Solid State Circuit Protection

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ATOM POWER INC

Primer on Circuit Breakers Today

All the power we consume travels through circuit breakers….and lots of them.

Circuit breakers are singularly purposed for circuit protection

Circuit breakers today are slow, have limited intelligence, static (don't change over time), and are exclusively mechanical

Circuit breakers are purpose-built for their specific application, making performance and usage purely hardware-driven

Sizes are from 15-amp up to 6,000-amp in residential, commercial, and industrial applications

Samples of Traditional Circuit Breakers

Anatomy of a traditional Circuit Breaker

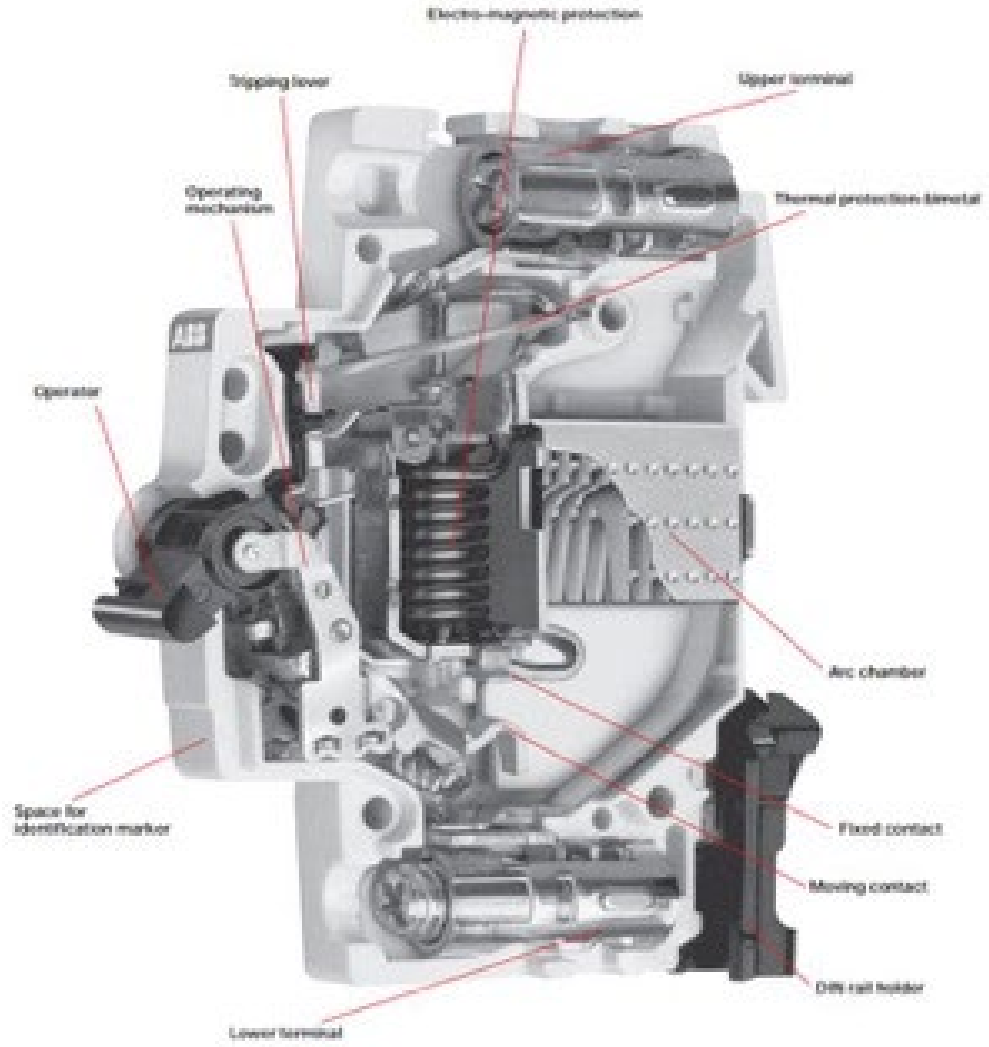
Two Mechanical methods for Fault protection

- Thermal Overloading using a bimetallic strip
- Electro-magnetic coil for short circuit

