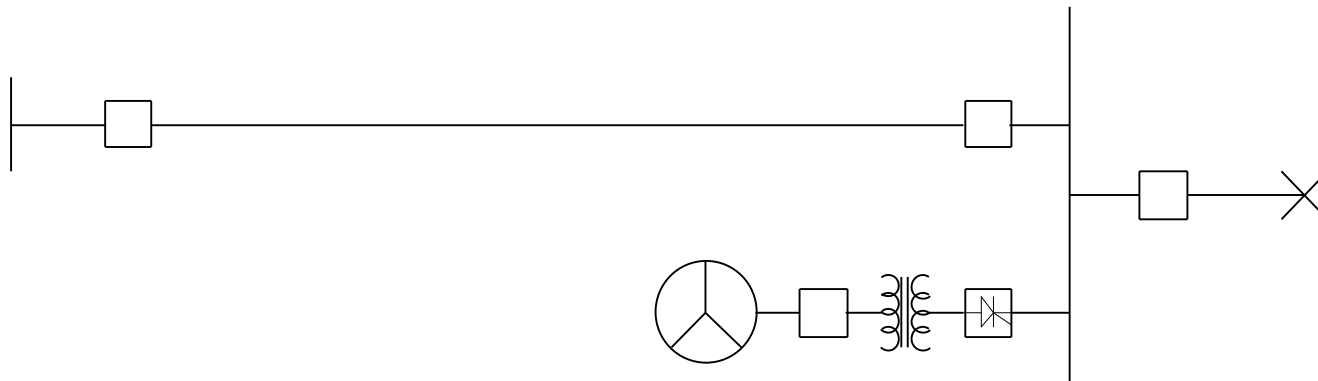
A Few Current Limiting Breaker Applications



Radial Distribution Feeder



Bus Tie Breaker



New Distributed Generation

The Need for New Generation

In California, “13 new power plants have been approved, 4 will be operational as early as this summer”

“1300 to 1900 new power plants are needed over the next 20 years”

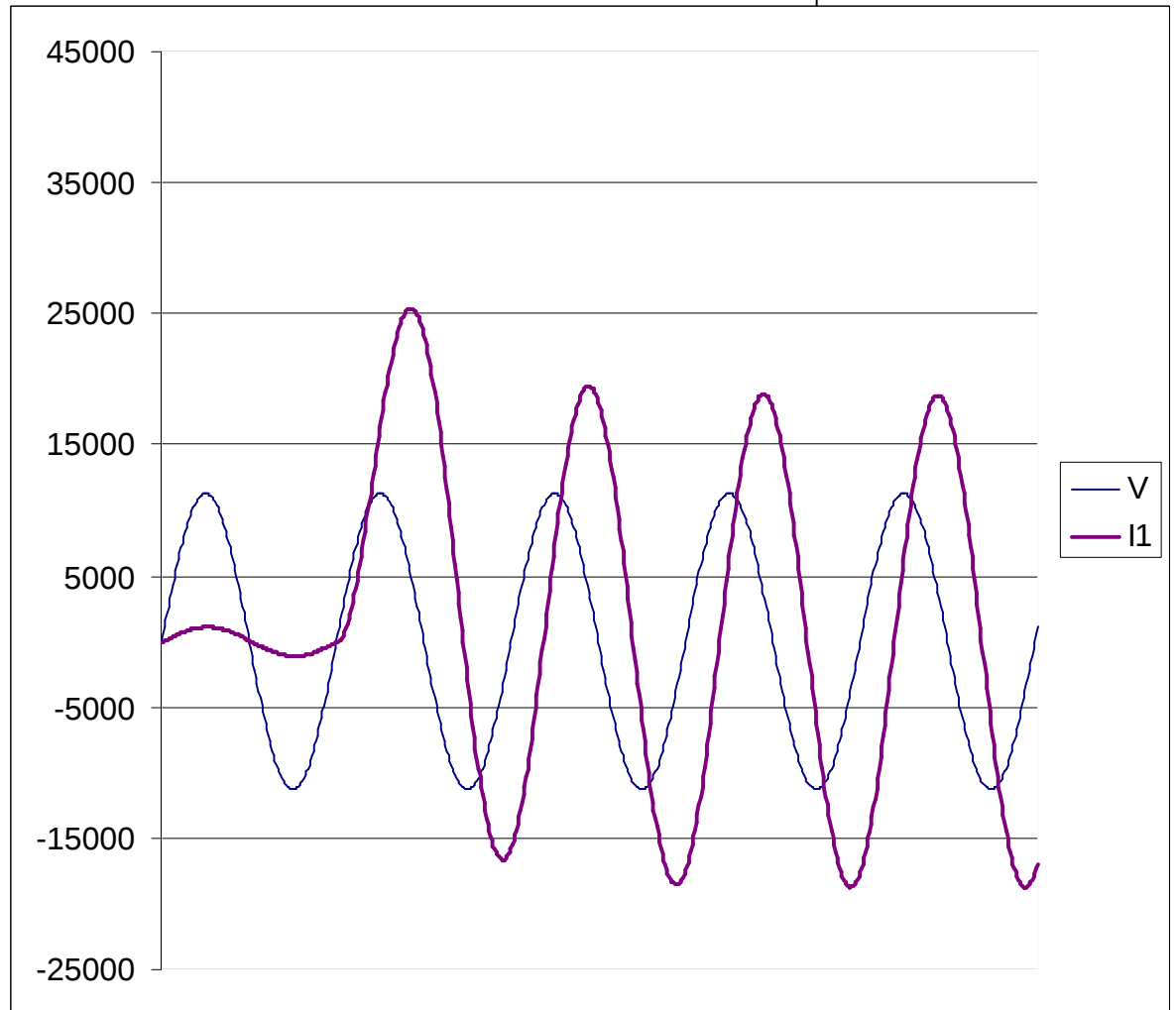
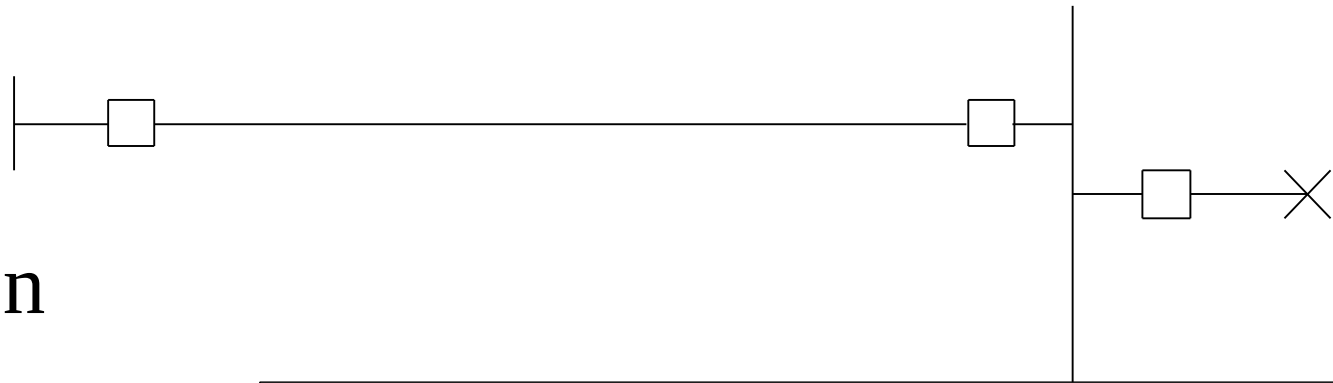
“That is a rate of installation of one every week”

New Distributed Generation

- The economic value of new generation in places like California has grown significantly
- Many new generation applications may be in the 1MW to 50MW size and located at customer sites
- These generators will be grid connected for backup power and revenue generation
- These generators may significantly contribute to available fault current levels
- Presently installed equipment may not be rated adequately to handle the new fault current levels

