DC Power Circuit Breaker Basics

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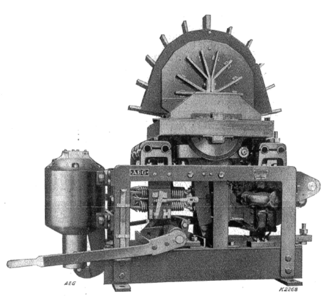
DC Breaker History

Power Circuit Breakers designed to protect dc distribution systems have been in service since the early 1900’s.

While the technology has advanced, many of the key features are still used today.



Picture courtesy of GE Energy

AEG DC Circuit Breaker, circa 1926
Rated up to 2500A, 1650VDC

Challenges Interrupting DC

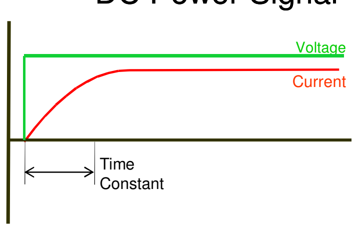
- No natural current zero to assist in interruption
- Must build and maintain arc voltage to interrupt current
- Arc movement/transfer at low currents
- Long time constants = high energy level to dissipate
- Short time constants = high fault currents to interrupt

DC versus AC

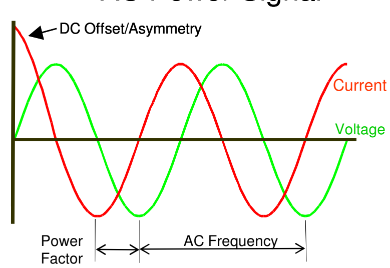
AC – alternating sinusoidal voltage & current

DC - constant voltage & current

DC Power Signal

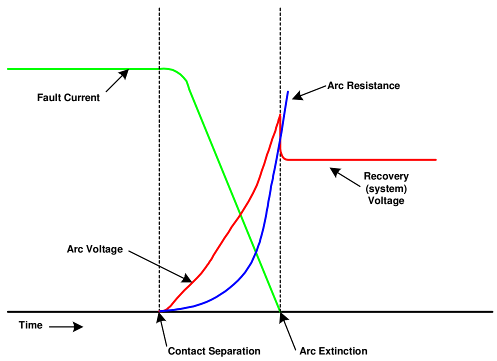


AC Power Signal



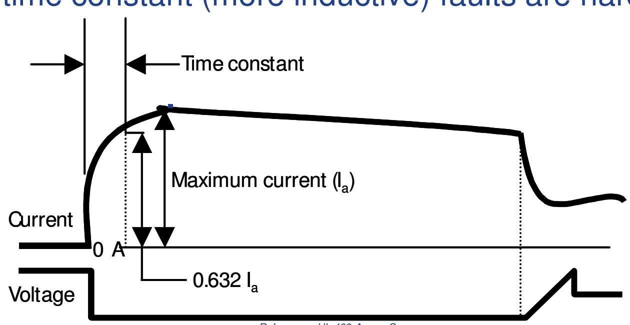
How DC Breakers do what they do

- No naturally occurring current zeros as is the case in ac systems.
- DC current must be forced to zero by the circuit breaker.
- Breaker design must generate an arc voltage which in turn causes the arc to collapse. Uarc > Usource – i*R



Effect of Time constant

- Time to reach 63% of fault current
- UL sets time constants at 8 ms for testing General Purpose Breakers, for faults greater than10KA
- IEEE has time constants ranging from 52ms to 340ms for High-Speed and Semi-High-Speed Breakers
- Longer time constant (more inductive) faults are harder to clear



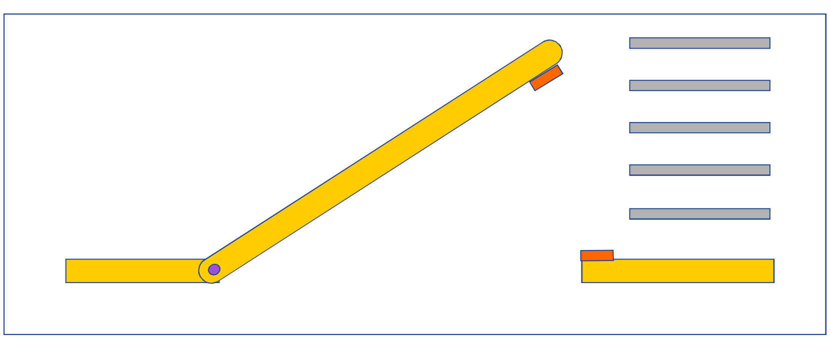
Reference: UL 489 Annex C

Manipulating the arc

- Early breaker designs relied on simply stretching and cooling the arc
- Achieving voltage drop in dc arcs of about 1 volt/millimeter was typical.
- US traction system, operating at 750 Vdc, the arc would have to be stretched nearly 30 inches
- Typical dc loads and fault currents are highly inductive, breaker must be capable of dissipating all of the energy stored in the circuit until arc extinction.

