

DC SOLUTIONS FOR THE INTEGRATION OF BUILDINGS AND ENERGY RESOURCES

Webinar: ***Power Electronics as a Key Enabling Technology for Building Decarbonization***

Dr. Niwton G. F. dos Santos (*Senior Member, IEEE*)

Centre of Excellence in Energy Efficiency

POWER ELECTRONICS GROUP

Estonian Research Council

IEEE Industrial Electronics Society

IEEE

ABOUT MYSELF

TalTech PEG



TOPICS COVERED

- **Modern Buildings** as Energy Hubs
- Conventional **AC Building** Infrastructure
- **DC Integration** in Buildings
- **Energy Resources**
- Solutions Developed by **TalTech PEG**
  - ✓ DC Lighting
  - ✓ Universal LED Driver
  - ✓ Opportunity EV Charging
  - ✓ BESS Using Partial Power Converter
  - ✓ The SHIFT2DC Project

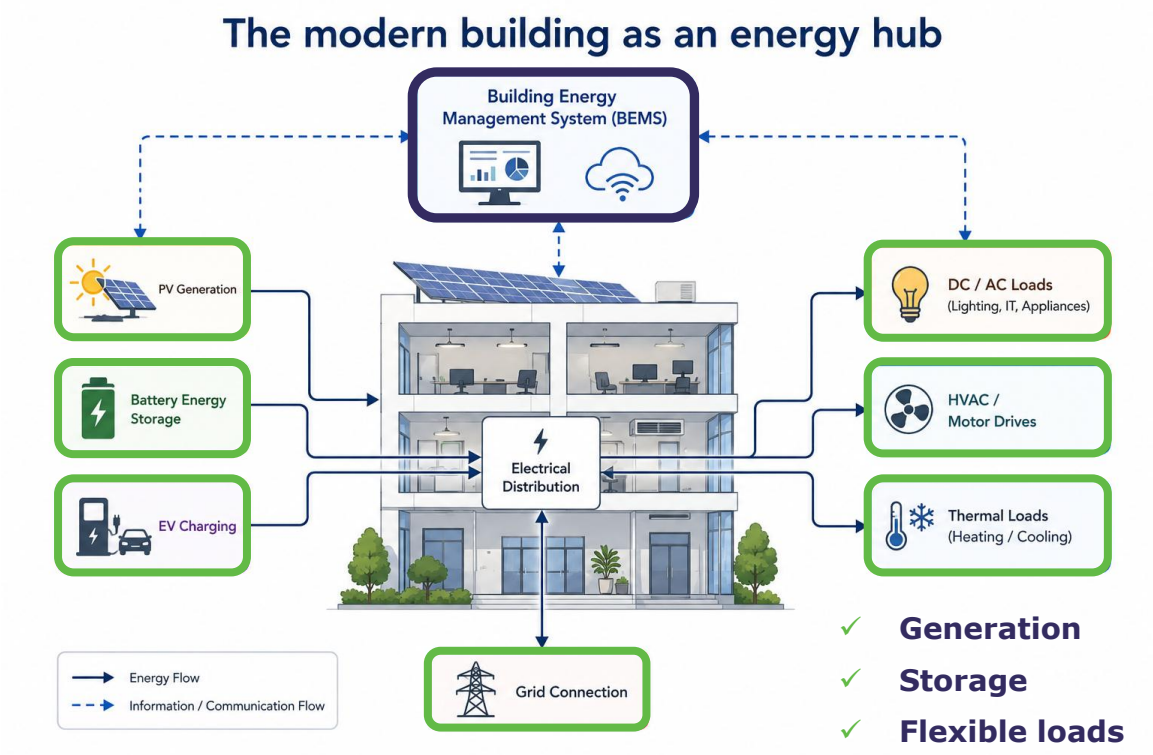


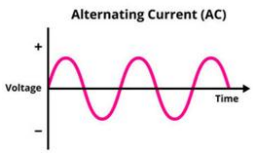
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MODERN BUILDINGS AS ENERGY HUBS

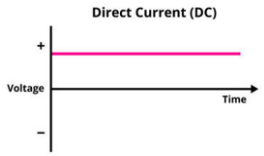
- **Buildings** are no longer **passive loads**. They are now **multi-energy-resource systems**
- **Modern buildings** host:
  - ✓ PV, battery energy storage, and EV charging
  - ✓ Loads, HVAC/motor drives, and grid connection
  - ✓ Building energy management system
- Many *resources/loads* are **naturally DC** or **DC-interfaced**
- Integration requires both **power conversion** and **intelligent coordination**

➢ How we coordinate everything with fewer conversion stages and better controllability?









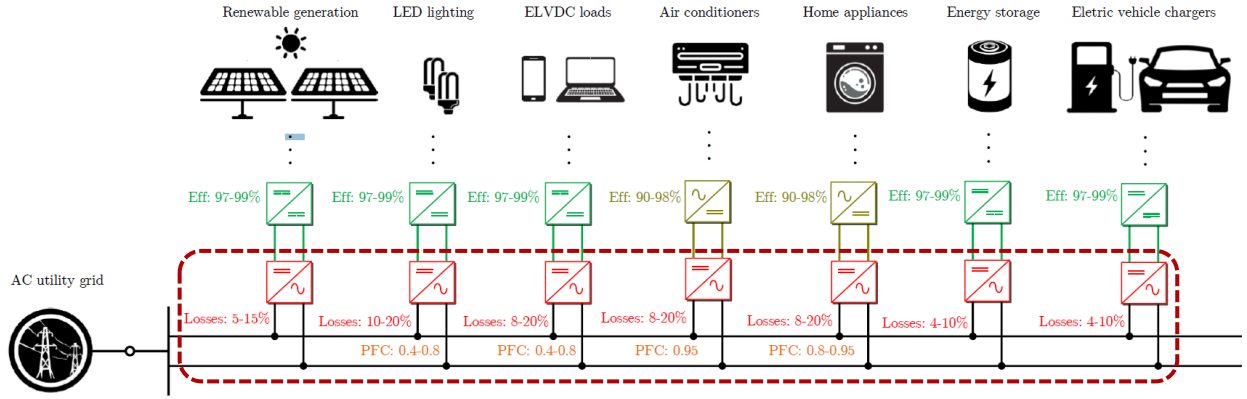
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WHY INTEGRATION IS DIFFICULT IN CONVENTIONAL AC BUILDINGS

1. The chain of suffering
   - ✓ AC → DC → DC (e.g., **AC grid to LEDs**)
   - ✓ AC → DC → AC (e.g., **AC grid to inverter fridges**)
   - ✓ DC → DC → AC (e.g., **PV systems to AC grid**)
   - ✓ DC → DC → AC → DC → AC (**PV to grid to fridge**)
2. Reactive power and **power factor**

- Power conversion losses = *wasted money*
- Multiple conversion stages
  - ✓ Separate converters often **operate independently**
  - ✓ More **failure points** (higher component count risk)
  - ✓ More **complex** energy management

Many devices repeatedly convert power between AC and DC



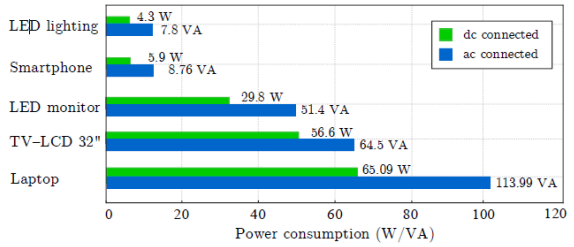








1	Urms	232.37	V
2	Irms	0.5766	A
3	P	65.09	W
4	S	133.99	VA
5	Q	117.12	var
6	Uthd	1.122	%
7	Ithd	86.841	%
8	PF	0.4858	
9	Udc	19.243	V
10	Idc	-3.022	A
11	P	-58.16	W