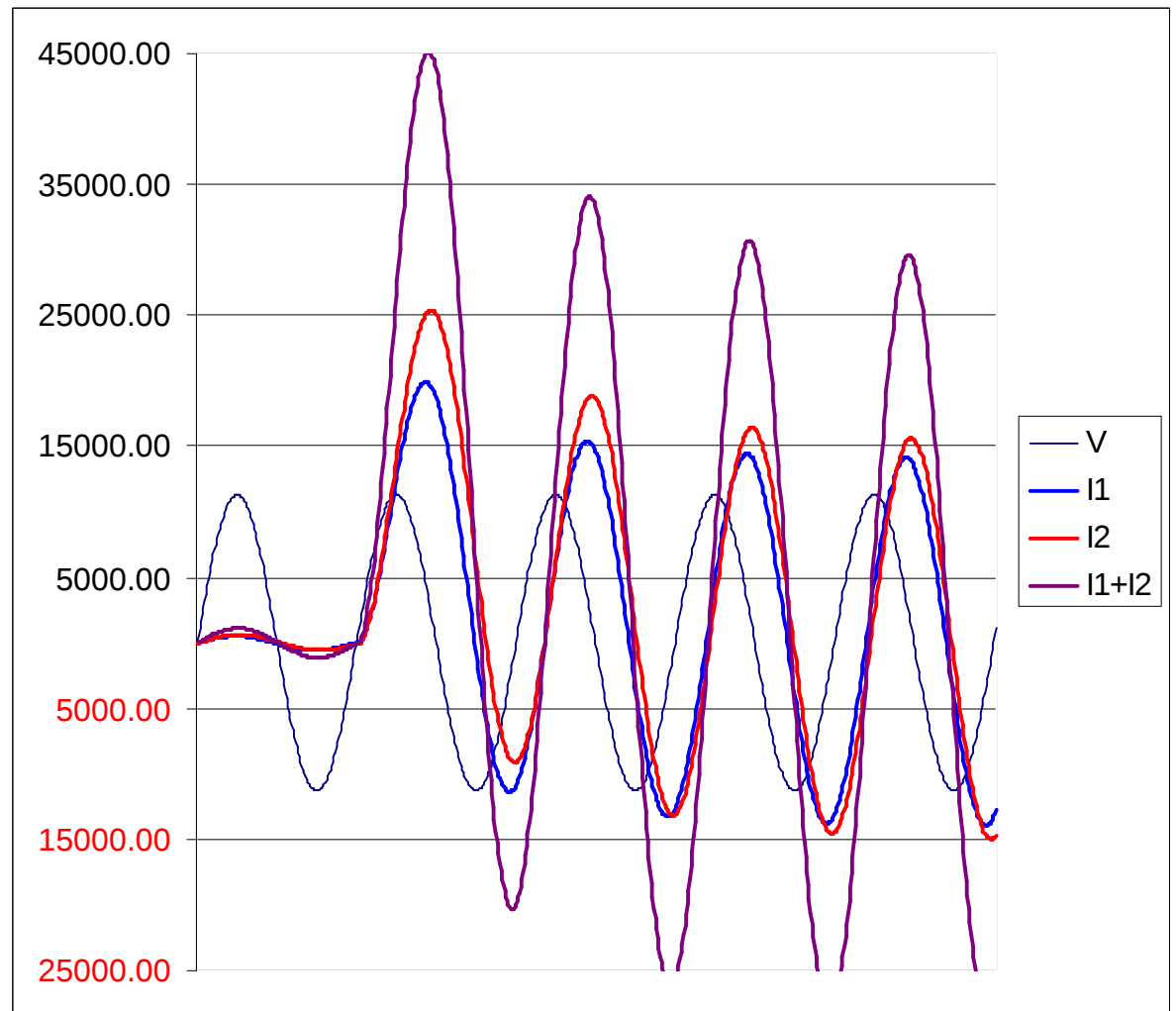
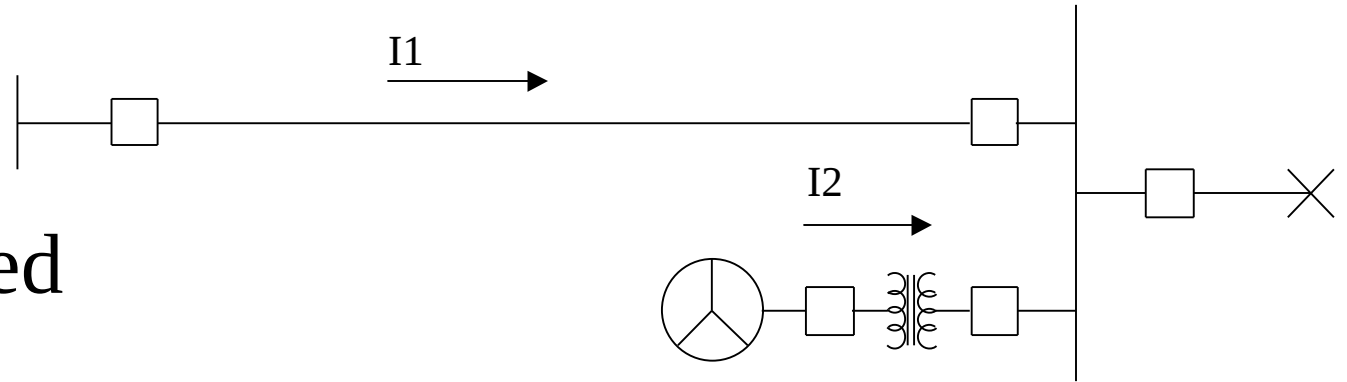
New Generation Scenario

- Present conditions
 - Fault current limited by system impedance
 - Single line to ground asymmetrical fault current 25 kA peak