Other components needed

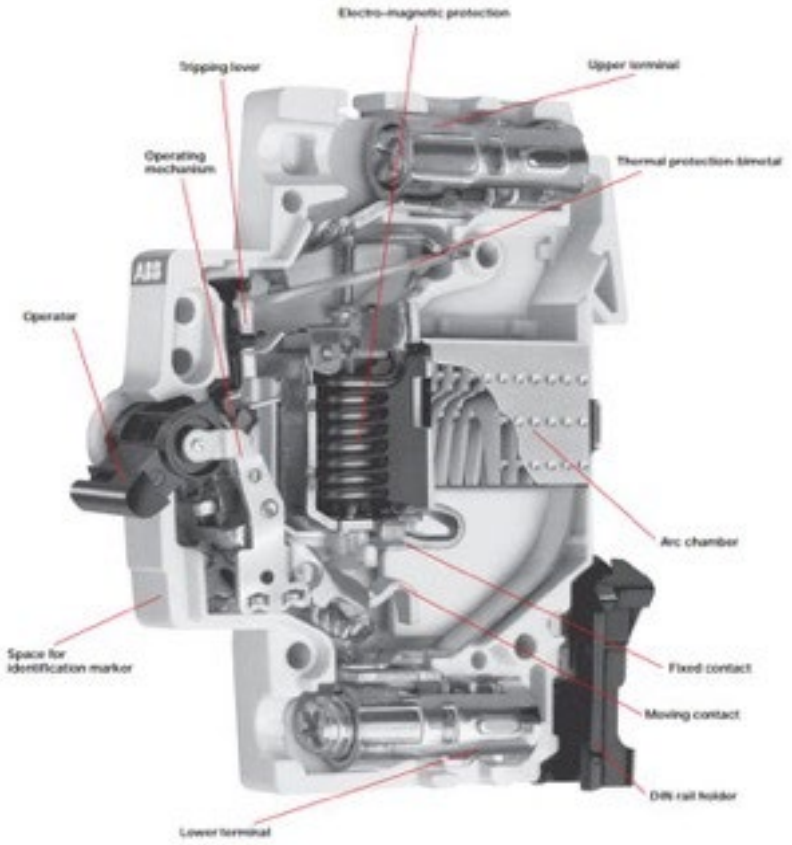
- Operator Switch / Lever
- Arc Chamber
- Contacts for making and breaking the circuit

Elegant Mechanical Design with years of engineering development, that works well, however.....



Challenges of a traditional Circuit Breaker

- Mechanical air gap opening
    - Degrades contacts over time, especially with inductive loading, AC breakers rely on Current Zero-crossing to extinguish arc
    - Slow to react under Short Circuit conditions. Best in class is about 8ms, allowing for build up of Source fault current passthrough in that time period creating “ARC FLASH”
        - Breaker needs to withstand full Fault Current (10kA, 30kA, 60kA or 100kA etc.)
        - Short Circuits degrade breaker **significantly**
    - Bimetallic and electro-magnetic actuation time can have some significant variability due to material and manufacturing process tolerances . This leads to the requirement of “Coordination Studies” when designing a distribution system.



ARC FLASH

Caused by energy being dissipated at the physical fault location.

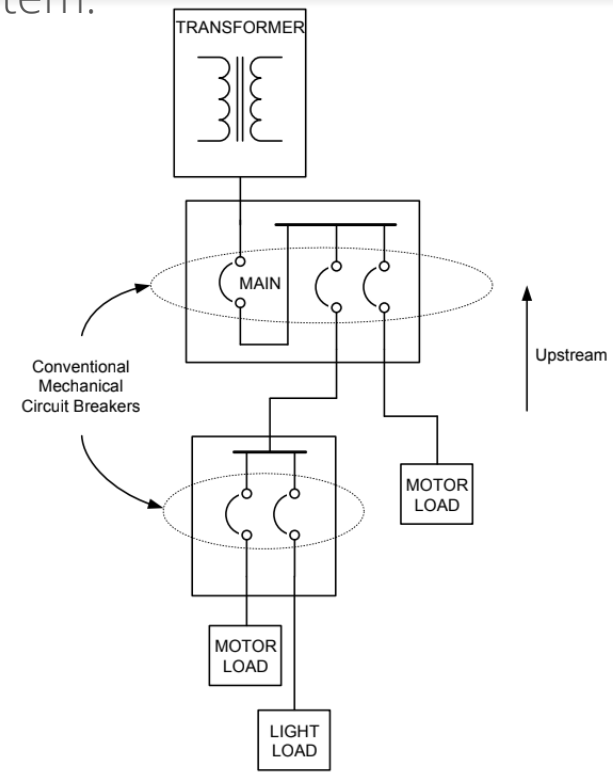
When a short circuit occurs depending on the size of the upstream transformer the available fault current will build up quickly and flow through the fault location. This causes an arc blast of molten metal at the fault location.