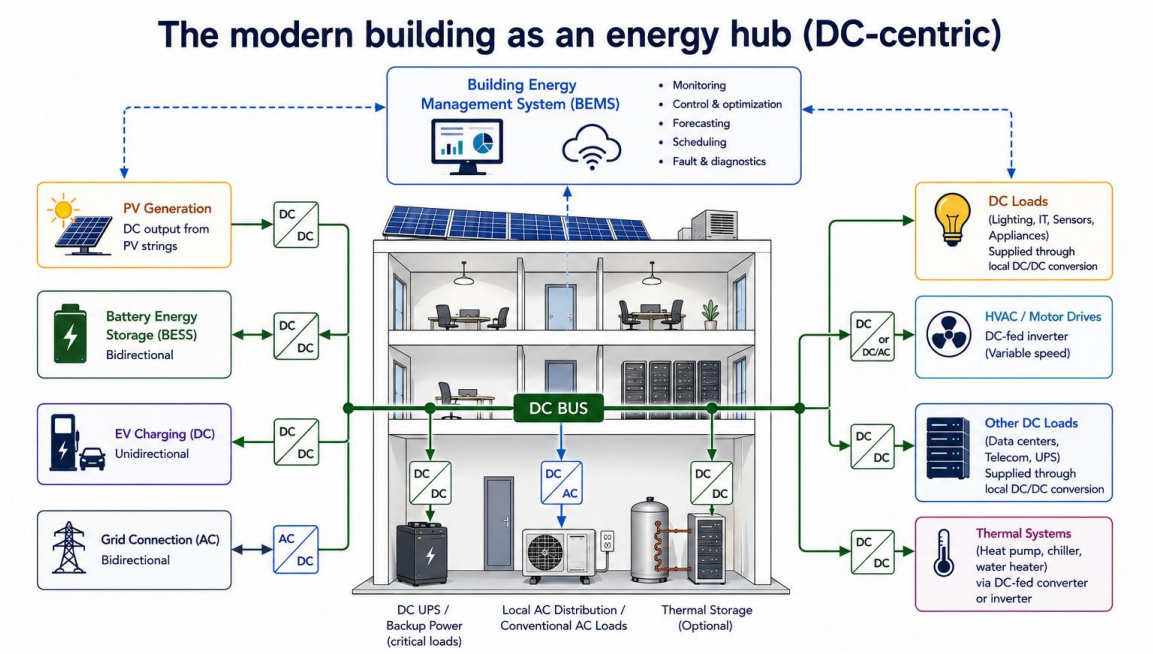


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WHAT DC INTEGRATION TRIES TO SOLVE

- Many *resources/loads* are **naturally DC-based** or **DC-interfaced**
- **DC integration** creates a **common electrical layer** for *DC resources/loads*
  - ✓ **Direct integration** of PV systems, batteries, EVs, and DC loads
  - ✓ **Reduced number of conversion stages**
    - ➢ **Less power processing!**
  - ✓ No **reactive power** problems
  - ✓ Higher **conversion efficiency**
  - ✓ Less **complexity** and high **interoperability** (e.g., **USB Type-C**)

30%
of energy saving







- ✓ Up to **55%** reduction in **distribution cabling mass** (copper or aluminum)
- ✓ Up to **85%** reduction in the **required connection capacity** to the AC distribution grid
- ✓ Up to **20%** reduction in **lifecycle costs** when a building is fully converted to DC

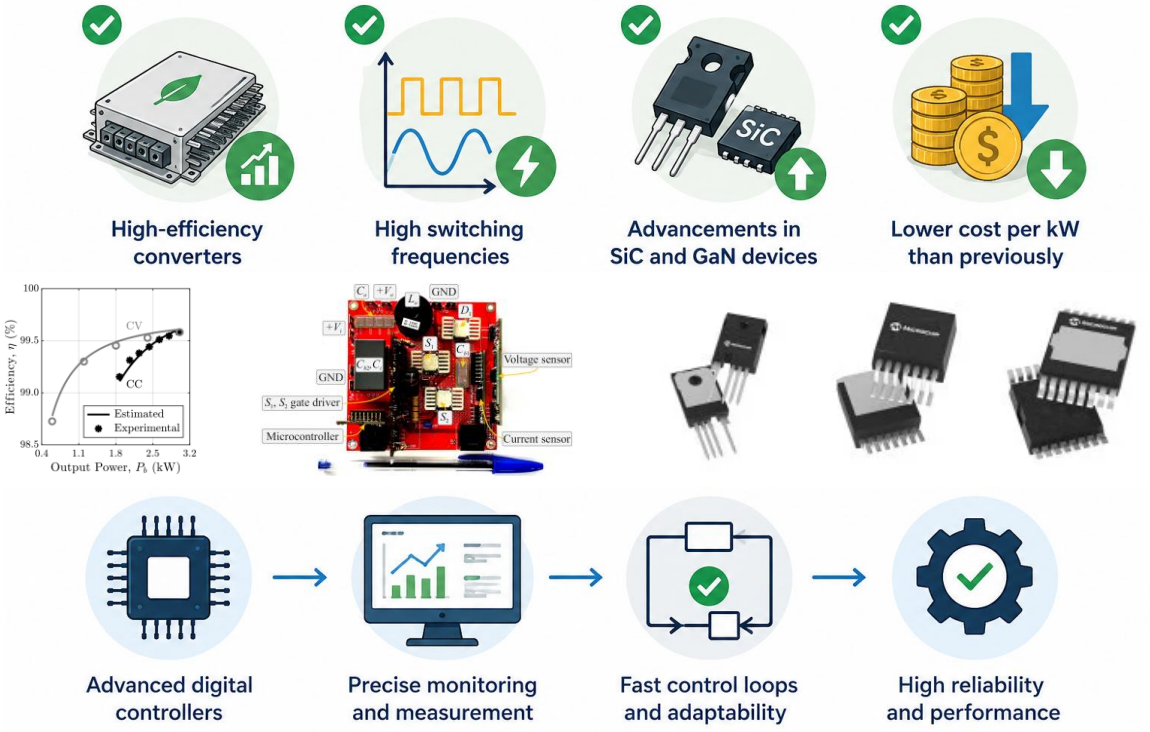
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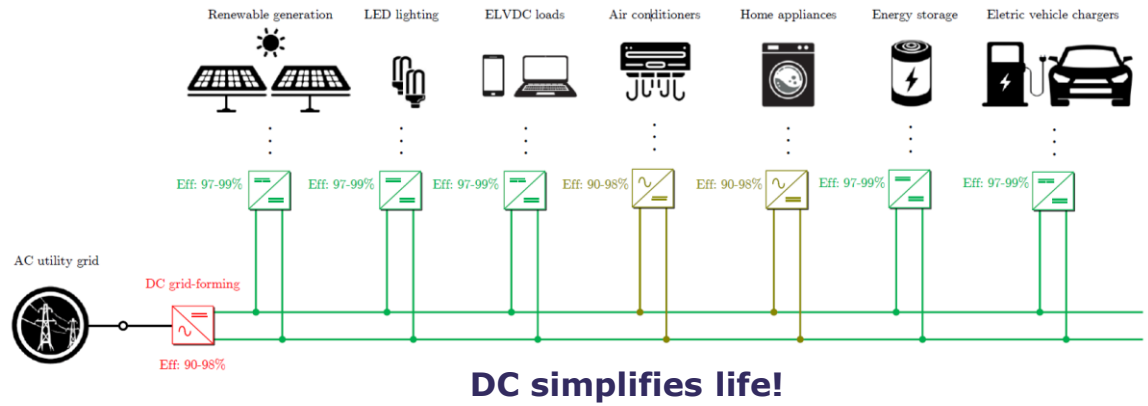
HOW DC INTEGRATION TRIES TO SOLVE

- **Power electronics** are well developed
  - ✓ High-efficiency converters
  - ✓ High switching frequencies
  - ✓ Advancements in **SiC** and **GaN** devices
  - ✓ Lower **cost per kW** than previously
- **Digital control** is mature