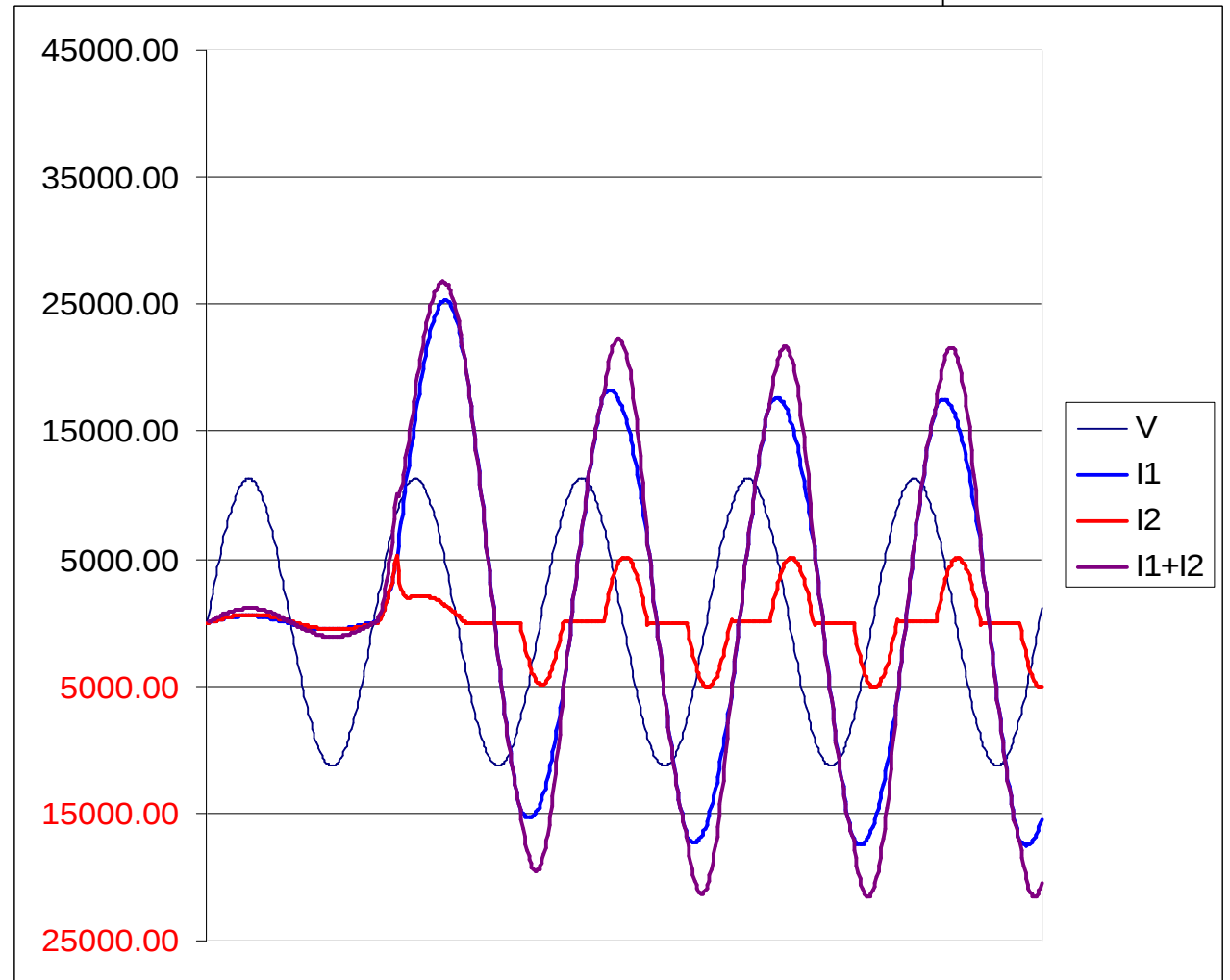
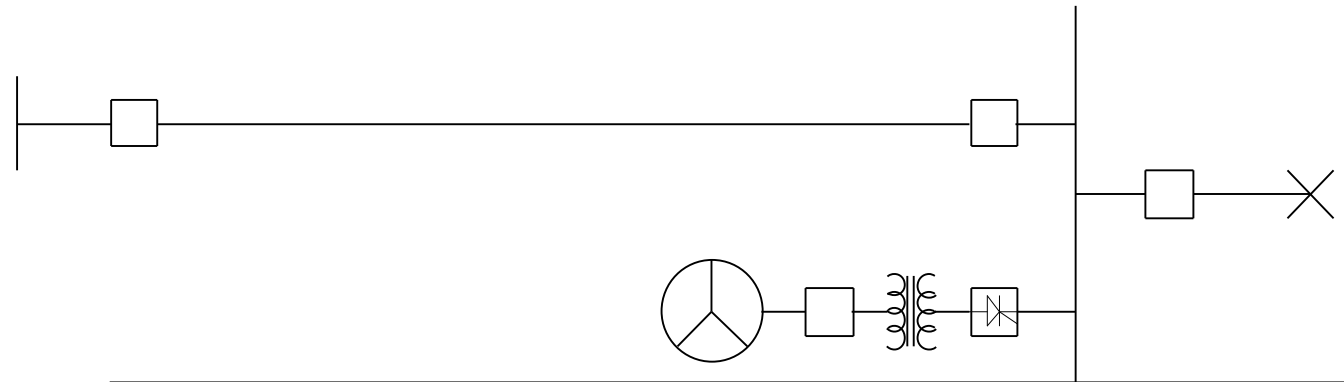
New Distributed Generation

- Distributed Generation located close to the load
- Asymmetrical fault current 45 kA peak



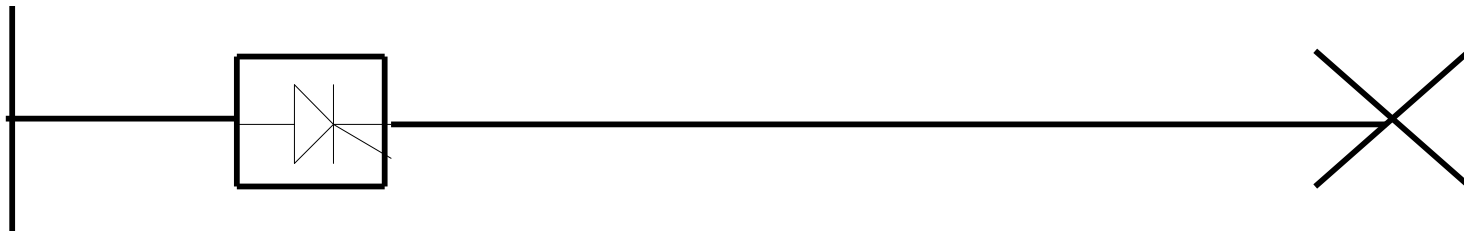
New Distributed Generation with SSCB

- Peak asymmetrical fault current is now 25 kA
- New generation with SSCB will not significantly contributed to available fault current levels



Single Line to Ground Fault on a Radial Distribution Feeder

- Distribution Voltages, 35 kV and below
- First Application for 10 kV modules
- Equipment Protection
- Substation Feeders
- Customer Loads



Radial Distribution Feeder

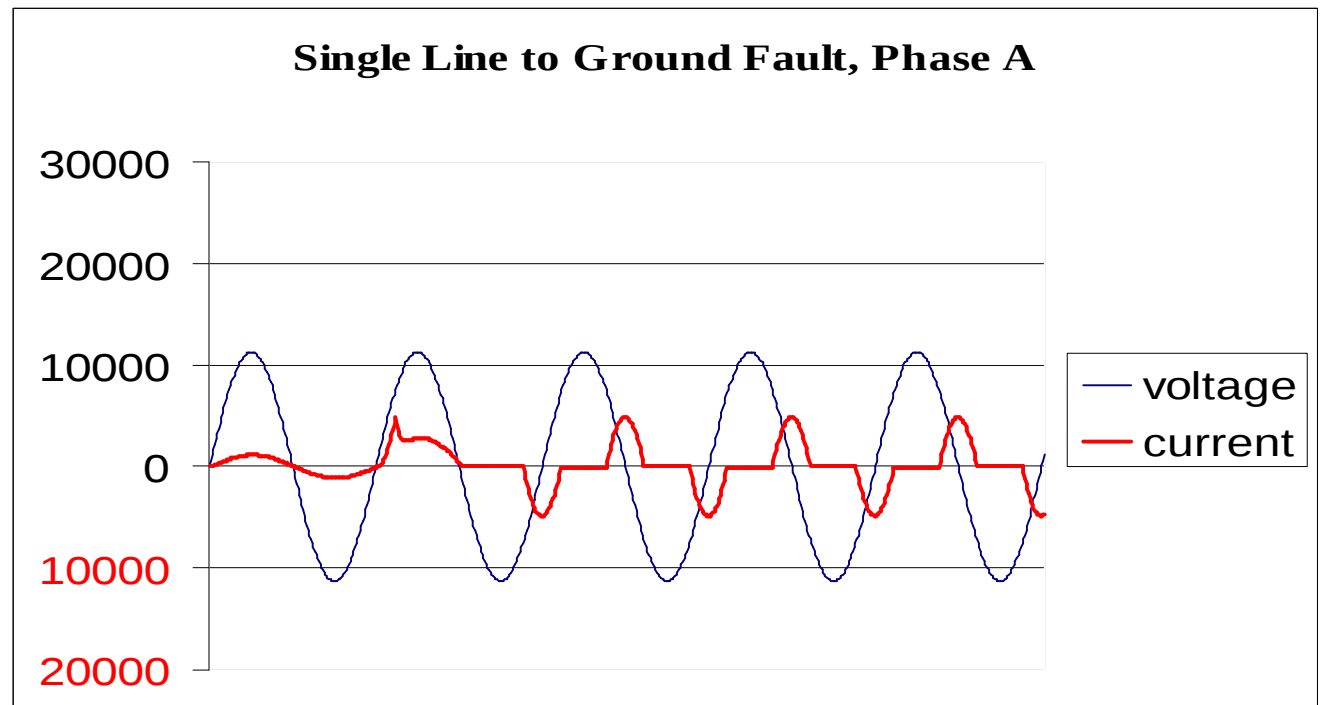
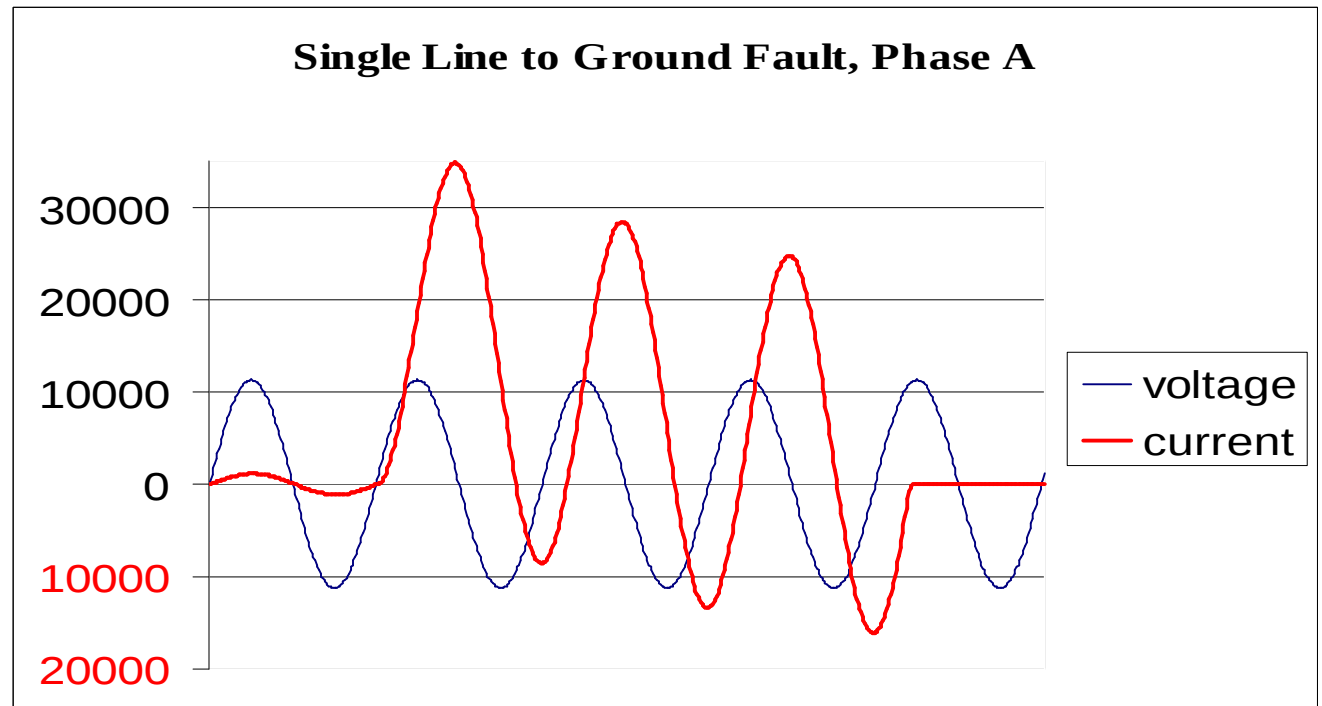
Breaker Comparison