Basic interruption

1. Contacts open
2. Arc forms
3. Arc moves to Arc Chute
4. Voltage builds
5. Arc stretched & cooled
6. Arc Extinguished



High-Speed DC PCB S/C Test

800 Vdc, 200kA peak, Cleared at 170kA, Two Opening Tests

DC Breaker Standards and Classifications

IEEE C37.14 Low-Voltage DC Power Circuit Breakers used in Enclosures

IEEE C37.16 Low-Voltage Power Circuit Breakers – Preferred Ratings

Three general breaker classifications:

- General Purpose – is not current limiting, has a short-time withstand rating to allow coordination with series breakers, are rated 325Vdc and below.
- Semi-High Speed - is current limiting on circuits with higher inductance, may have a short-time withstand rating, 300-3200Vdc
- High Speed - is current limiting, may have a short-time withstand rating, 300-3200Vdc
- Rectifier Breaker - short-time withstand rating matching the rectifier, short-circuit rating of n-1 rectifiers, 300-3200Vdc

All breakers must have a short-circuit (interrupting) rating, and typically a peak current rating.

Modern DC Power Circuit Breaker Design

Thermal performance - continuous current

Maintaining dielectric strength

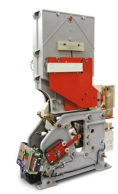
Switching current - load, overload

Containment - pressure, gasses, heating

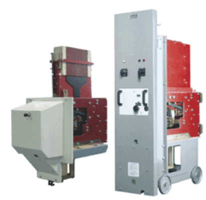
Trip time performance - high speed = current limiting

Current sensing - directional or bidirectional

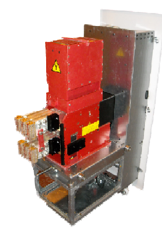
Picture courtesy of Whipp & Bourne



Picture courtesy of EMC Traction S.r.l.



Picture courtesy of Controlled Power, LLC



Picture courtesy of GE Energy

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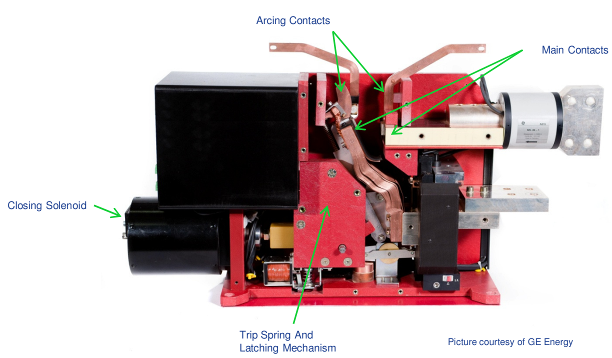
Modern DC Power Circuit Breaker Design

- 2-stage contact designs (main and arcing contacts)
- Mechanisms use solenoids, magnetic actuators or a gear motors to close.
- Tripping via springs or magnetic actuator.
- Closed position is maintained through the use of a mechanical latch, magnetic latch or a solenoid.



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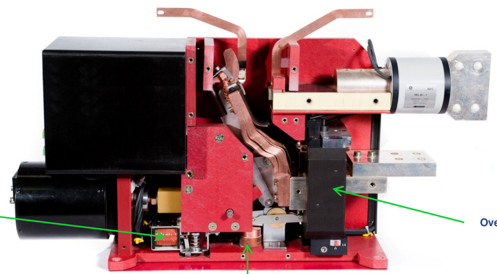
Modern DC Power Circuit Breaker Design

- Over current trip device is internally mounted, direct-acting (OCT).
- OCT can be fixed, or adjustable (1 to 4X of rated load current), generally instantaneous in operation.
- OCT devices on feeders are typically bi-directional
- OCT devices on rectifier breakers, most often only sense and trip for current flowing in the reverse direction.
- Typical options are shunt trip coils or high-speed trip coils (for use with external protective relays, such as rate-of-rise protection), or undervoltage tripping coils.



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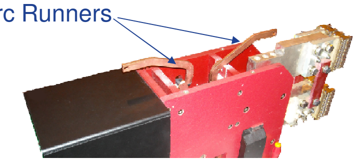
Arc Manipulation

Arc Runners
- Leads the arc away from contacts
- Transitions arc into Arc Chute
- Driven by electromagnetic forces



Picture courtesy of GE Energy

Blowout Coils
- Secondary copper coil in series with arcing contacts
- Ferrous coil around main current path
- Electro-magnetic field helps move arc into arc chute

Puffer
- Stream of air to assist moving arc into arc chute

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Arc Chute Design

Cold cathode (bare-metal-plate) arc chutes are the most common method of dc arc interruption today. The cold cathode arc chute is well suited to the interruption of dc currents as it provides a fairly fixed or predictable arc voltage regardless of the arc current.
In the arc chute, the arc is moved under the influence of it's own magnetic field, upwards, after transferring from the contacts onto the arc runners and up into the arc chute. Once the arc is in the chute, it is then split into a number of smaller arcs by a series of splitter plates and is cooled.

Steel plates in insulated housing

Breaks arc into multiple smaller arcs

Plates cool arc, absorb heat

Materials impact arc stability

Plate shape impacts arc mobility

Picture courtesy of GE Energy

Typical DC Power Circuit Breaker Applications

Traction Market
- Tramways, Trolleys
- Light & Heavy Rail

Industrial Applications
- DC Drives in Steel Works, Metal Processing
- Electrolysis
- Mining

Energy
- Wind
- Photovoltaic
- Storage

Others
- DC Data Centers
- Research/Testing Labs

Thank You

and

Questions?

References

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[6] ANSI/IEEE C37.16 Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors – Preferred Ratings, Related Requirements, and Application Recommendations - 2000