

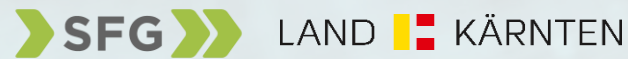


DC MICROGRIDS FOR INDUSTRY AND LOW POWER CHARGING INFRASTRUCTURE

19. SYMPOSIUM ENERGIEINNOVATION, 11.-13.02.2026, GRAZ

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WHY DC

... WE HAD THIS DISCUSSION ALREADY

THE CURRENT WAR
THE TALE OF AN EARLY TECH RIVALRY

DC

DIRECT CURRENT

The flow of electricity is in one direction only. The system operates at the same voltage level throughout and is not as efficient for high-voltage, long distance transmission.

Direct current runs through:

- Battery-Powered Devices
- Fuel and Solar Cells
- Light Emitting Diodes

"[TESLA'S] IDEAS ARE SPLENDID, BUT THEY ARE UTTERLY IMPRACTICAL."
- THOMAS EDISON

FALLING OUT
Edison promised Tesla a generous reward if he could smooth out his direct current system. The young engineer took on the assignment and ended up saving Edison more than \$100,000 (millions of dollars by today's standards). When Tesla asked for his rightful compensation, Edison declined to pay him. Tesla resigned shortly after, and the elder inventor spent the rest of his life campaigning to discredit his counterpart.

EDISON FRIES AN ELEPHANT
In order to prove the dangers of Tesla's alternating

THOMAS EDISON VS. **NIKOLA TESLA**

You would have never found two geniuses so spiteful of each other beyond turn-of-the-century inventors Nikola Tesla and Thomas Edison. They worked together—and hated each other. Let's compare their life, achievements, and embittered battles.

1847 BORN 1858

Milan, Ohio BIRTHPLACE Smiljan, Croatia

Wizard of Menlo Park NICKNAME Wizard of the West

Home-schooled and self-taught EDUCATION Studied math, physics, and mechanics at The Polytechnic Institute at Graz

Mass communication and business FORTE Electromagnetism and electromechanical engineering

Trial and error METHOD Getting inspired and seeing the invention in his mind in detail before fully constructing it

DC (Direct Current) WAR OF CURRENTS: ELECTRICAL TRANSMISSION IDEA AC (Alternating Current)

Incandescent light bulb; phonograph; cement making technology; motion picture camera; DC motors and electric power

NOTABLE INVENTIONS Tesla coil - resonant transformer circuit; radio transmitter; fluorescent light; AC motors and electric power generation system

1,093 NUMBER OF US PATENTS 112

0 NUMBER OF NOBEL PRIZES WON 0

1 NUMBER OF ELEPHANTS ELECTROCUTED 0

AC

ALTERNATING CURRENT

Electric charge periodically reverses direction and is transmitted to customers by a transformer that could handle much higher voltages.

Alternating current runs through:

- Car Motors
- Radio Signals
- Appliances

"IF EDISON HAD A NEEDLE TO FIND IN A HAYSTACK, HE WOULD PROCEED AT ONCE... UNTIL HE FOUND THE OBJECT OF HIS SEARCH. I WAS A SORRY WITNESS OF SUCH DOINGS, KNOWING THAT A LITTLE THEORY AND CALCULATION WOULD HAVE SAVED HIM 90 PERCENT OF HIS LABOR."
- NIKOLA TESLA

WAR OF CURRENTS OFFICIALLY SETTLED
In 2007, Con Edison ended 125 years of direct current electricity service that began when Thomas Edison opened his power station in 1882. It changed to only provide alternating current.

NOBEL PRIZE CONTROVERSY

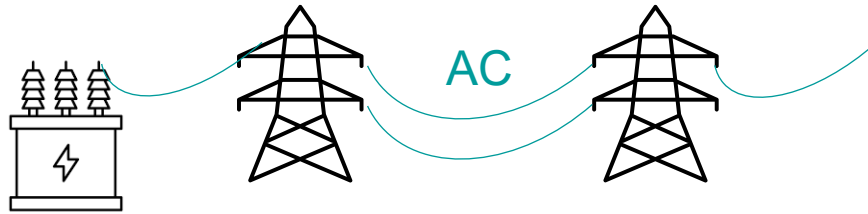
LATE BLOOMER
Thomas Edison, the youngest in his family, didn't learn to talk until he was almost 4 years old.