30%
of energy saving

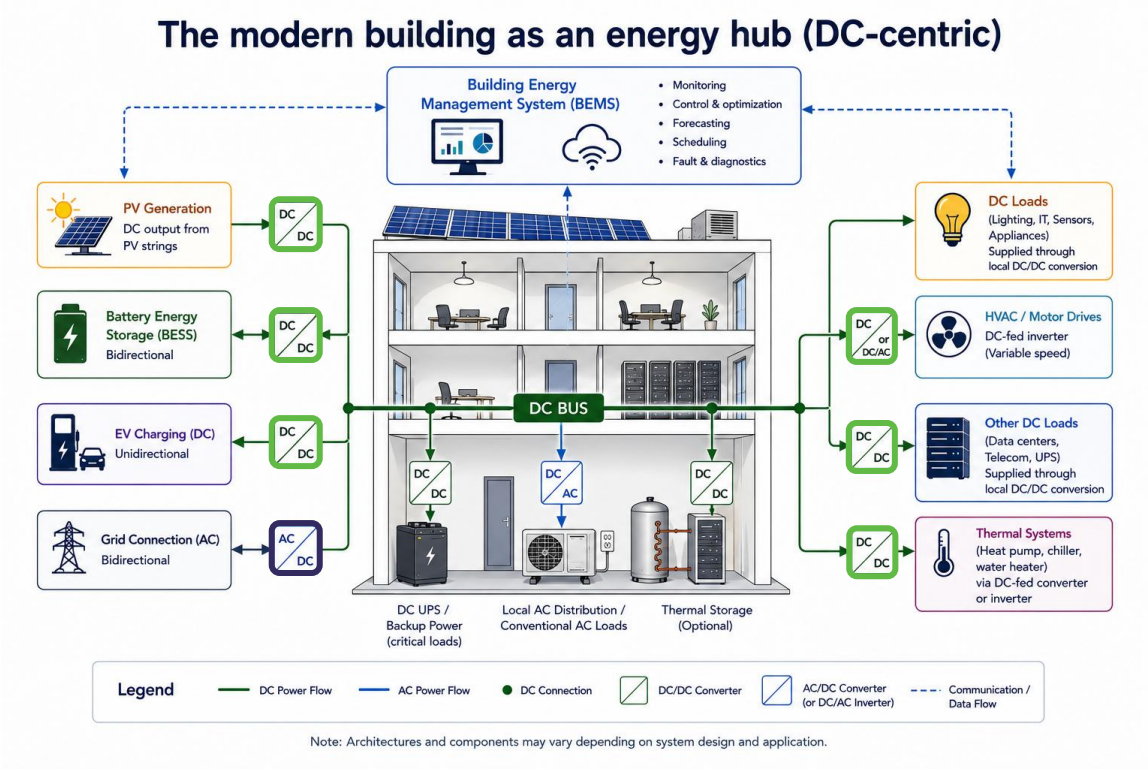


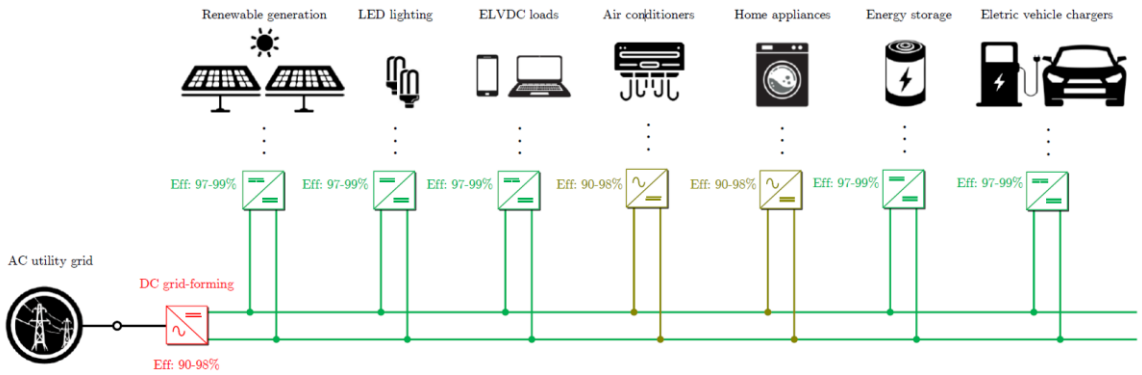


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MAIN ENERGY RESOURCES CONNECTED TO THE DC BUS

- Each *resource* needs a suitable **power-electronic interface**
  - ✓ **PV**: variable generation, MPPT required
  - ✓ **Battery**: bidirectional power flow, state-of-charge control
  - ✓ **EV**: charging load or mobile storage
  - ✓ **Grid**: backup, import/export, flexibility services
  - ✓ **Loads**: regulated voltage through converters
- **Integration depends on converters!**
  - ❖ The **converters** define power flow direction, controllability, efficiency, and dynamic behavior

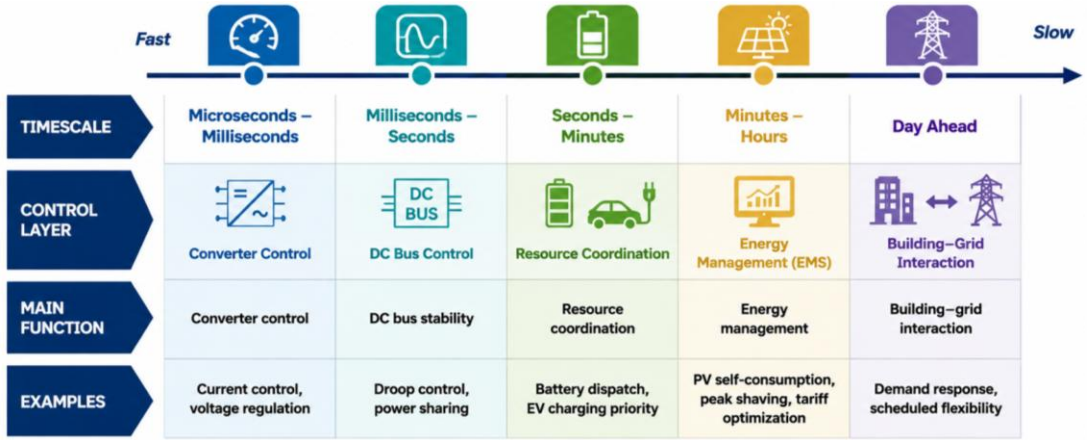




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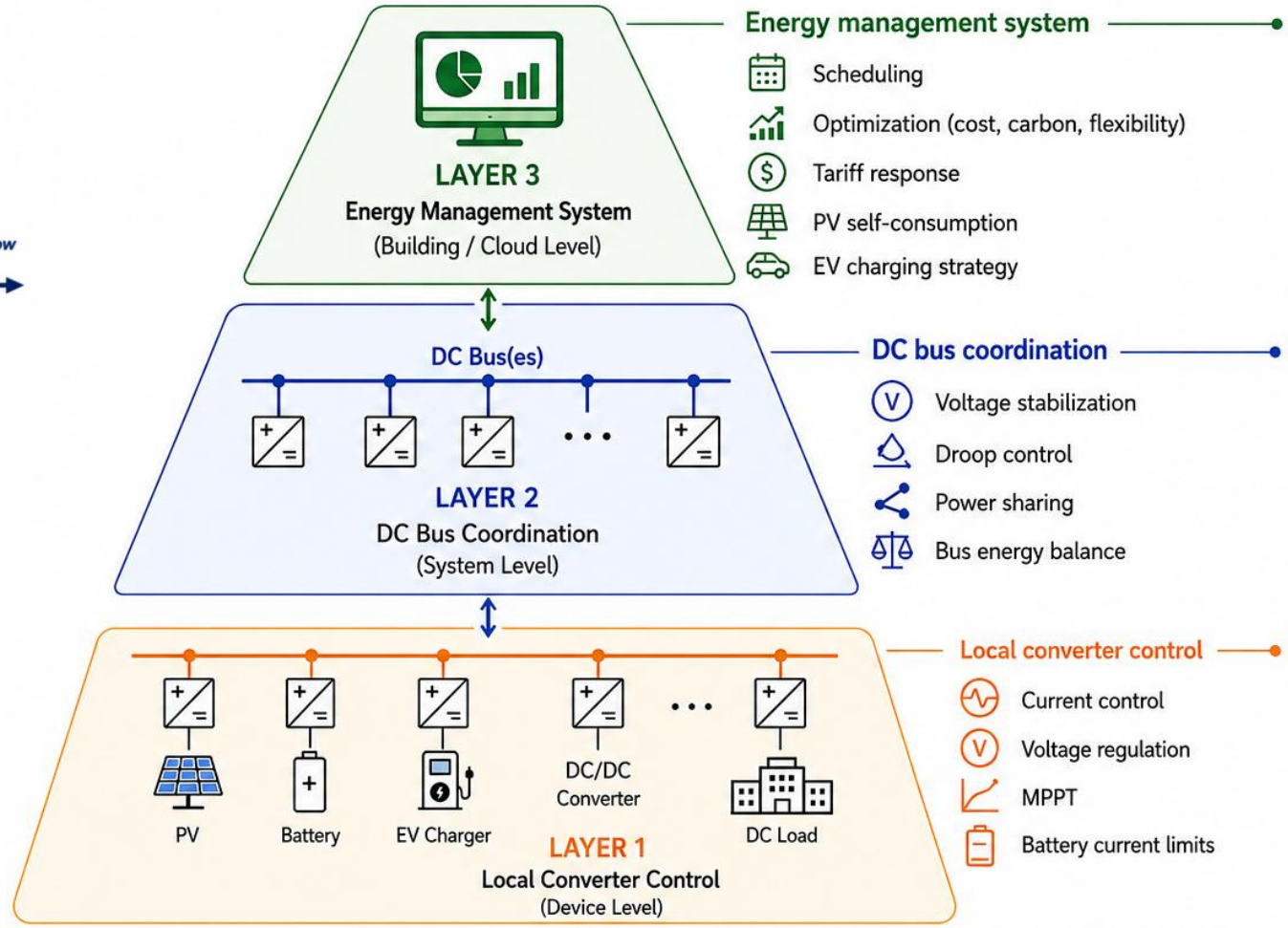
HIERARCHY FOR DC BUILDING INTEGRATION