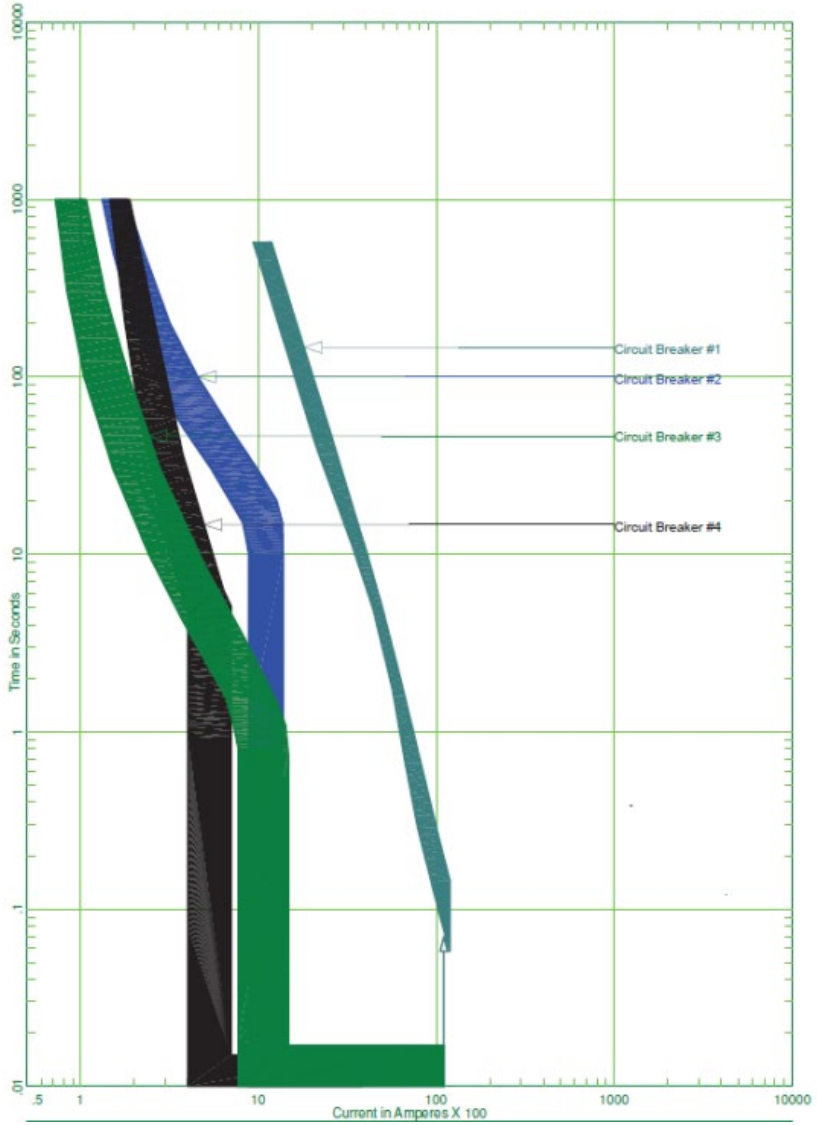
Amount of Energy dissipated is proportional to $I^2(t)$, fault currents can reach up to 10kA or 100kA depending on size of upstream transformer.

Selective Coordination

Mechanical circuit breakers have large varying tolerances in their time curve characteristics (TCC).

When designing an electrical distribution system, engineers must ensure that that any fault in the system must be cleared by the closest (first line) circuit breaker upstream of the fault, without bringing down the entire system.





Standard for Circuit Breakers

UL 489

Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures

Three major test sequences (X, Y, Z) and EMC

X – 6X inductive current loading
Y – mechanical endurance test 10,000 cycles
Z – Short Circuit, open and closed shots

Environmental Tests

Dry heat test (7 days)
Humidity test (7 days)
Thermal Cycling

Most circuit breakers in North America require Underwriters Laboratories (UL®) listing

The Atom Switch is the only Solid State Circuit Breaker in the world with a UL listing!