"Genius is one percent inspiration and ninety nine percent perspiration."
- Thomas Edison

<https://allabtinstru.blogspot.com/2016/09/the-war-of-currents-ac-vs-dc-power.html>

MOTIVATION

DC AS A PART OF THE FUTURE



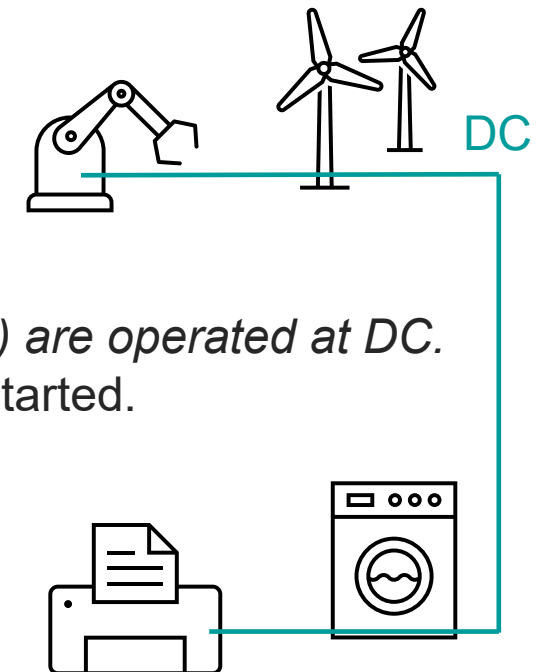
In 1880s

AC won due to the transmission over wide distances enabled by transformers

Today

End user devices, EVs, PV, battery energy storage (BESS) are operated at DC. Due to the usage of Power Electronics a silent revolution started.

The Future is **Hybrid**, Not Exclusive



OUTLINE

THE DC ADVANTAGE

≡ Transmission Efficiency

- ≡ No skin effect and reactive power losses

≡ Renewable Integration

- ≡ Native integration of photovoltaics and batteries
- ≡ End-User Devices mostly operate already on DC

≡ Grid stability

- ≡ Frequency synchronization vs. DC-bus voltage control

≡ Footprint

- ≡ DC requires less conductor cross section

≡ Structural deficit of copper supply

- ≡ A supply demand gap of 10Mt is expected in 2035 [1]
- ≡ Saving copper will decrease costs dramatically

“Putting all these levers together, we project global copper demand to grow by around 70% to over 50 Mt per annum by 2050 – an average growth rate of 2% per year.” [2]

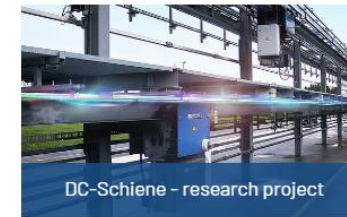
[1] <https://www.bhp.com/news/bhp-insights/2024/09/how-copper-will-shape-our-future>
[2] <https://investingnews.com/bhp-copper-market-forecast/>