■ Conventional Breaker

- 35 kA peak asymmetrical fault current
- All three phases interrupted

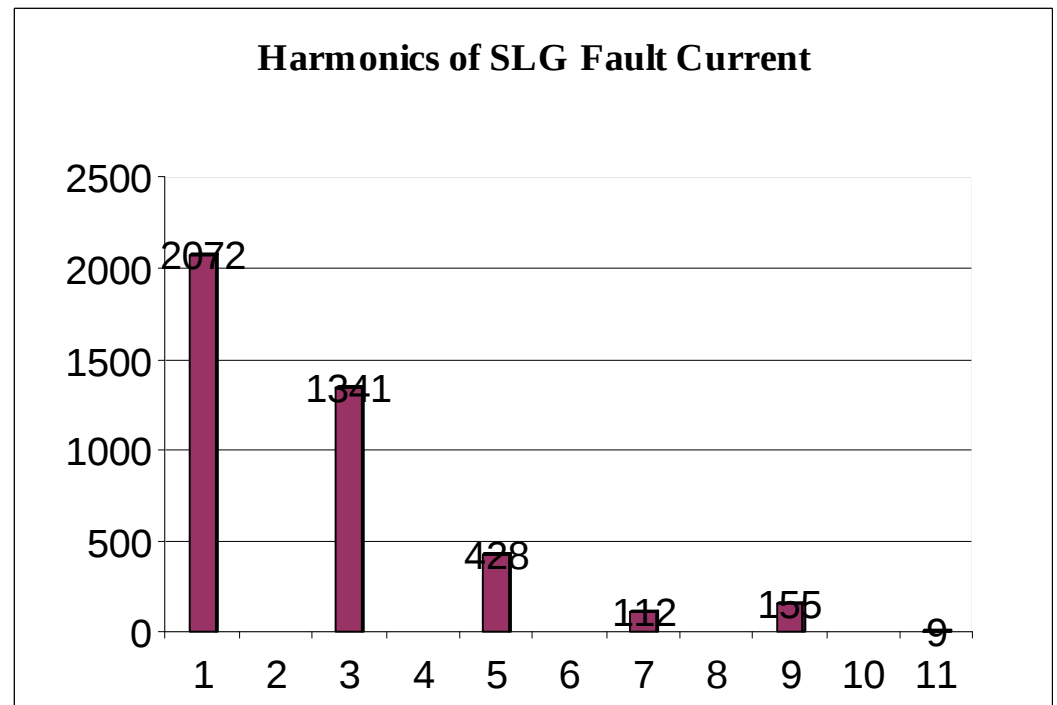
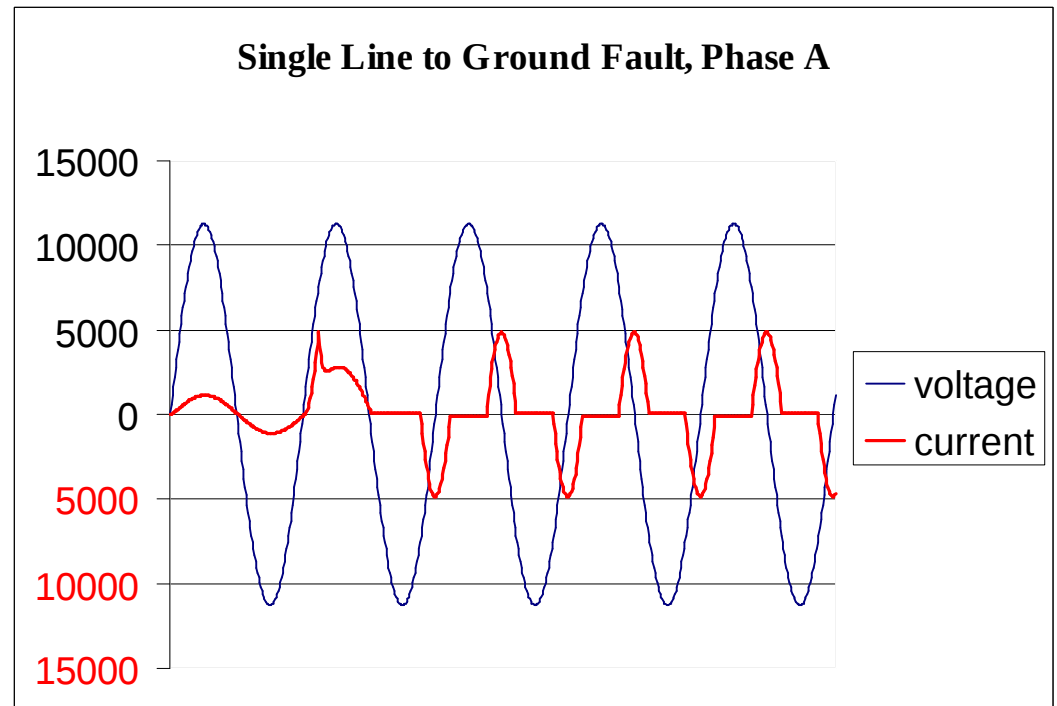
■ SSCB