UL Listing a Solid State Circuit Breaker

Requires all TESTS from UL 489 PLUS

UL 489i

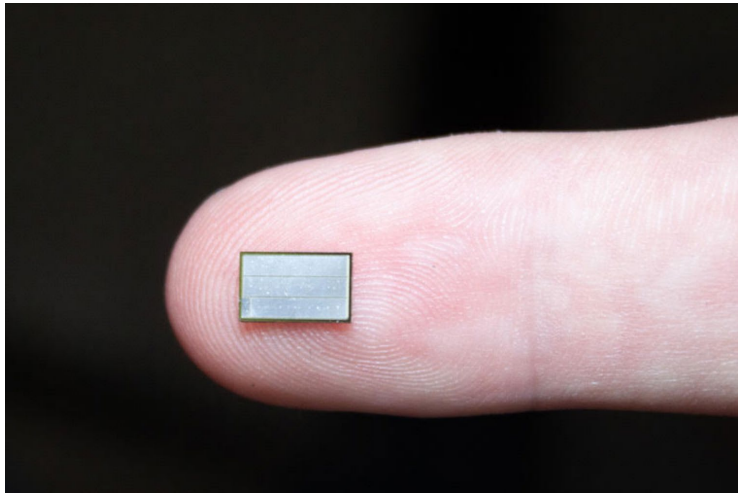
Outline for investigation for Solid State Molded-Case Circuit Breakers.

- Introduces “STANDBY” state and defines operation

- Adds UL 991 reliability study
- Adds Leakage test for STANDBY not to exceed 0.5mA
- Adds Abnormal Voltage Test
- Adds Breakdown of Components Test