DC IS ALREADY IMPLEMENTED

SOME USE CASES

Use Cases

ODCA 
direct current by zvei



<https://odca.zvei.org/use-cases>

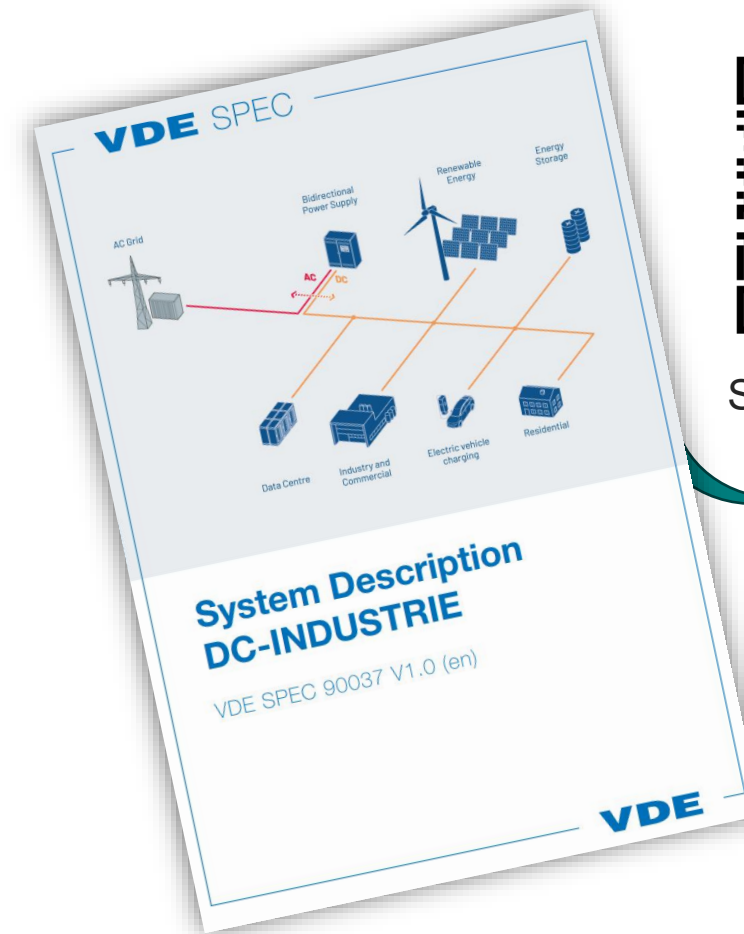
DC MICROGRIDS FOR INDUSTRY

GENERAL

Key advantages of DC compared to AC:

- ≡ **Reduced copper cabling** requirements and **lower cable losses**
- ≡ **Decreased overall energy consumption** and the ability to recover braking energy
- ≡ **Direct** and efficient **integration of renewable** energy systems
- ≡ Increased system availability due to **fewer energy conversion stages** and, consequently, fewer components that may fail
- ≡ Lower infeed power and **reduced peak power demand** through the **integration of battery energy storage systems (BESS)**

<https://experience.odca.zvei.org/benefits.html>

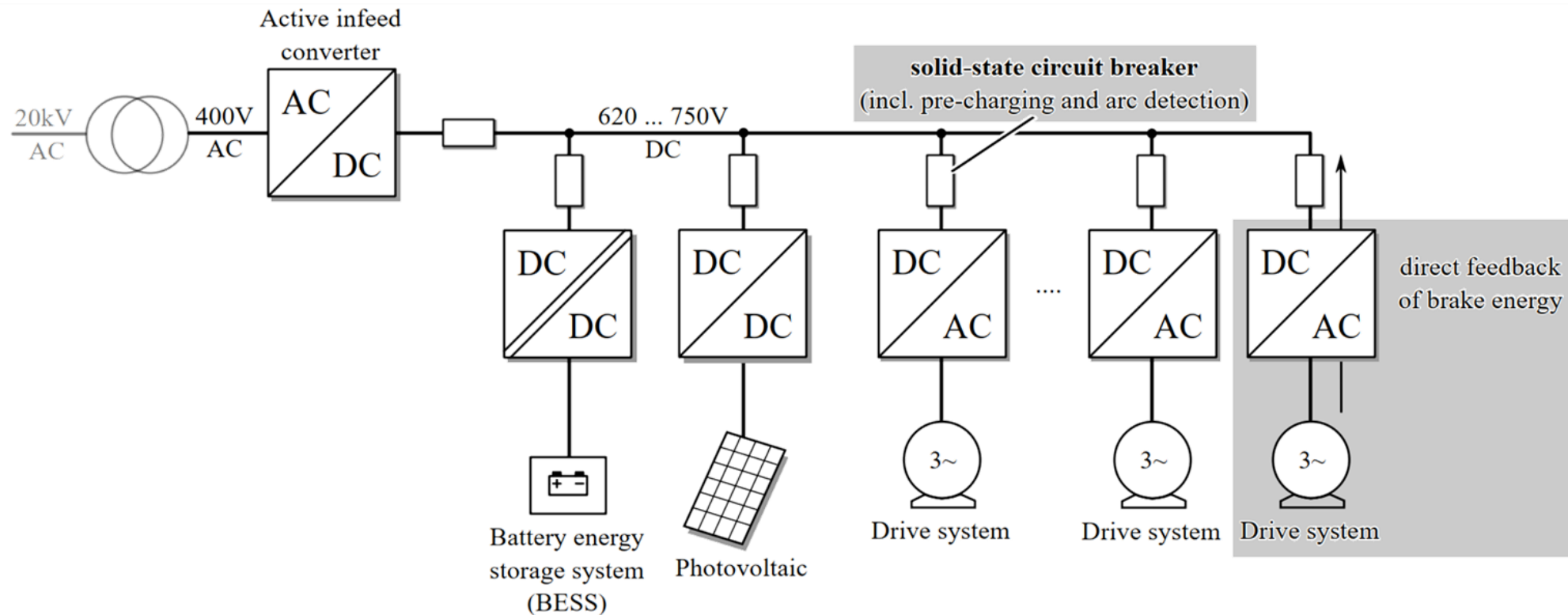


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<https://www.vde.com/resource/blob/2360634/86d934eebf76ee6f480565c94d4d319/vde-spec-90037-v1-0--en--data.pdf>