- 5 kA peak symmetrical fault current
- Other 2 phases uninterrupted



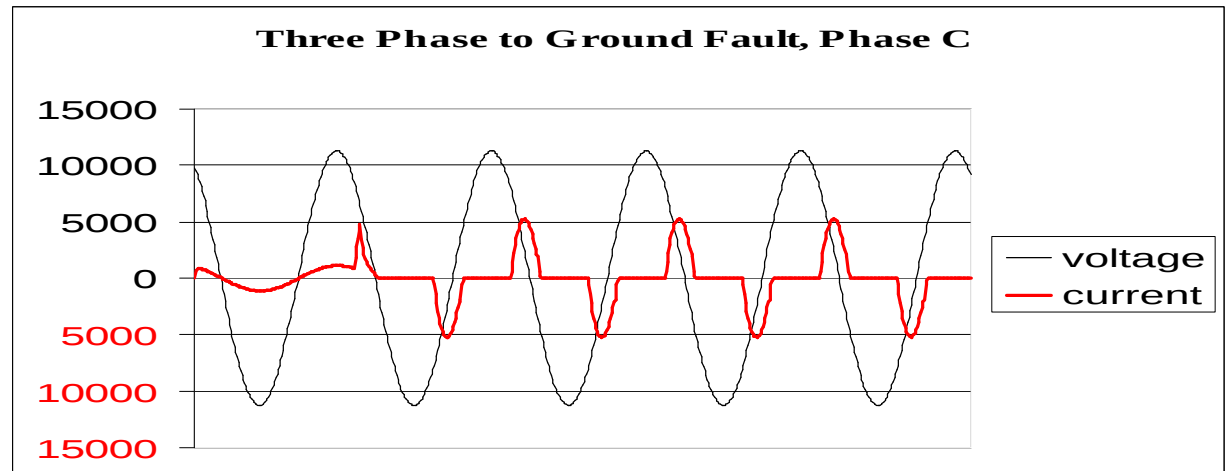
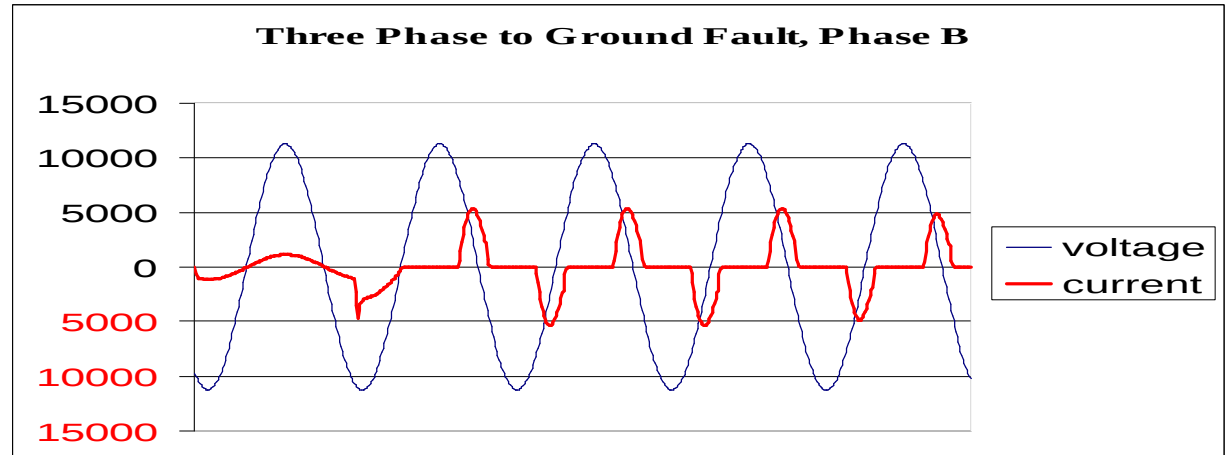
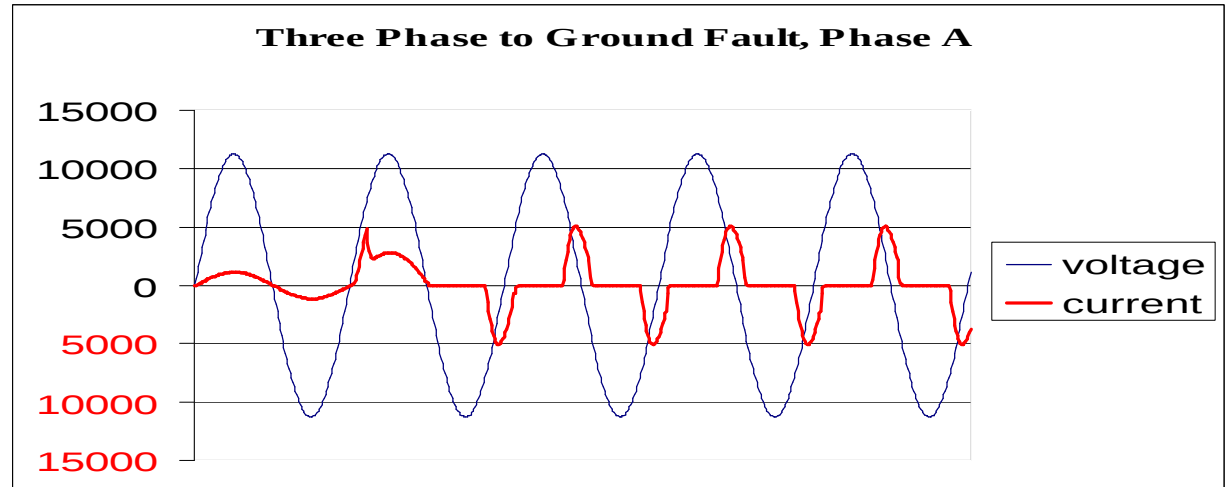
SSCB Current Limiting for SLG Fault

- SCR commutates at first 5 kA
- Series impedance is inserted for first half cycle
- Current Limit at 5 kA by phase controlling SCR
- Harmonic content,
1st-2,072 A rms
3rd-1,311 A rms



