USING SOLID-STATE BREAKERS TO CHARGE AN EV FROM THE ELECTRICAL PANEL

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Contents

- Introduction
- Solid-State Circuit Breaker
- EV Charging 101
- EV Charging From a SSCB
  - Energy Management
  - Increased Safety & Reliability
  - Decreased Costs
- Standards for SSCB and EVSE
  - SAE
  - UL
  - NEC
  - IEEE vs ISO
  - NIST vs ANSI
- Conclusions
Introduction

• Circuit Breaker patented by Thomas Edison in 1879
• Inverse Time Element Breaker released by Cutter Manufacturing in 1904
• Circuit Breakers relied on 2 main elements, thermal and magnetic
• Thermal heating caused by overloading a circuit would cause bimetal to heat and bend until the breaker opened
• Magnetic forces from high fault currents would force a breaker open
• In the 70s GFCI Breakers were introduced to reduce electrocution deaths
• In the 90s AFCI Breakers were introduced to reduce arcing fires
Solid-State Circuit Breakers

- 2019 the world's first UL listed Solid-State Circuit Breaker was introduced by Atom Power
- Silicon Carbide transistor opens and closes the circuit
- Programmable TCC
- No Arcing
- Digital Control – Remote Operation
Traditional Circuit Breakers

Pure mechanical operation/breaking

Solid-State Circuit Breaker

Semiconductor breaking (no moving parts)
Breaker operations are digital via software
Electric Vehicle Supply Equipment (EVSE) – The conductors, including the ungrounded, grounded, and equipment grounding conductors and the electric vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the electric vehicle.

3 Levels of Charging:
• Level 1 – 120VAC up to 1.9kW of power = Days to recharge
• Level 2 – 240VAC up to 19.2kW of power = Hours to recharge
• Level 3 – 400-800VDC up to 300kW of power = Minutes to recharge
Energy Management

- NEC 625.42 Rating. ...Service and feeder shall be sized in accordance with the product ratings. Where an **automatic load management system** is used, the maximum equipment load on a service and feeder shall be the maximum load permitted by the automatic load management system.
- With locally monitored energy management, utility service upgrades can be delayed or prevented entirely.
- Demand avoidance can have massive energy cost savings
Current Status Quo:

- Maximum Electrical Capacity
- Amount of Power Available for EV Charging (100KW)
- NEC Connected Load
- Actual Building Load

Dynamic Energy Management:

- Maximum Electrical Capacity
- NEC Connected Load
- Amount of Power Available for EV Charging (variable up to 450KW)
- Actual Building Load
### NUMBER OF EVs³ CHARGED PER DAY⁴ WITH 208V

<table>
<thead>
<tr>
<th>Available Electrical Capacity</th>
<th>Miles Driven Per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td><strong>400A Groups</strong></td>
<td># of Panels</td>
</tr>
<tr>
<td>1</td>
<td>1-8</td>
</tr>
<tr>
<td>2</td>
<td>2-16</td>
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<tr>
<td>3</td>
<td>3-24</td>
</tr>
<tr>
<td>4</td>
<td>4-32</td>
</tr>
</tbody>
</table>

### NUMBER OF EVs³ CHARGED PER DAY⁴ WITH 240V

<table>
<thead>
<tr>
<th>Available Electrical Capacity</th>
<th>Miles Driven Per Day</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>3-24</td>
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<tr>
<td>4</td>
<td>4-32</td>
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</tbody>
</table>
Increased Safety and Reliability

- Opening and closing circuit from the breaker means entire run deenergized while not actively charging
- Built in CCID for ground fault protection with auto-retry
- Integrated lockable disconnect for easy LOTO practice
- Lowest let-through current of any OCPD
- Lowest incident energy
- Rated at 200kAIC
- Millions of Operations
- Tested at the circuit breaker standards
<table>
<thead>
<tr>
<th></th>
<th>EVSE UL 2231</th>
<th>CIRCUIT BREAKER UL 489</th>
<th>UL 489/UL 2231</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overload Testing</td>
<td>150% of rating 50x</td>
<td>600% of rating 50x</td>
<td>600% of rating 50x</td>
</tr>
<tr>
<td>(489.7.1.3 vs 2231.27)</td>
<td></td>
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</tr>
<tr>
<td>Endurance Testing</td>
<td>6,000 operations</td>
<td>10,000 operations</td>
<td>10,000+ operations</td>
</tr>
<tr>
<td>(489.7.1.5 vs 2231.28)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Surge Protection</td>
<td>6kV</td>
<td>4kV</td>
<td>6kV</td>
</tr>
<tr>
<td>(489.5F4.5 vs 2231.24.10)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Short Circuit Test*</td>
<td>3.5kA</td>
<td>5kA</td>
<td>200kA</td>
</tr>
<tr>
<td>(489.7.1.7 vs 2231.32)</td>
<td></td>
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</tr>
<tr>
<td>Voltage to the Pedestal While Not Charging</td>
<td>Typically Present</td>
<td>N/A</td>
<td>No</td>
</tr>
<tr>
<td>How Fast Can You Stop Power</td>
<td>N/A</td>
<td>100ms</td>
<td>400μs</td>
</tr>
<tr>
<td>Let Through Current</td>
<td>Maximum Available Fault Current</td>
<td>Maximum Available Fault Current</td>
<td>1.5kA</td>
</tr>
</tbody>
</table>