DC MICROGRIDS FOR INDUSTRY

GENERAL

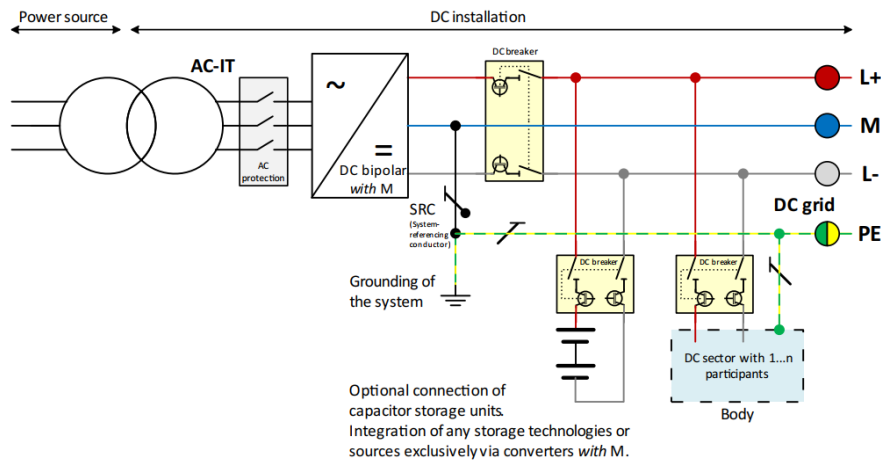


DC MICROGRIDS FOR INDUSTRY

INTRODUCTION

≡ Different layout concepts similar to AC such as

DC-TN-S system with midpoint grounding



≡ Power balance in DC microgrids is maintained by using a specific DC bus voltage band to signal power adjustments



Table 7.1: Voltage bands and limit values (based on [11.]), see footnote 25 on U6

Band	Nominal voltage: 540 V	Nominal voltage: 650 V
B7	Forbidden band - Damage of devices is very likely	
U6	2000 V	
B6	Overtoltage protection band - Switching operations can cause this voltage range - Surge protection devices (SPDs) operate and try to protect devices	
U5	880 V	
B5	Temporary overvoltage band - Surge protection devices (SPD) are not active - Breakers disconnect in this band - Insulation and components shall withstand this for up to 5 s - Devices may lose functionality in order to protect themselves	
U4	800 V	
B4	Overtoltage band - Devices may reduce their power - This shall not last longer than 60s - Measures to reduce the voltage must be taken (e.g. charge storage, switch-on power resistors)	
U3	750 V	
B3	Nominal band - Normal operating range - Devices shall be operated permanently - Devices perform with their rated power	
U2	485 V	620 V
B2	Emergency band - Overload condition - Loads have to be reduced - AIC must only be operated for a few milliseconds	
U1	400 V	
B1	Blackout Band - Smart Breakers disconnect - Band will be used during pre-charging - Occurs briefly during short-circuit conditions	

VDE Verband der Elektrotechnik Elektronik Informationstechnik e. V. (2020). System Description: DC-INDUSTRIE (VDE SPEC 90037 V1.0 (en)).

DC MICROGRIDS FOR INDUSTRY

COPPER SAVINGS

≡ Analysis considers installation condition **B2** according to **OVE E 8101** (international equivalent: IEC 60364), assumption: cable length 100m