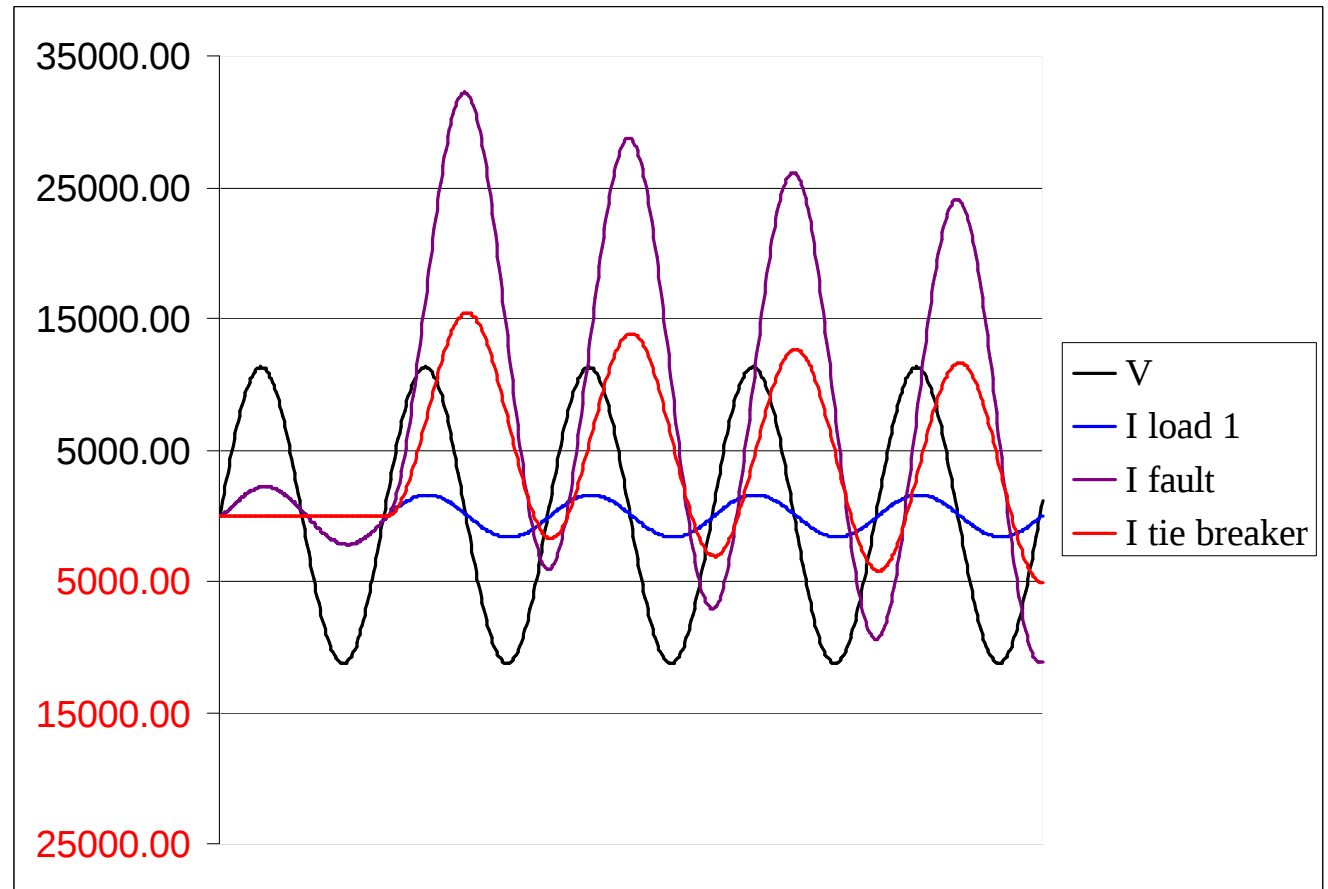
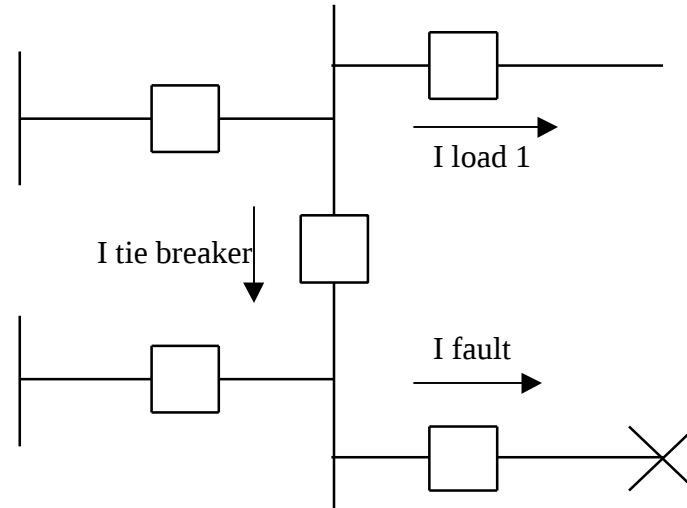
SSCB Current Limiting, 3 Phase to Ground Fault

- Each phase acts independently as though each is seeing a SLG fault
- All phases are current limited at 5 kA
- All phase currents are returning on the neutral



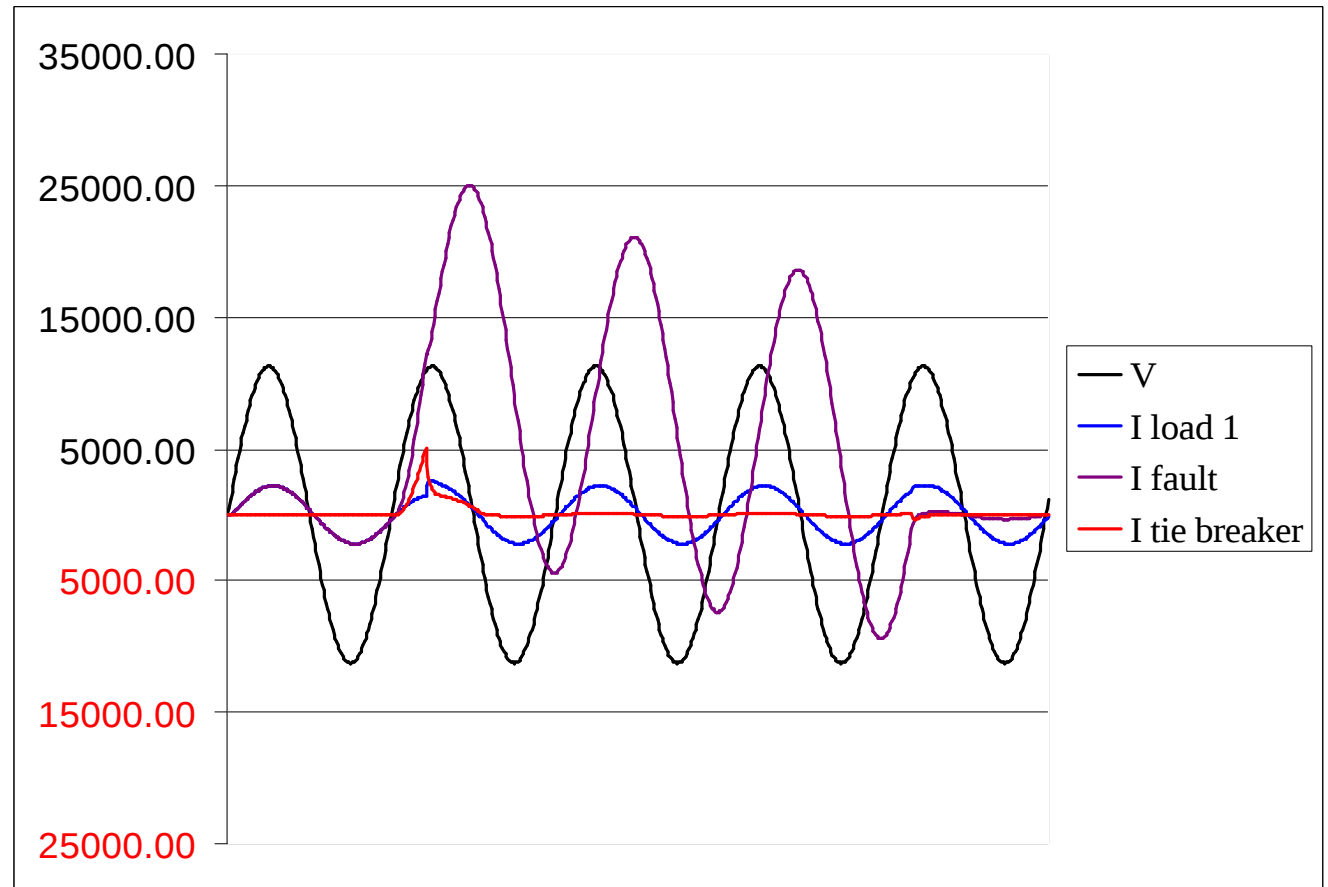
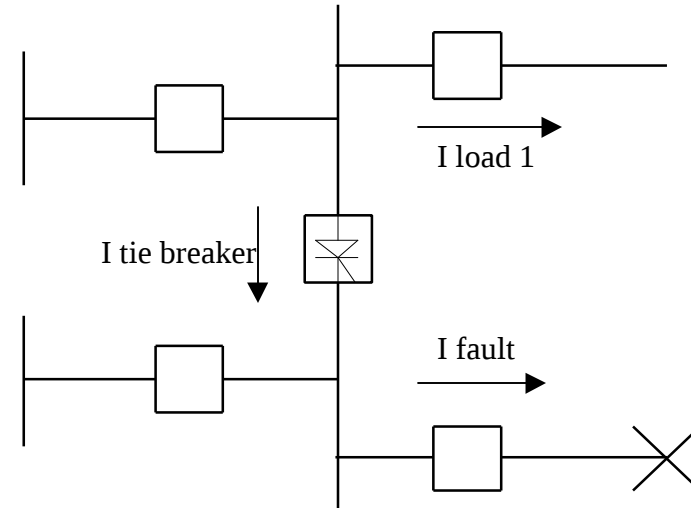
Bus Tie Breaker, No Current Limiting