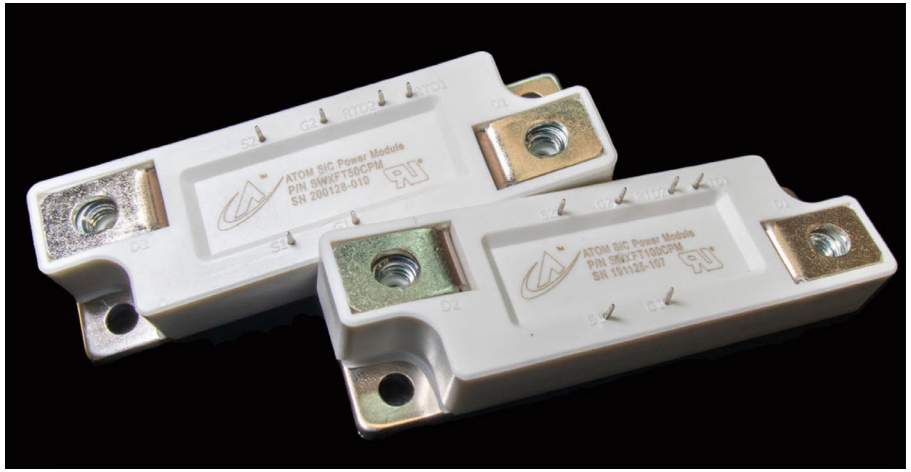
Wide Band Gap (WBG) Semiconductors

Fundamental Building Block for the SSCB

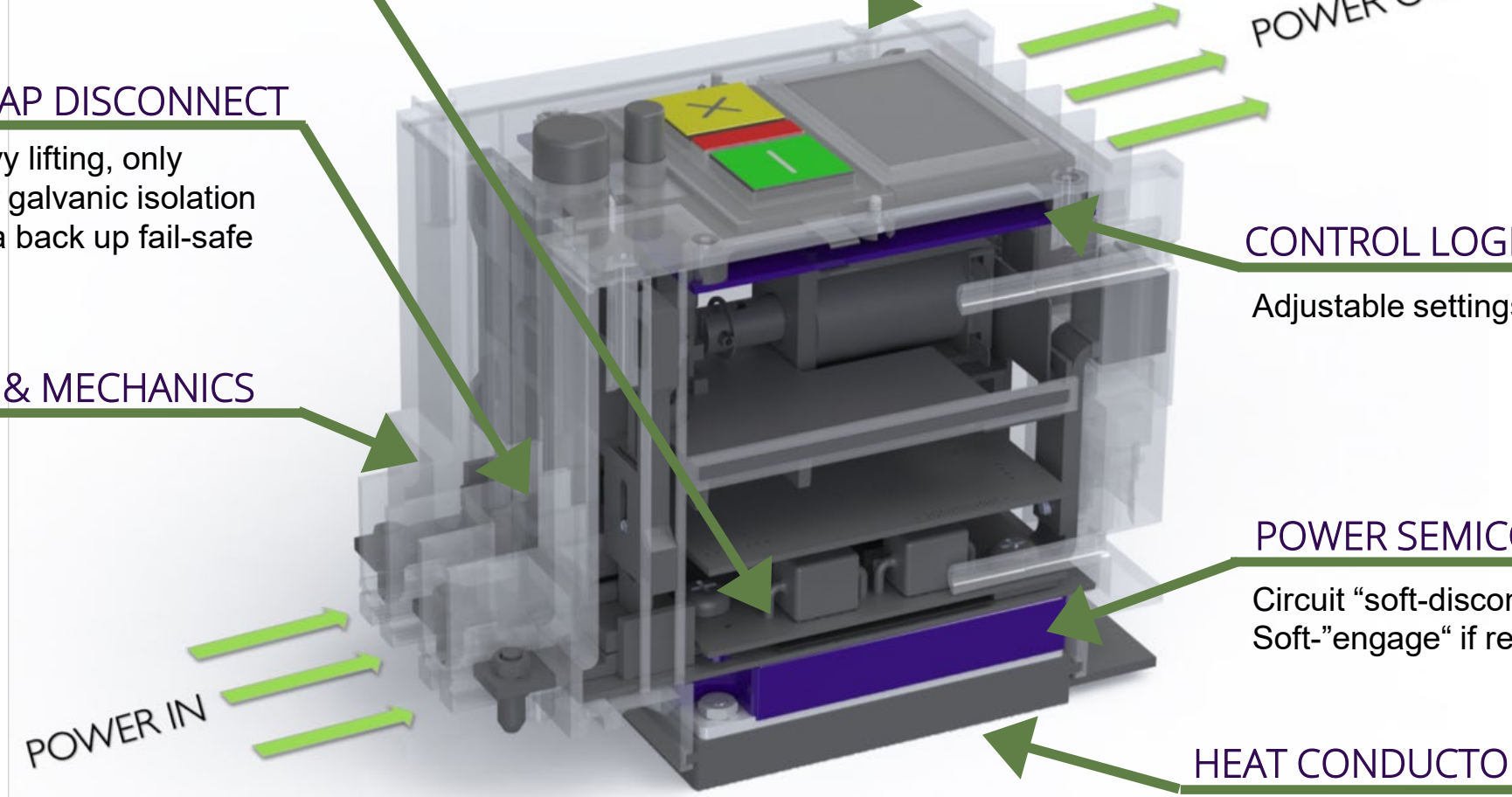


- Recent advances in SiC have enabled the production of power switching devices like MOSFETS to have blocking voltages as high as 1700V and tens of milliohms of ON resistance.

- Designing a specific module for circuit protection with back to back MOSFETS allows for a simplified form factor of a Solid State Circuit Breaker.



Anatomy of a Solid-State Circuit Breaker



TVS ARRAY

Surge suppression
for transients

AIR GAP DISCONNECT

No heavy lifting, only
used for galvanic isolation
and as a back up fail-safe

CASE & MECHANICS

DISPLAY & ILLUMINATED BUTTONS

Provides intelligent user feedback

CONTROL LOGIC & FIRMWARE

Adjustable settings and TCC

POWER SEMICONDUCTORS

Circuit “soft-disconnect” and
Soft-”engage“ if required

HEAT CONDUCTOR

Advantages of Solid State Circuit Breakers

ARC FLASH is effectively eliminated

- Detection of short circuit condition and opening of semiconductors can be achieved in approximately 40us. This is not only 200 times faster than mechanical circuit breakers but allows for about 4000 times less energy let through. By measuring di/dt and setting a threshold of about 20-50 A/us rise as the turn-off trigger point we also limit peak current to less than 1000A.

Short Circuit

- Unlike mechanical breakers there is NO degradation to a SSCB under short circuit conditions, meaning no replacement for the life of the breaker. Atom Switch has been tested to 100kA and 200kA available fault current, without any observable degradation.

- No limit to the number of short circuits

Advantages of Solid State Circuit Breakers

Overloading

- Severe inductive overloading (i.e. locked rotor test) current is dissipated in approximately 1ms. No degradation to the SSCB
- Light thermal overloading can be interrupted at Zero-crossing. Less stress on the device and power distribution system. (no Voltage transients)

Time Curve Characteristic

- TCC becomes adjustable and settable through software. TCC is also very precise when set.
- When used as branch circuit protection, with upstream mechanical breakers, Selective Coordination is EASY.

Advantages of Solid State Circuit Breakers

Maintenance and Self-diagnostics

- Firmware intelligence to self-diagnose problems and report.
- Ability to TRIP and LOCK OUT when major problem is identified.

Other Features

- Power metering capabilities with reporting
- Unlimited ON/OFF cycles to STANDBY allowing for remote power management and demand management applications
- Can be used as a motor soft-starter / transformer soft-energizer / or capacitive loading in rush current limiter.

Disadvantages of Solid State Circuit Breakers

Heat Management

- 480V 100A 3-ph fully loaded SSCB operates at 99.8% efficiency, which dissipates about 200W

COST ???

- More expensive than traditional circuit breakers, but if factoring in high fault current capabilities and other features can become very cost effective in specific applications.