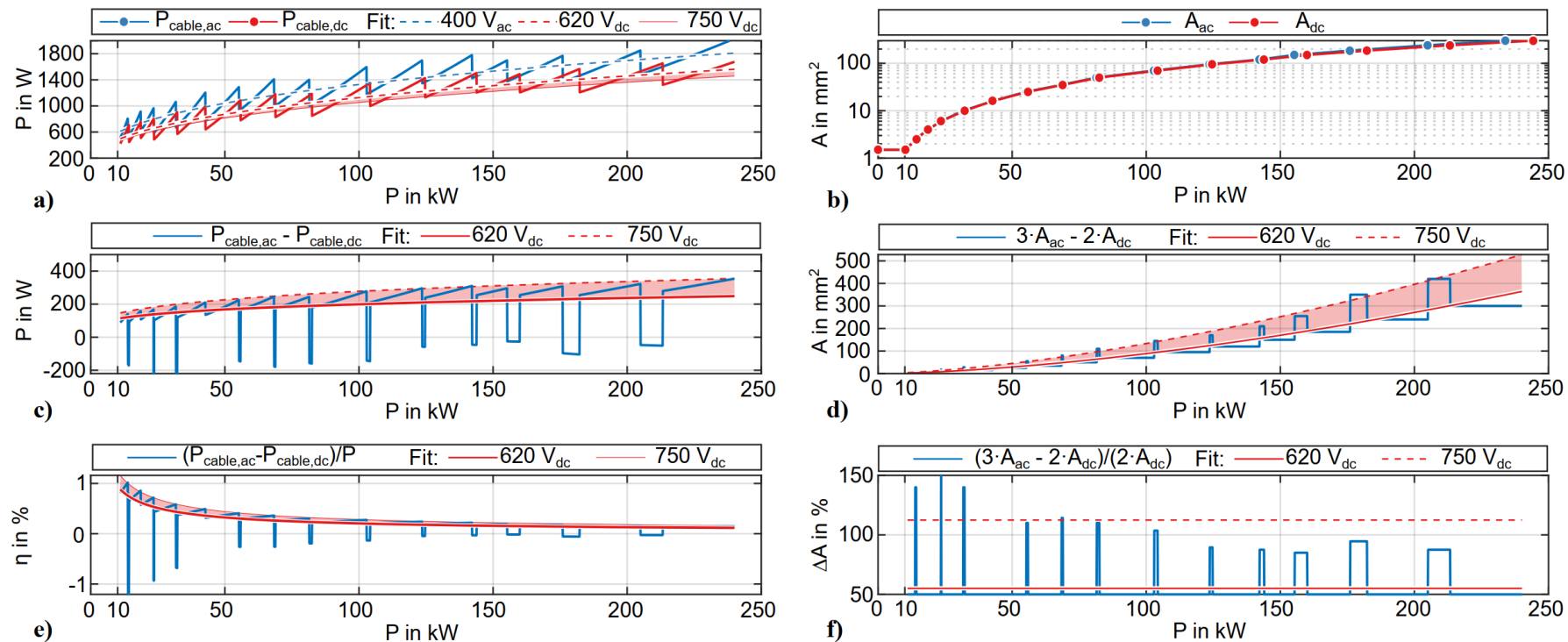


Figure: Comparison of ohmic losses and conductor cross-sections for AC (400 V) and DC (620 V - 750 V) systems (100 m). a) transmission losses; b) cross-sections per OVE E 8101 / IEC 60364 (B2); c) loss delta; d) total conducting area, e) efficiency impact and f) percentage variance.

DC MICROGRIDS FOR INDUSTRY

SOLID STATE CIRCUIT BREAKER

Mandatory features:

- ≡ Short circuit protection
- ≡ Reliable isolation

Optional features:

- ≡ Pre-charging of DC-lines
- ≡ Switch off at low voltage
- ≡ Voltage and current monitoring

Depending on layout and grounding:

- ≡ A two-pole SSCB is needed

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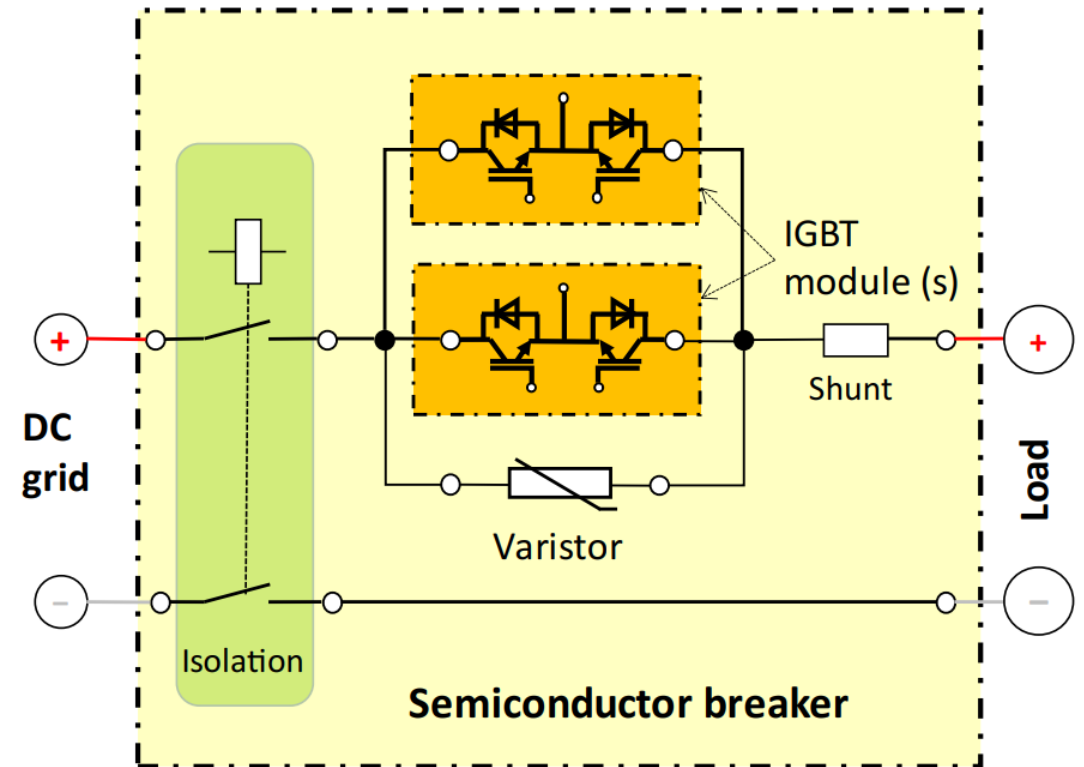