- **Integration** requires *layered control*, from converter stability to building optimization



❖ **Without coordination, high-efficiency components do not automatically create a high-efficiency system!**

~700 VDC, ~350 VDC, or 12/24/48 VDC
Unipolar or bipolar architecture

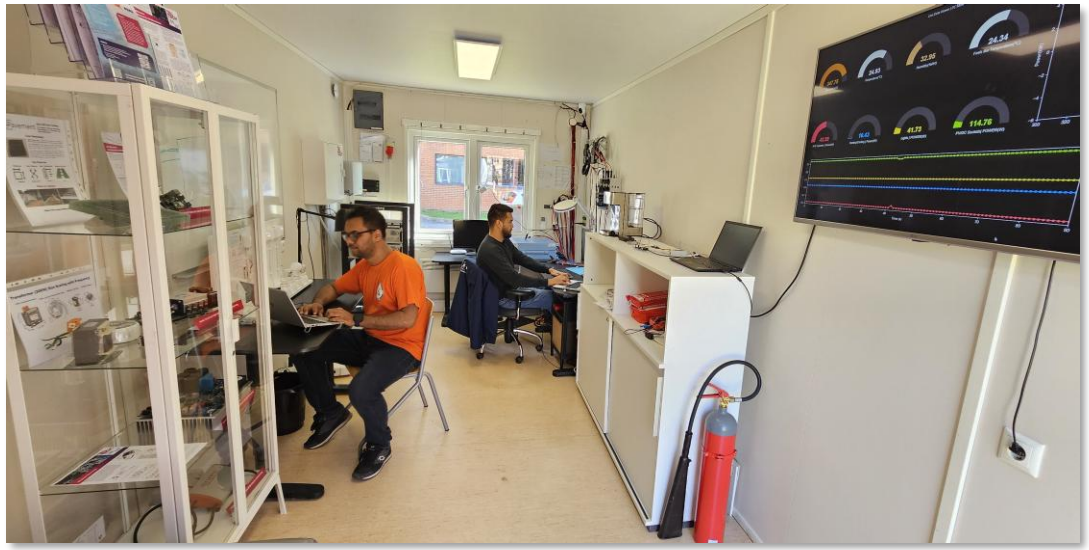


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KEY SOLUTIONS DEVELOPED BY TALTECH PEG

- **DC** optimizes **efficiency** and supports **decarbonization** in *EU-compliant* nearly zero-energy buildings (**NZEBs**)
- **R&I fields** at **TalTech** address emerging needs in power converters, flexibility, control, monitoring, and related **DC technologies**

❖ **First** DC experience center in Northern Europe



PEG *is one of the key players in the* ***Estonian Energy Efficiency Centre of Excellence (ENER)****, which brings together the best expertise in engineering, data science, and social sciences in* ***Estonia*** *and contributes to addressing Estonia's societal and economic challenge of transforming* ***75%*** *of the existing low-energy-efficiency building stock into emission-free buildings by* ***2050***

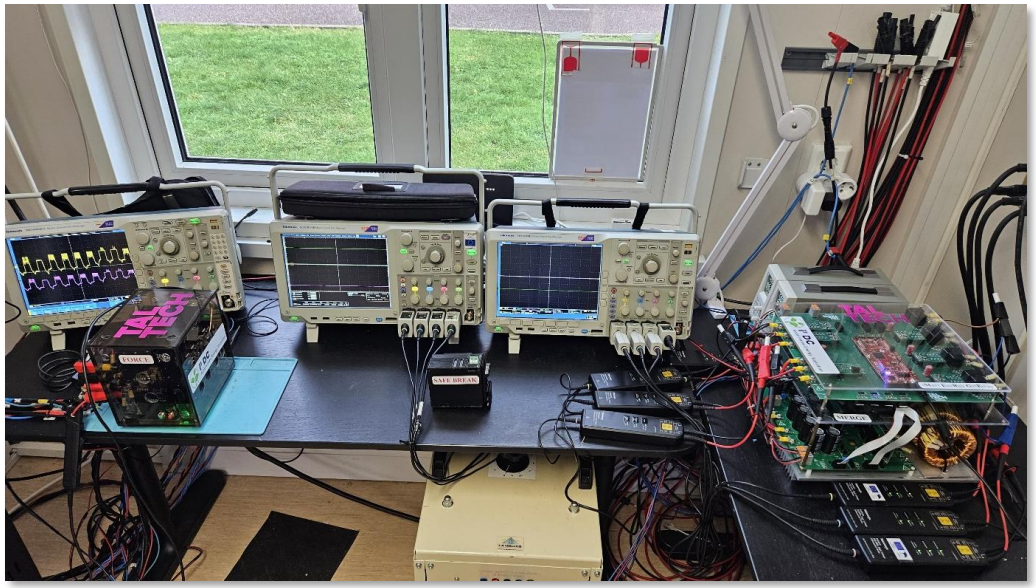
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350 VDC is the substitute for the 230 VAC