- 32 kA peak asymmetrical fault current
- 15 kA peak asymmetrical tie breaker current



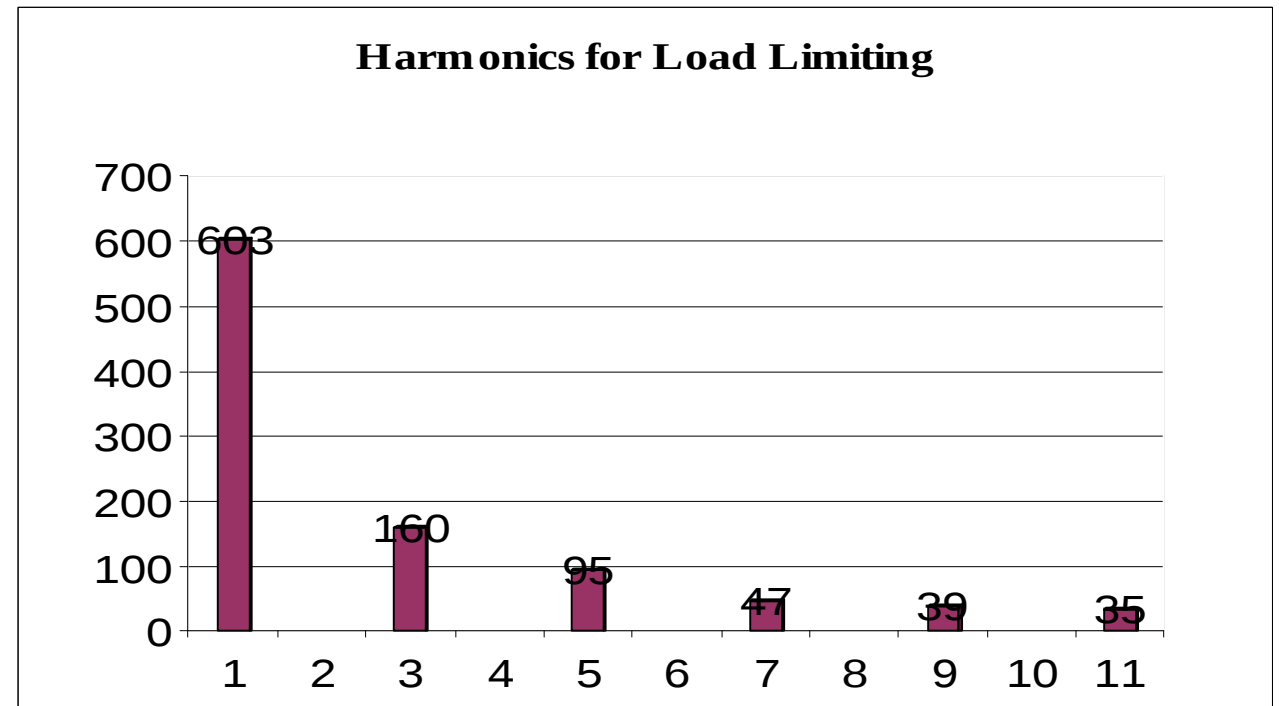
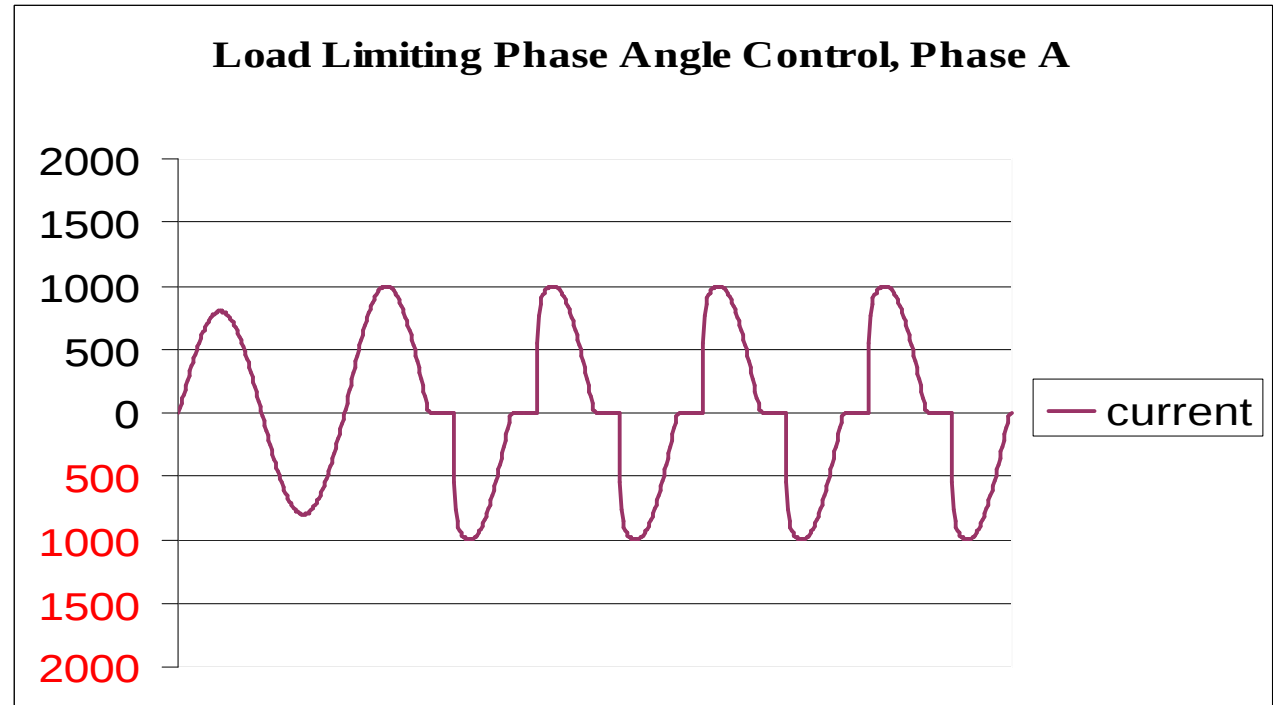
Bus Tie SSCB

- Commutate SCR on first peak
- The tie breaker does not conduct any follow on fault current
- Peak asymmetrical fault current limited to 25 kA



Load Current Limiting

- Normal operation, clean 60 Hz, no current limiting
- Phase control after the current exceeds 600 A rms
- Limit customer load current to 600 A rms
- Some harmonics will result from customer overload control