Figure 12.10 Schematic circuit diagram of a single-pole semiconductor breaker [29.]

DC MICROGRIDS FOR INDUSTRY

SOLID STATE CIRCUIT BREAKER

Proof of concept

- ≡ Reaction times of less than 200ns
- ≡ Hall based current sensing
- ≡ Analog detection circuit
- ≡ SiC semiconductors

New trend with wide-band-gap semiconductors

- ≡ Utilization of JFETs

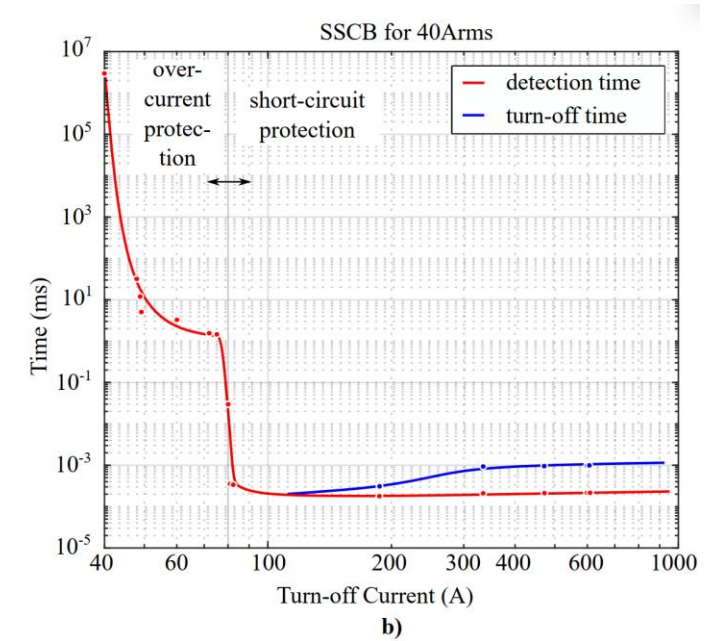
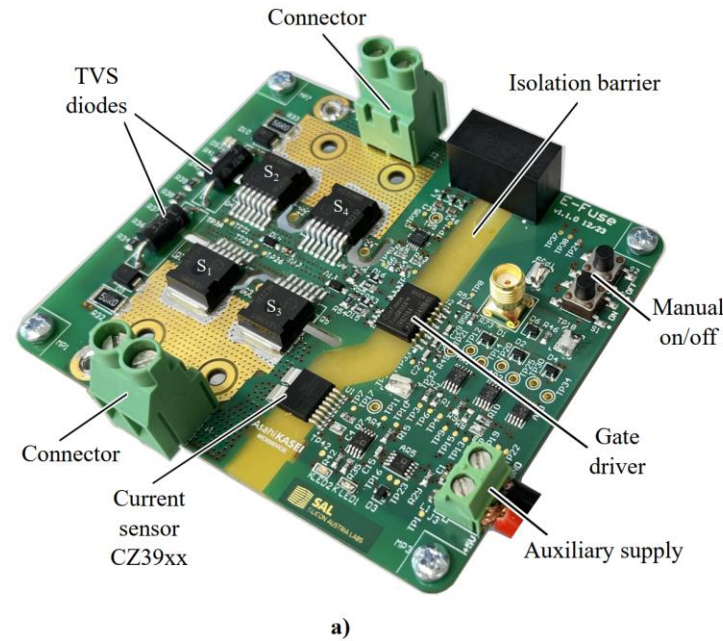


Figure: Proof-of-concept of an automotive Solid-State Circuit Breaker (SSCB), commonly referred to as an E-Fuse [7]. a) Layout of the PCB and its primary components; b) Characterization of the system's reaction and turn-off times.