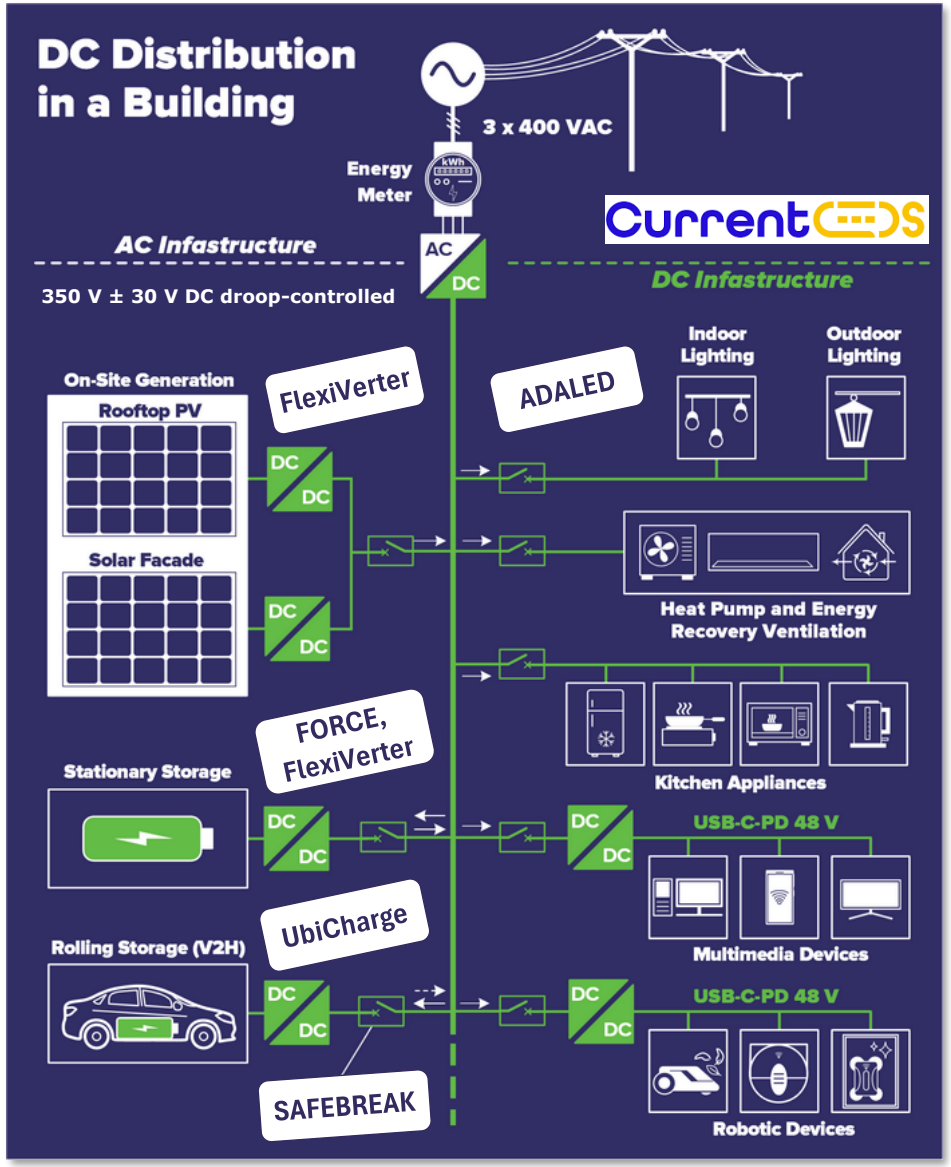


KEY SOLUTIONS DEVELOPED BY TALTECH PEG

- **DC** optimizes **efficiency** and supports **decarbonization** in *EU-compliant* nearly zero-energy buildings (**NZEBs**)
- **R&I fields** at **TalTech** address emerging needs in power converters, flexibility, control, monitoring, and related **DC technologies**



International open platform for *research* and *demonstration* of DC technologies



EXAMPLE 1:
DC LIGHTING SOLUTION

TRIDONIC

- **350-V** centralized **DC** bus solution (in our **lab**):
  - ✓ **Next step**: Outdoor lighting system connected to the **DC Hub**
  - ✓ **Team**: Niwton Feliciani, Andrei Blinov, Tanel Jalakas, and Dmitri Vinnikov







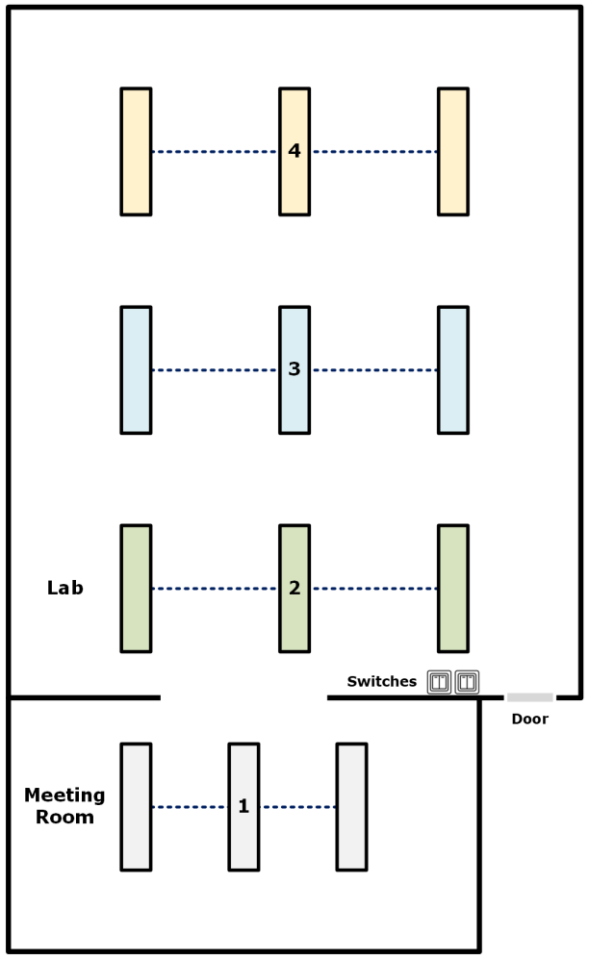


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✓ **12 LED lamps** model **ELA 1200x300mm 3800lm 840 ADV2**