IEEE
Decreased Costs

- All in one device means less equipment needed
- Expensive equipment in the electrical room
- No moving parts, no maintenance plans
- Single point of connection for lower cloud fees
- Avoid service upgrades
- Avoid high energy bills
By Controlling Demand Charges and Delaying Transformer Upgrades, 
Up to 80% Cheaper to Operate Over 5 Years

Project Stats:
• 40 L2 EV chargers
• Austin, TX
• Cheap electricity
• Demand charges occurred in 36 of 60 months (60%)
• Minimal transformer upgrade
Standards for SSCB and EVSE

- SAE – Society of Automotive Engineers
- UL – Underwriters Lab
- NEC – National Electrical Code
- IEEE vs ISO for Next Level Communication
- NIST vs ANSI for Metering
SAE – Society of Automotive Engineers

- J1772: EV Conductive Charge Coupler – Covers the physical, electrical, functional and performance requirements of charging an EV in North America. Defines the Levels of AC and DC charging. Defines the pilot wire communication between the EVSE and the EV.
- J1773: EV Inductive Charge Coupler - Covers wireless charging
- J2178-1/2/3/4: Class B Data Communication Network Messages
- J2894-1: Power Quality Requirements for Electric Vehicle Chargers
UL – Underwriters Lab

• 2594: Electric Vehicle Supply Equipment – Main safety standard
• 2231-1/2: Personnel Protection Systems for EVSE – Covers CCID and Grounding
• 2251: Plug, Receptacles and Couplers
• 489/489i: Circuit Breakers/Solid-State
• 67: Panelboards
• 1998: Software in Programmable Components
NEC – National Electrical Code

- Article 625 Electric Vehicle Charging Systems
- 625.40 Electric Vehicle Branch Circuit: Each outlet for EV charging shall be supplied by an individual branch circuit.
- 625.42 Rating: load on a service and feeder shall be the maximum load permitted by the automatic load management system. Restricted access shall be accomplished by; (1) cover or door that requires a tool to open, (2) locked doors accessible only to qualified personnel, (3) password protected software
- 625.42 Disconnecting Means: Required on greater than 60A or 150V to ground.
IEEE vs ISO for Next Level Communication

- IEEE 2030.5 (SEP) Standard for Smart Energy Profile Application Protocol
- CA requires on all solar inverters to connect to the grid
- Current V2G pilot program in CA to test standardization of protocol

- ISO 15118 (Plug & Charge) Vehicle to Grid Communication Interface
- Vehicle OEMs fully supported: Audi, BMW, Daimler, Ford, Lucid, Porsche, Volvo, VW
- CA considering requiring “hardware-ready” in 2023
- Power Line Communication between the EVSE and the EV
- Used with CCS
NIST vs ANSI for Metering

- NIST – National Institute of Standards and Technology
- NIST Handbook 44 – Specification, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices
- NIST HB 44 3.40 EV Fueling Systems: 1% accuracy at the point of dispensing

- ANSI - American National Standards Institute
- ANSI C12.1 – 1% accuracy for electric meters
- ANSI C12.20 - .5%, .2%, .1% accuracy for electric meters
Conclusion

- Solid-State breakers are the next evolution in circuit protection
- EV adoption is exponential over the next couple years
- Every electron must pass through a breaker to get to an EV
- Charging an EV from the breaker makes sense and has benefits
- Energy management will be crucial for large scale adoption
- Using a SSCB EVSE will have increased safety and reliability with decreased cost
- There are many standards being developed in safety and usability of EVSE. The industry is young and still has room to be influenced.
Questions?

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