Langbauer, T., Feibel, T., Huang, Z., Okada, I., & Shikama, T. (2024, June). A high voltage eFuse for automotive applications. Bodo's Power Systems, 34–38. <https://www.bodospower.com/>

DC MICROGRIDS FOR LOW POWER CHARGING GENERAL

Current Infrastructure:

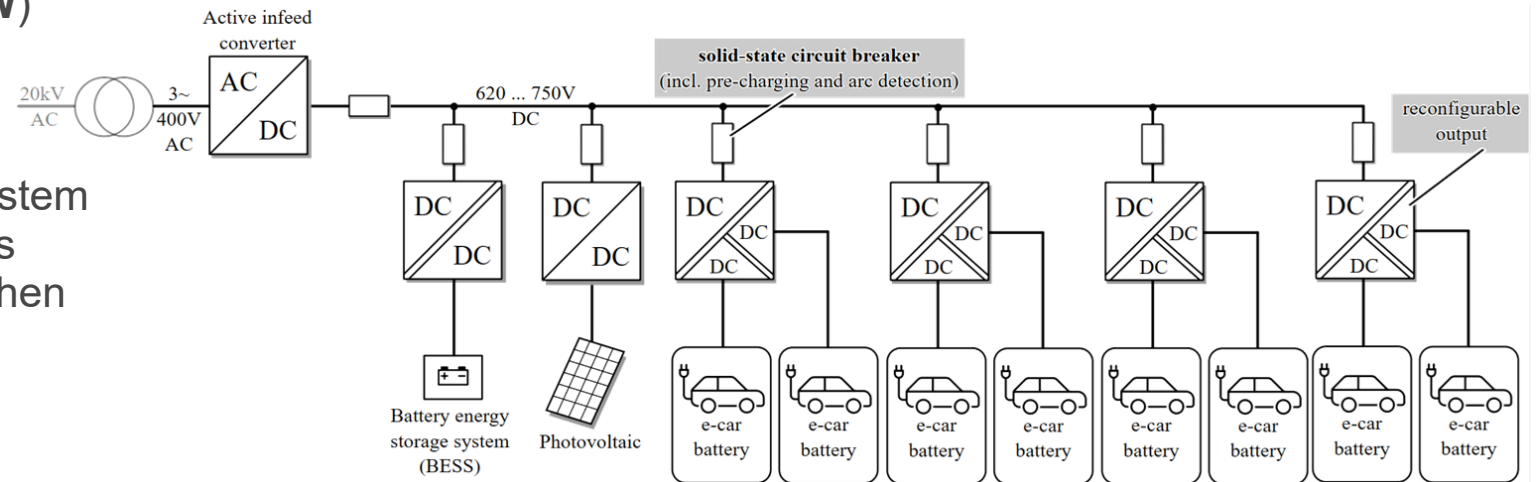
- Existing low power EV charging predominantly uses **AC** (typically from **7kW** up to **22kW**)

System Efficiency with Renewables:

- Integrating EV charging within an ecosystem that includes **PV** and **BESS** necessitates multiple inefficient power conversions when using AC chargers.

Advantage of a DC Bus:

- Implementing a direct **DC bus** architecture enhances overall system



DC MICROGRIDS FOR LOW POWER CHARGING SHIFT IN OWNERSHIP

Charging-as-a-Service:

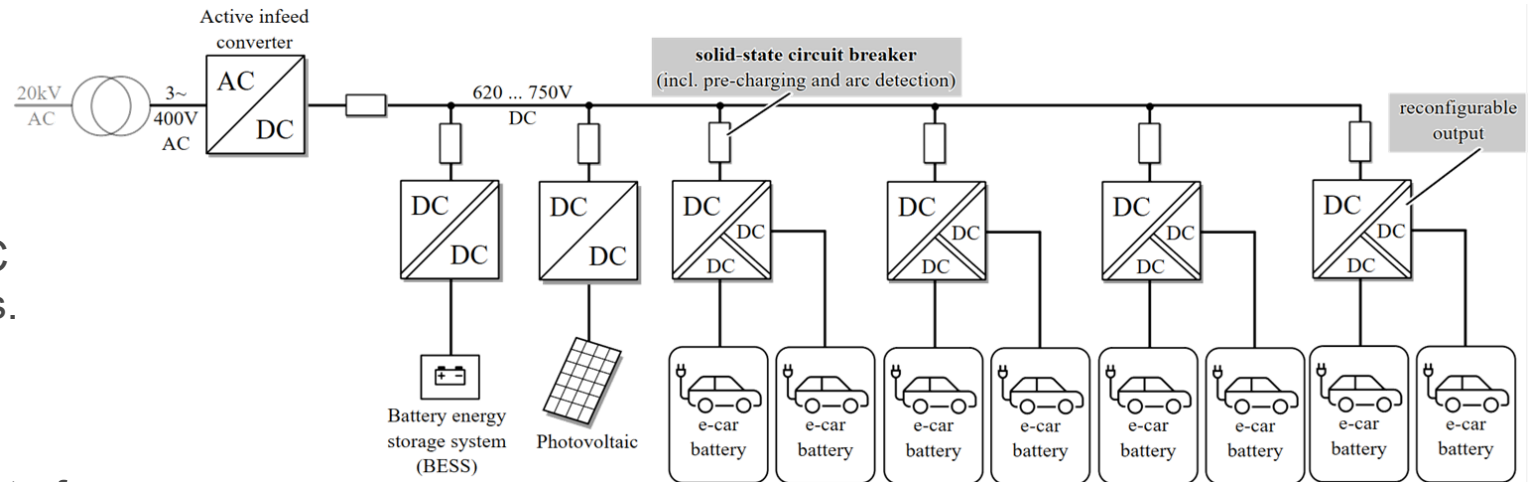
- ≡ Site hosts can now use "turnkey" models where a third party owns and maintains the DC equipment, and the host pays a predictable monthly fee.

