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

![Graph showing voltage and current]
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

Phase Controlled Breaker Closing

current
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 ~ 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.