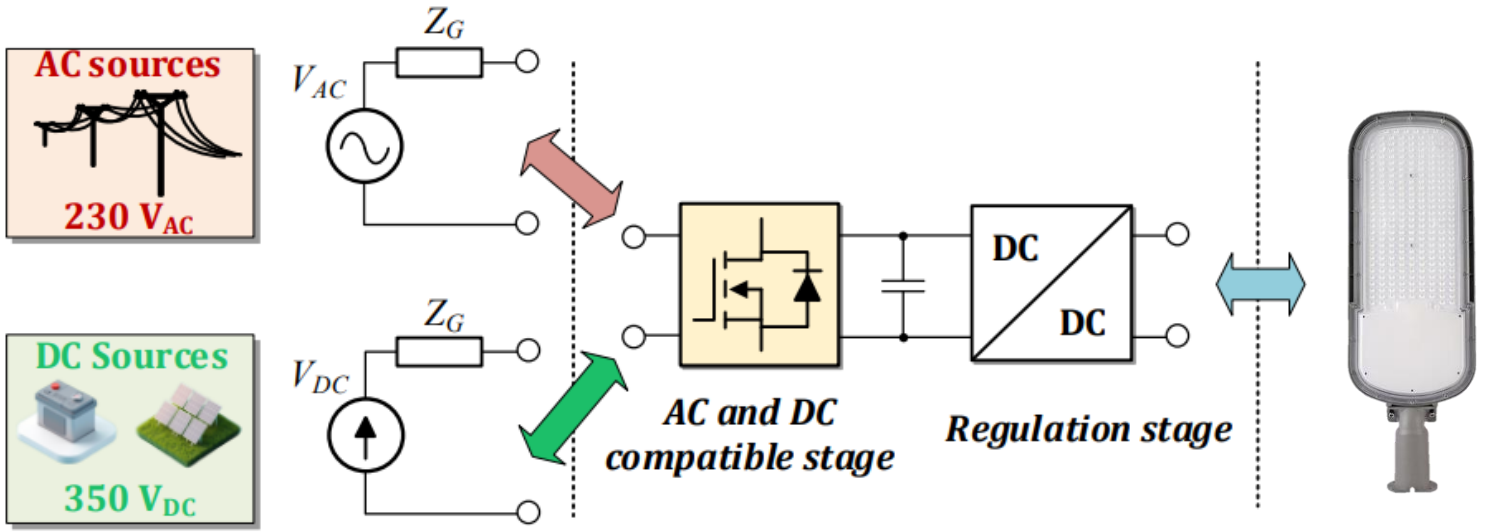
✓ **4 groups** of **3 lamps**

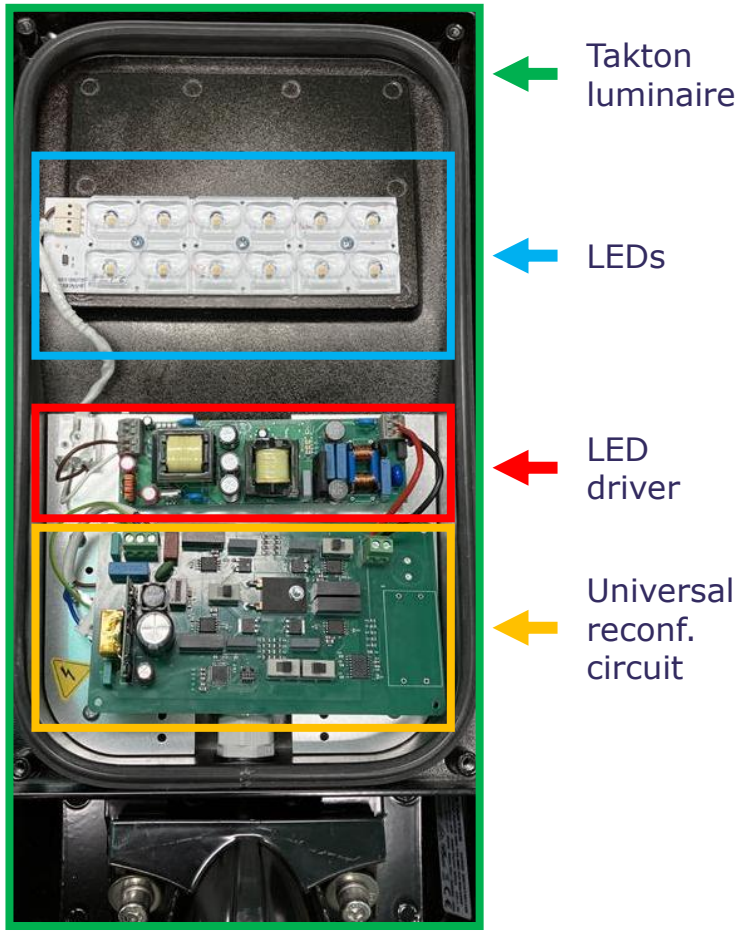


EXAMPLE 2:
UNIVERSAL LED DRIVER

TRIDONIC TAKTON

- **Key idea**: **Universal LED driver** to operate from either **AC** or **DC**
  - ✓ **Team**: Mihkel Türnpu, Niwton Feliciani, Andrei Blinov, and Dmitri Vinnikov
  - ✓ **Patent pending**
- **Solution**: A *reconfigurable* input-stage LED driver (**AdaLED**)
- **Challenges**: rectification, circuit breaker operation, pre-charge, etc.

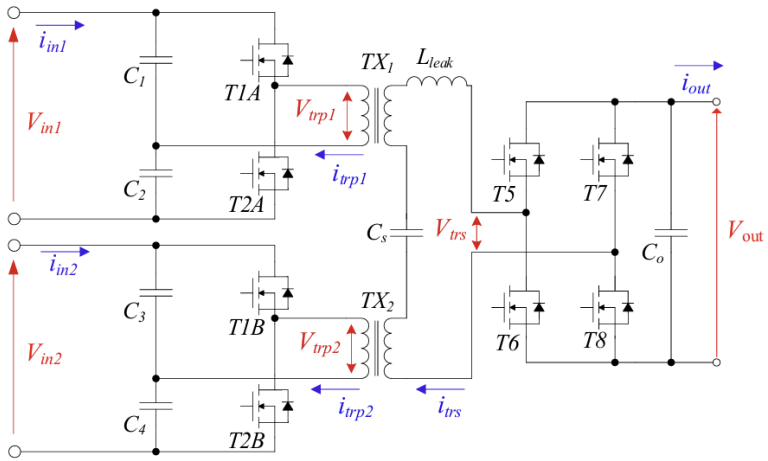




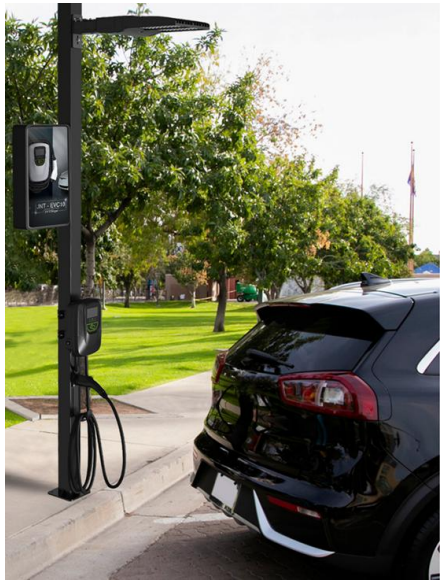
EXAMPLE 3:
UBICHARGE: OPPORTUNITY EV DC CHARGING

- **Key idea**: Addresses the *urban infrastructure challenges* through **opportunity EV DC charging** (G2V/V2G/V2V), leveraging frequent *long* stops and *short* travel distances
  - ✓ **Team**: Hans Anniste, Andrei Blinov, and Dmitri Vinnikov
- **Solution**: EV charging whenever/wherever it is parked (patent **P201800004**)
- **Challenges**: Cost-effective, broad coverage, infrastructure-compatible