Making it all Work - Solid State Circuit Protection

Circuit Breakers

100-amp, 3-phase
Atom Switch

50-amp, 3-phase
Atom Switch

100-amp, 2-pole Atom
Switch

50-amp, 2-pole
Atom Switch

100-amp
Atom SiC Power Module

50-amp
Atom SiC Power Module

Panels

400-amp, 3-phase
Atom Panel

225-amp, 3-phase
Atom Panel

Software

Atom OS Software

Commercial Applications
(beyond just circuit breakers)

Reimagining Motor Controls

⅔ the Cost

¼ the size

10x Easier

and…

Mitigates arc flash where it happens the most

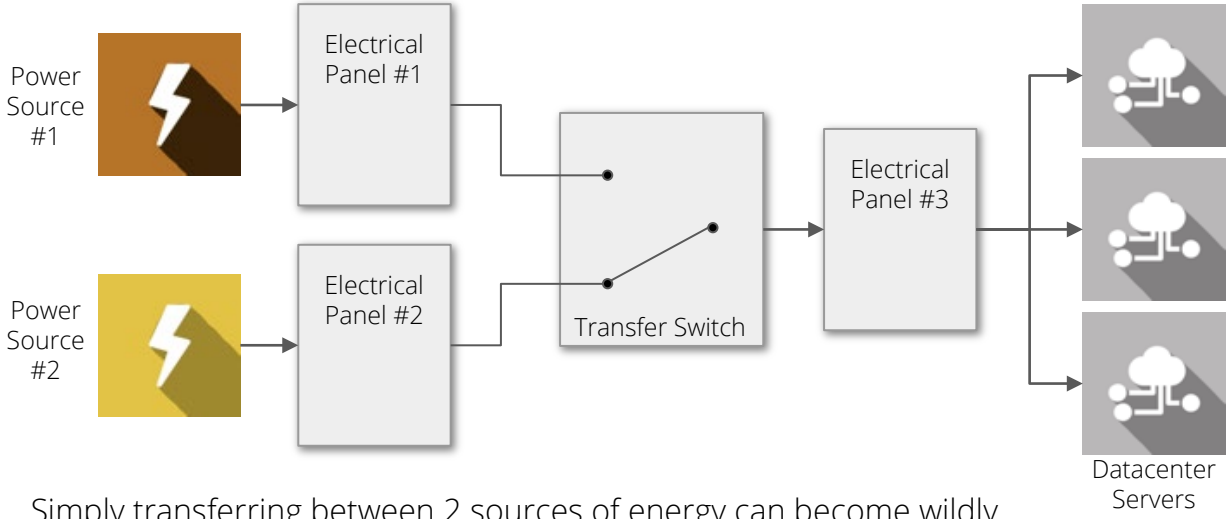
Traditional Motor Control Center

The Atom Panel Does All of This

Data Center Applications

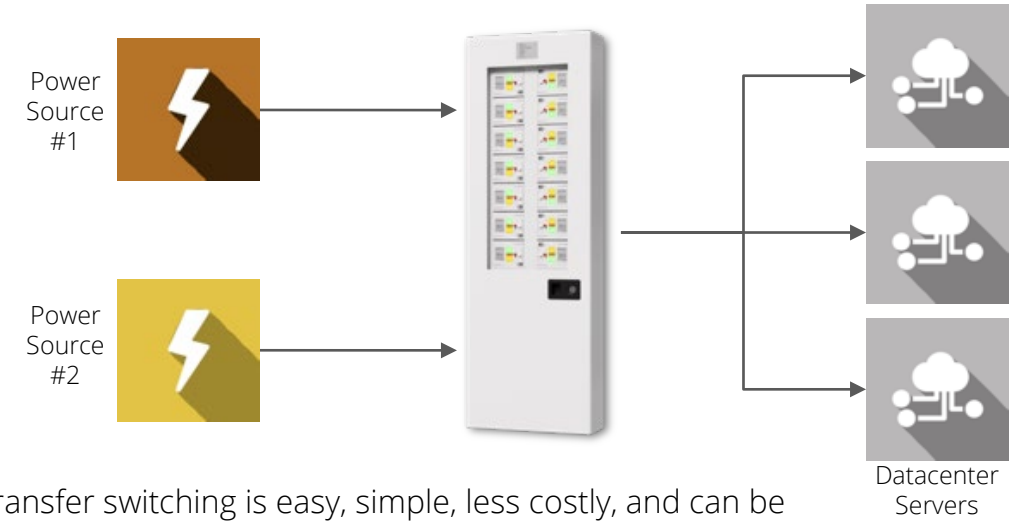
**Data provided by CBRE US Data Center Trends Report*

Transfer Switching Problems Today



Simply transferring between 2 sources of energy can become wildly difficult and risky within a datacenter. Complex and expensive transfer switching equipment is required for this and usually at a macro level.