Other Advantages

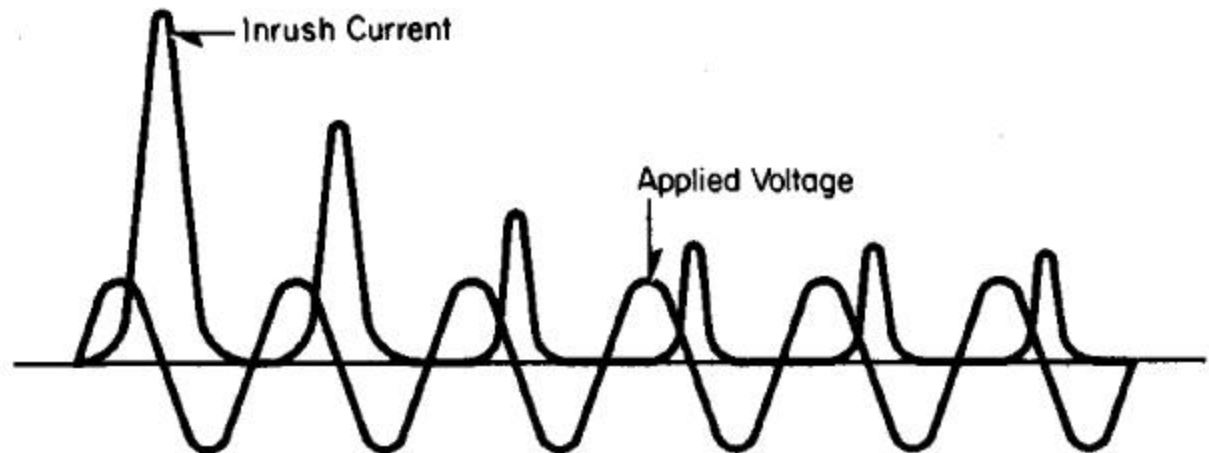
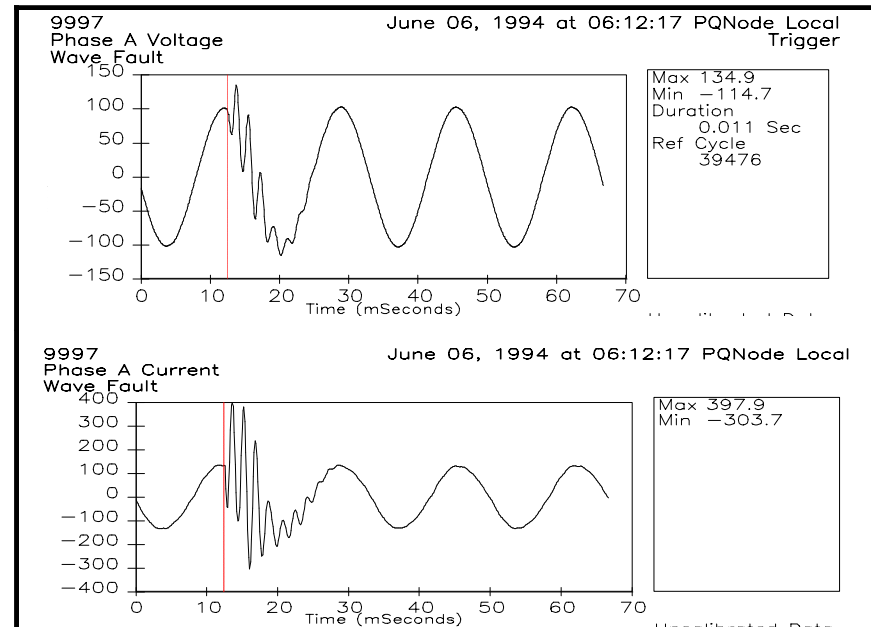
Soft On Operations

■ Capacitor Switching

- Can exceed 2 times nominal voltage
- Eliminated by switching at zero voltage crossing

■ Transformer inrush current

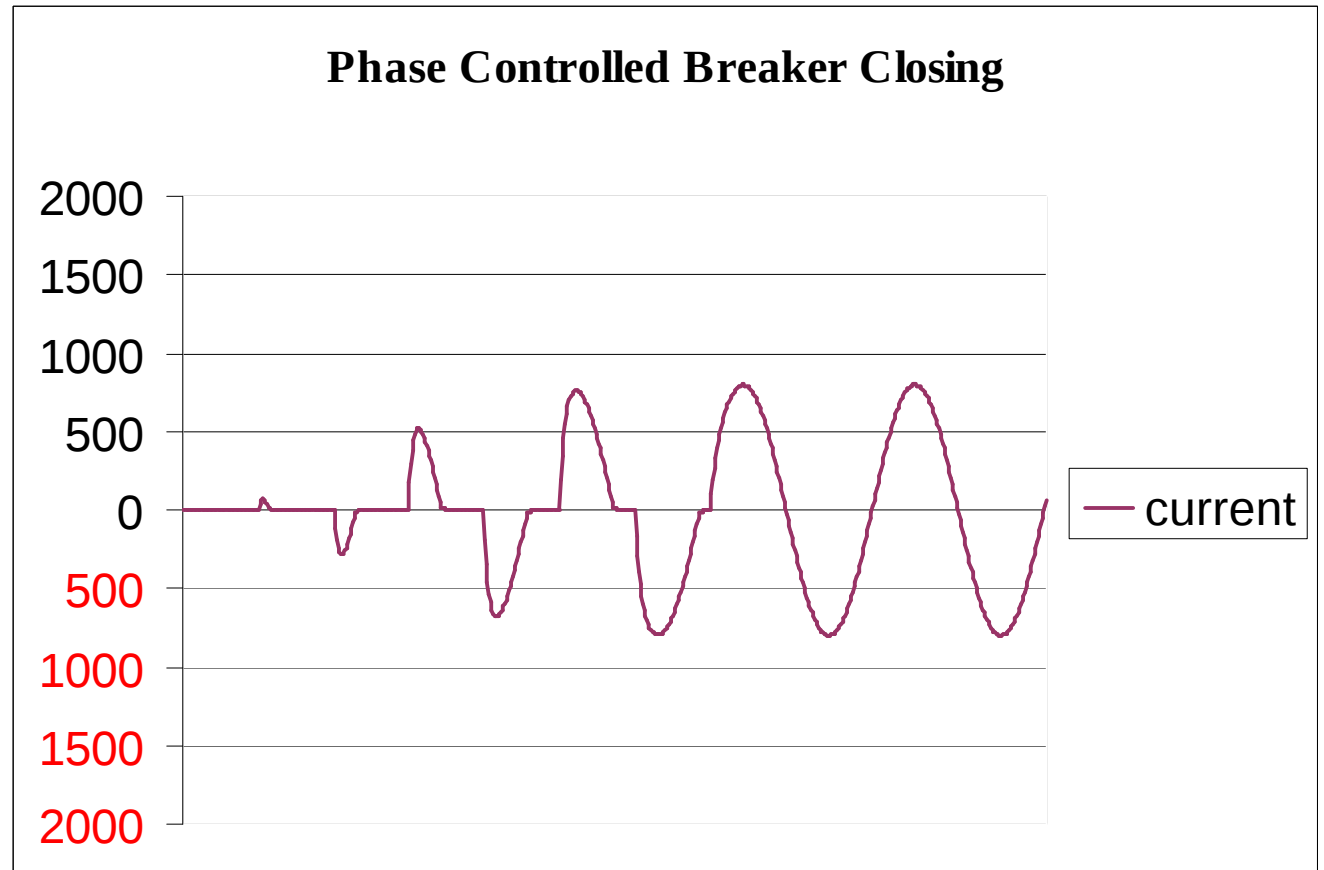
- Eliminated by switching at peak voltage



Other Advantages

Breaker Closing

- Reclosing into fault
- Transmission switching transients



ConEd Participation

- Powell is developing, with ConEd and EPRI, a current limiting solid state circuit breaker for distribution and transmission Voltages
- Utility participants will provide valuable technical insight into breaker operation, coordination, and control.
- Host utility sites are needed for product testing

Powell Power Electronic Circuit Breaker

■ Development Plan

- Develop and lab test 10 kV module
- Develop and lab test distribution class, three-phase circuit breaker using 10 kV modules
- Field test of distribution class breaker in 65 weeks
- Commercialize distribution class breaker
 - ◆ Utility and industrial markets
 - ◆ Breaker includes current limiting, metering, and programmable protection
 - ◆ Foot print? 1 SSCB = 2 Conventional Breaker Bays

Powell Power Electronics Circuit Breaker

■ Development Plan

- Develop and lab test 20 kV modules
 - ◆ New, higher voltage devices are currently being promoted by vendors
- Develop and field test 138 kV breaker in 201 weeks
 - ◆ Current limiting, metering, and programmable protection
 - ◆ Sale price $\sim$ 2.5 times conventional breaker

Summary

- Solid state circuit breakers have a niche in the market where current limiting is desired
- A successful product needs to meet the cost goal of less than 2.5X conventional costs
- Powell is developing distribution and transmission SSB/CL to meet the cost goals.
- Utility participation will create the right product for the right application