UBICHARGE
CHARGE ANYWHERE, ANYTIME

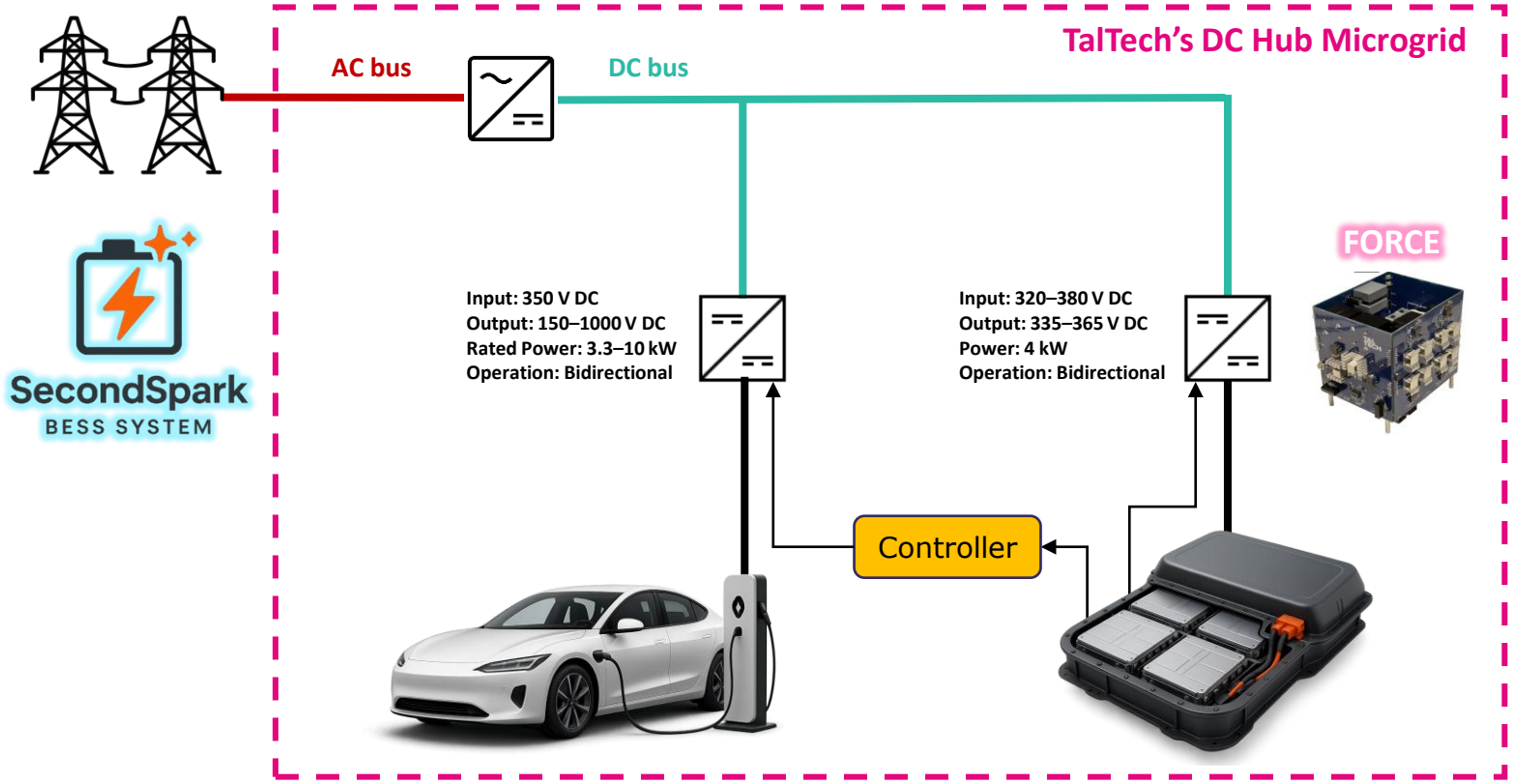


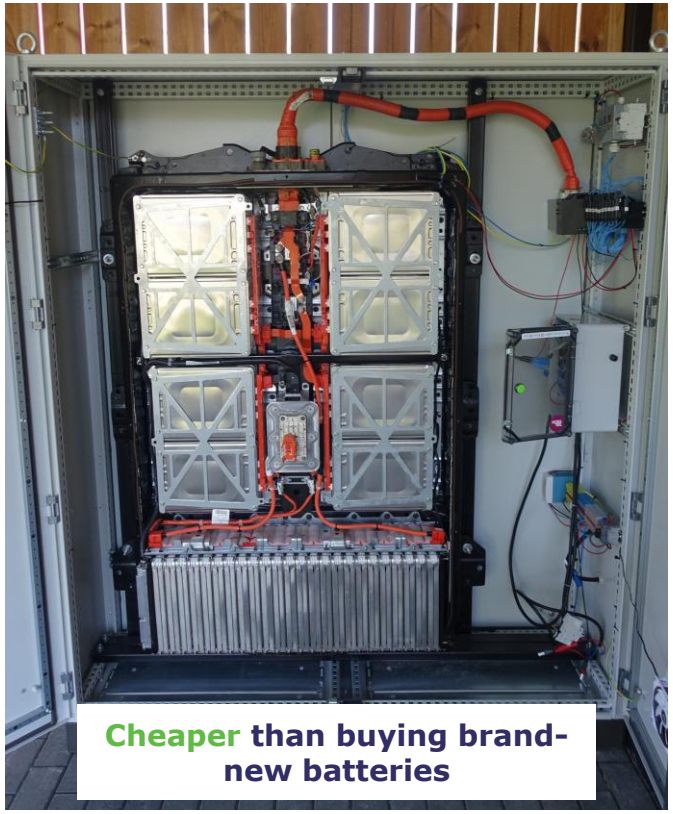




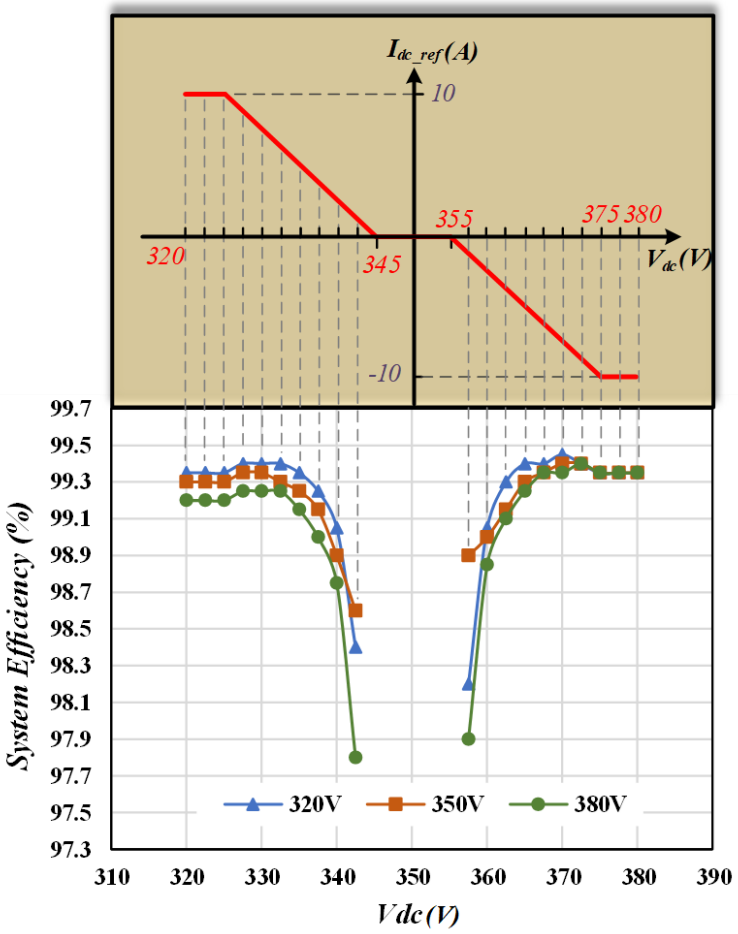
EXAMPLE 4:
SECONDSPARK USING FORCE



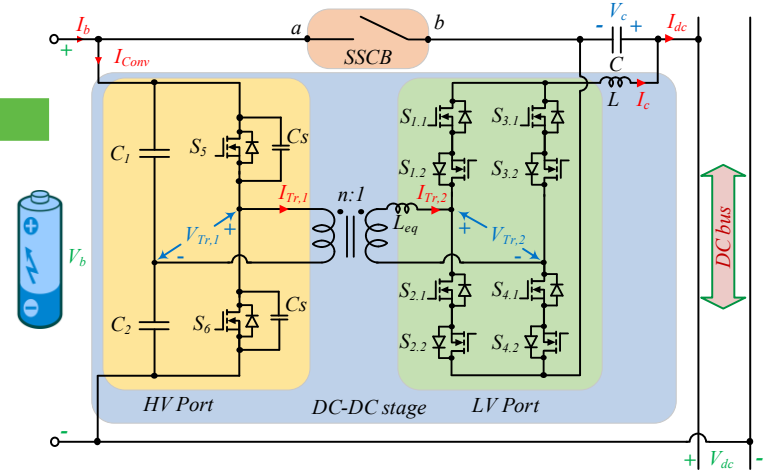




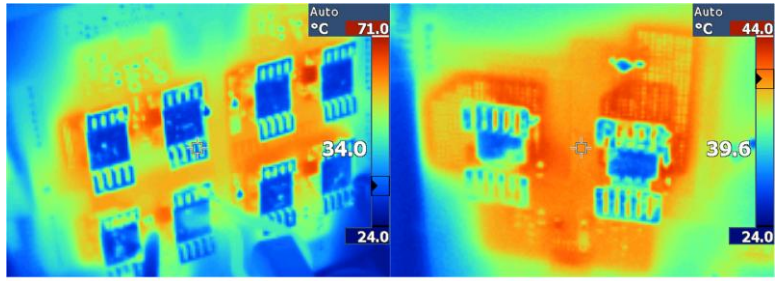
EXAMPLE 4:
THE FORCE TECHNOLOGY







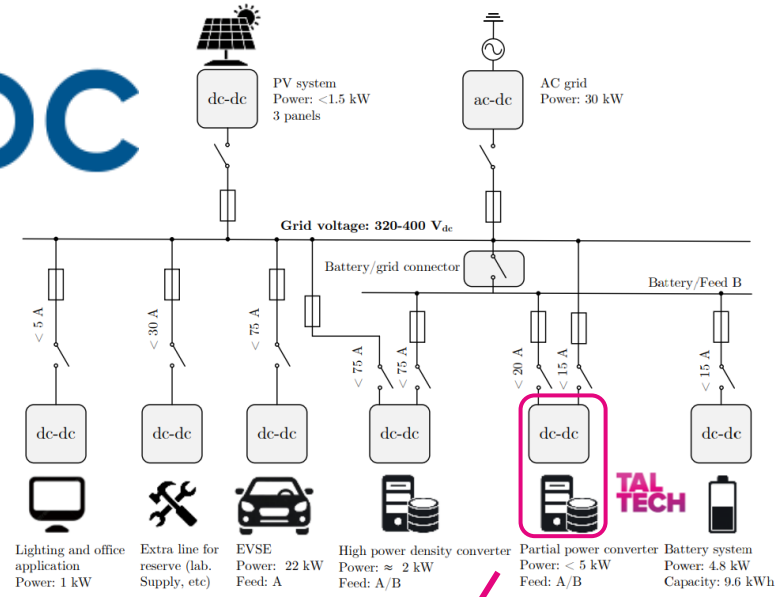
High-efficiency partial power converter (PPC)