With Atom Power



Now transfer switching is easy, simple, less costly, and can be performed at any level in the power system.

Fault Tolerance Problems Today

Datacenter power systems are huge and have extremely high available fault currents, causing owners to purchase more expensive high fault current circuit breakers and with much higher degree of arc flash hazards.

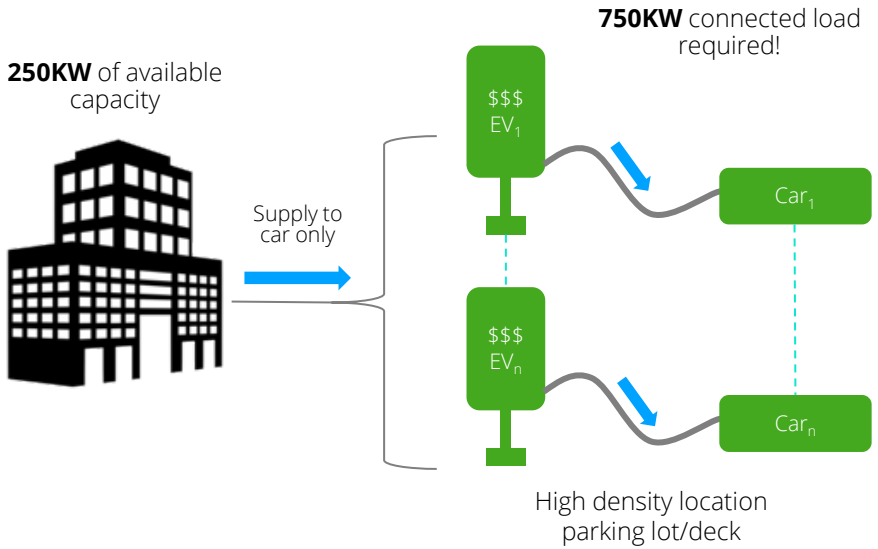
With Atom Power

Every Atom Switch is rated for 200,000-amps of fault current. At the upper end of the fault current spectrum, these circuit breakers can be put into any system, including massive data centers and all while reducing arc flash hazards to just about nothing.

High Density EV Charging

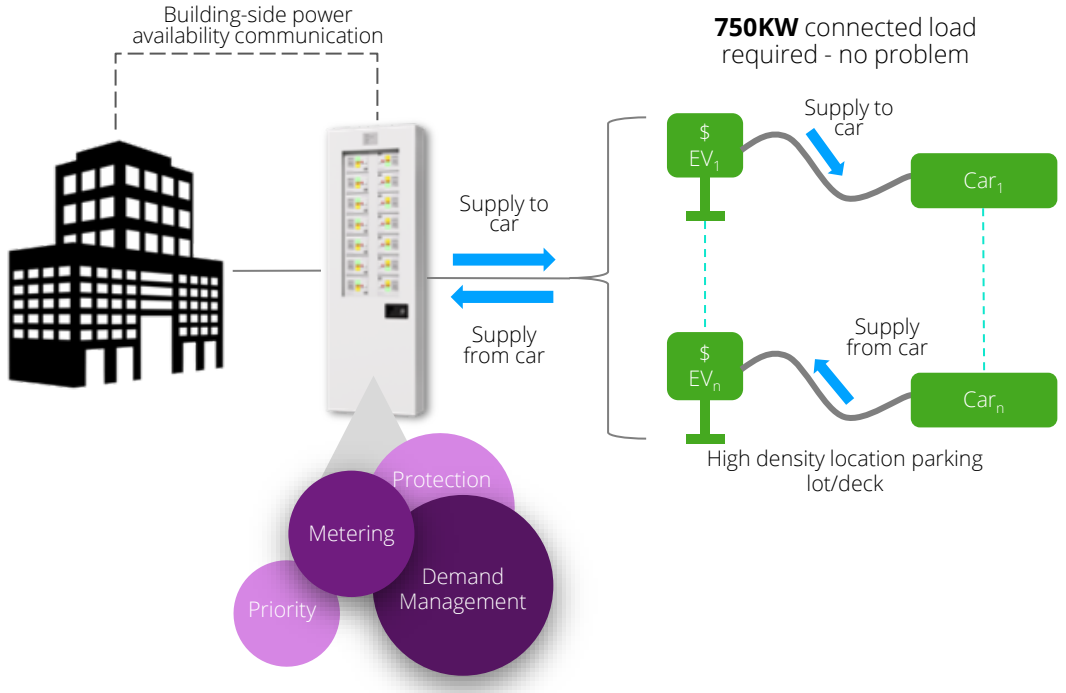
**Estimated number of new EV DC Fast Charging Points that will be installed in the next 20 years -- "From Pump to Plug -- A US $6tn Investment to Power EVs -- Goldman Sachs Equity Research, Oct 19, 2017 p54*