Attractivity:

- ≡ Retailers (supermarkets, malls) view DC charging to attract high-value customers.

Return of Investment:

- ≡ For industrial fleet owners, the initial cost of DC charging stations is recouped through lower vehicle costs and better energy efficiency



DC MICROGRIDS FOR LOW POWER CHARGING CONVERTER CONCEPT

Architecture:

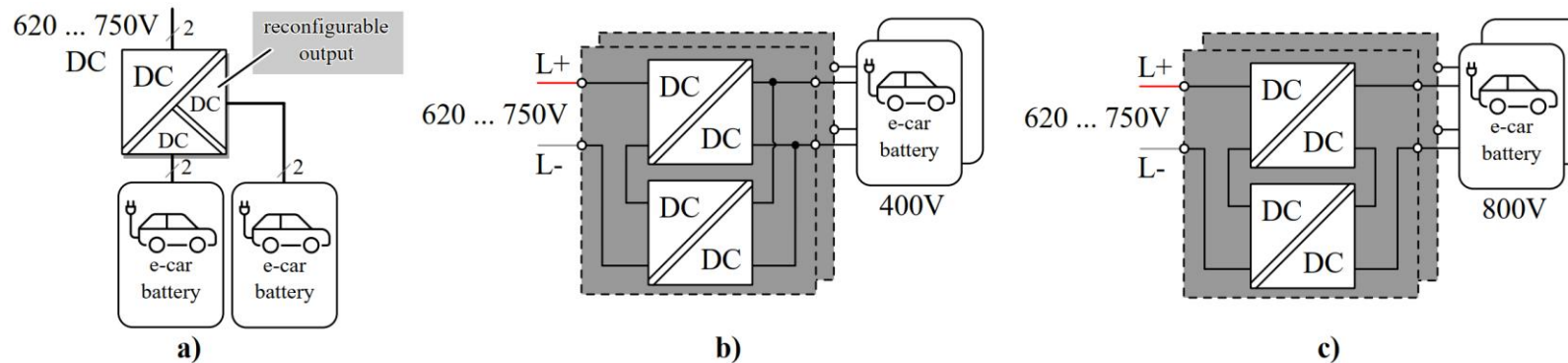
- ≡ The system comprises multiple converter modules (e.g., four modules of 6.25 kW each) and a switch matrix.

Functionality:

- ≡ The switch matrix connects the modules to distribute charging power to one or multiple EVs (both 400V and 800V possible)

Benefits:

- ≡ The modules have synergies with BESS (Battery Energy Storage Systems) and can be mass-produced, likely to help manage grid demand, store renewable energy, and reduce operational costs.



CONCLUSIONES

DC MICROGRIDS

- ≡ **DC Microgrids** are a viable, efficient industrial solution.
- ≡ They provide substantial **copper and energy savings** (55%+ copper reduction).
- ≡ A **post-2035 shift** to off-board DC electromobility is underway.
- ≡ **Off-board DC** systems boost efficiency, eliminate conversion losses, and enable lighter vehicles.

- ≡ **Technical hurdles**
 - ≡ Arc Faults
 - ≡ Corrosion
- ≡ **Knowledge/Experience Gap:**
 - ≡ Lack of specific expertise is a major barrier to success.

**THANK YOU FOR YOUR
ATTENTION!**

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