Today



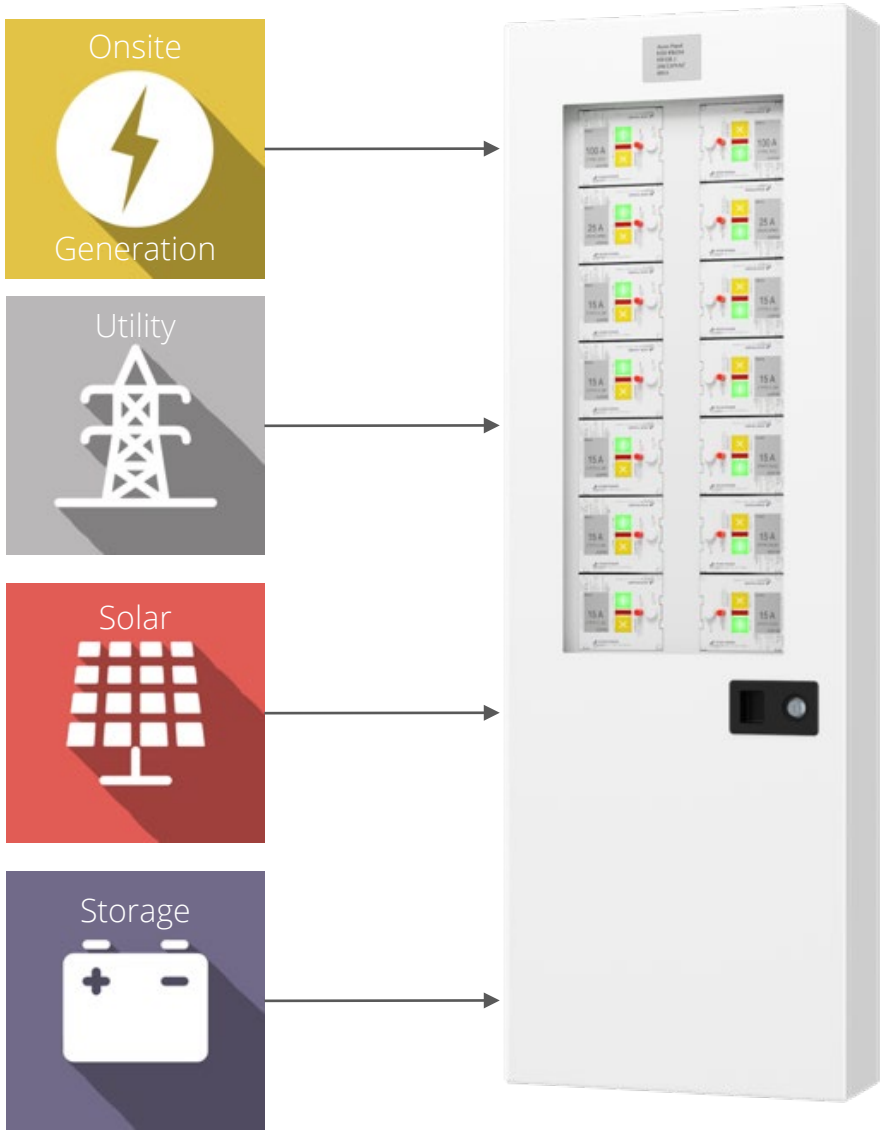
Problem #1 - Not enough electrical capacity in a building/utility to supply large quantities of EV chargers
Problem #2 - Expensive car chargers with too many features
Problem #3 - Vehicle-to-grid is not feasible

With Atom Power



Solution - Solid-state circuit breaker demand management enables under-provisioning electrical capacity
Solution - Simpler EV chargers. Control, visibility and monitoring is all done by the Atom Panel since every EV charger requires a circuit breaker anyway
Solution - Facility enablement of vehicle-to-grid

Enabling Distributed Energy (DER)



Today's Biggest challenge for renewables: Bringing all power sources into a single location

Customer Facility

Atom Switches can be programmed to dynamically and seamlessly transfer input power between the utility, renewables, onsite generation, and/or battery storage.

Today, to even get close to this capability requires multiple components with significant installation and maintenance costs.

THANK YOU!!!!