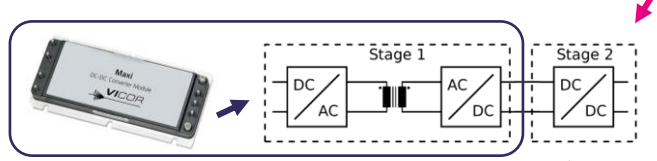


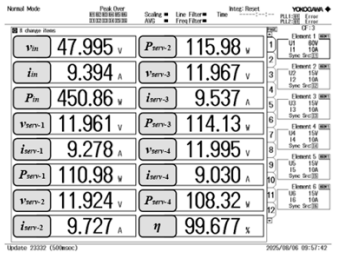
EXAMPLE 5:
THE SHIFT2DC PROJECT

- **10 countries, 21 partners, 11 M€**
- Integration of **DC** solutions in <u>four</u> demonstrators
  - ✓ **<u>Data center</u>**, port, building, and industry
- **Team:** Niwton Feliciani, Kristjan Uus, and Andrii Chub
  Solution: *Server system* including 600-W modules, each including a step-down isolated DC–DC converter and a DC–DC converter that performs **differential power processing (DPP)**

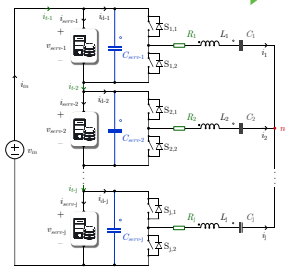




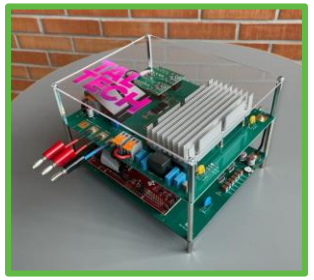




99.7% peak efficiency (DPP)



<u>DPP converter</u>

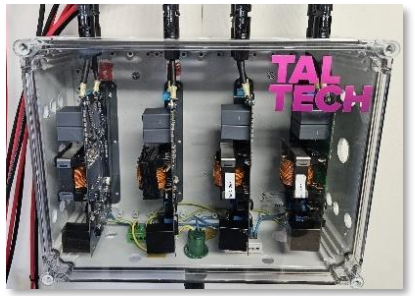


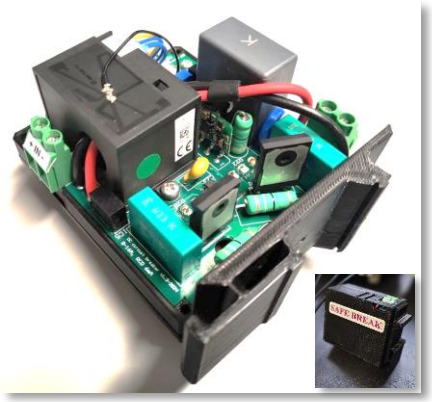
Power-Optimized, Reliable, Intelligent, Sustainable DC Module (PRISM)

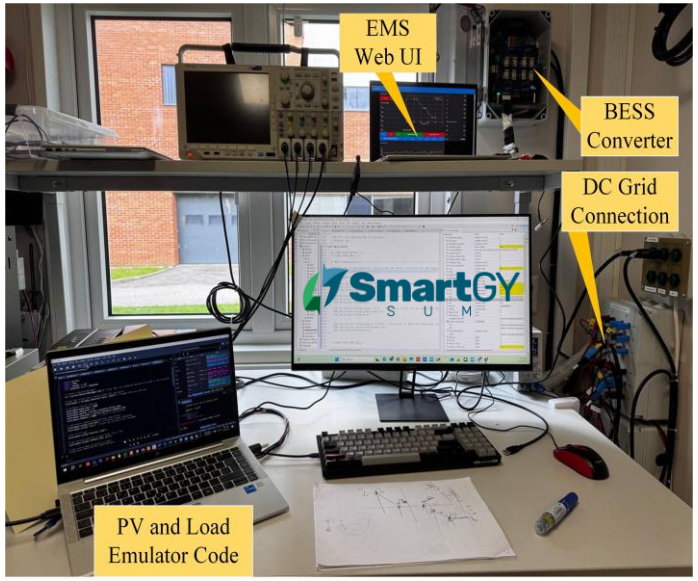
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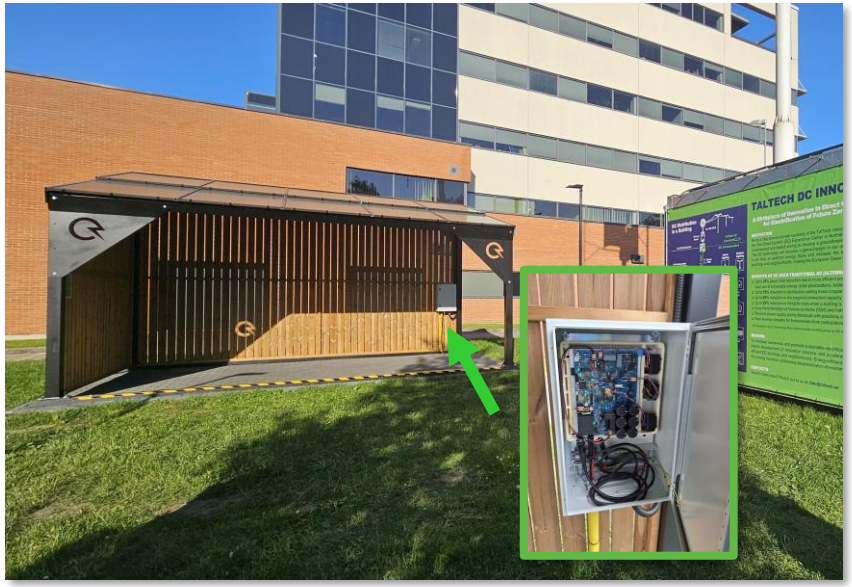
KEY SOLUTIONS DEVELOPED BY TALTECH PEG

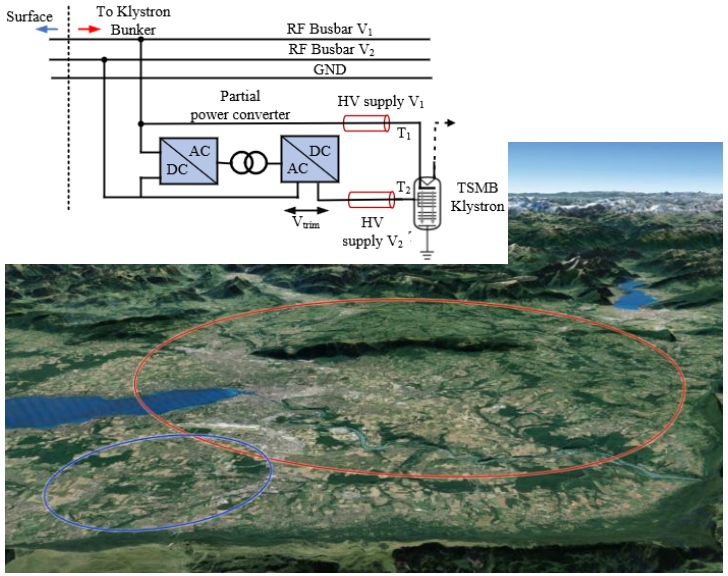
- Other solutions developed or under development by **TalTech PEG**:
  1. **SafeBreak**: Multifunctional solid-state circuit breaker for DC buildings
  2. **DC-powered** solar carport
  3. **SmartGYsum**: Energy management in *droop-controlled* DC microgrids
  4. **DC Technologies** for the CERN **Future Circular Collider (FCC)**
  5. **Etc.**









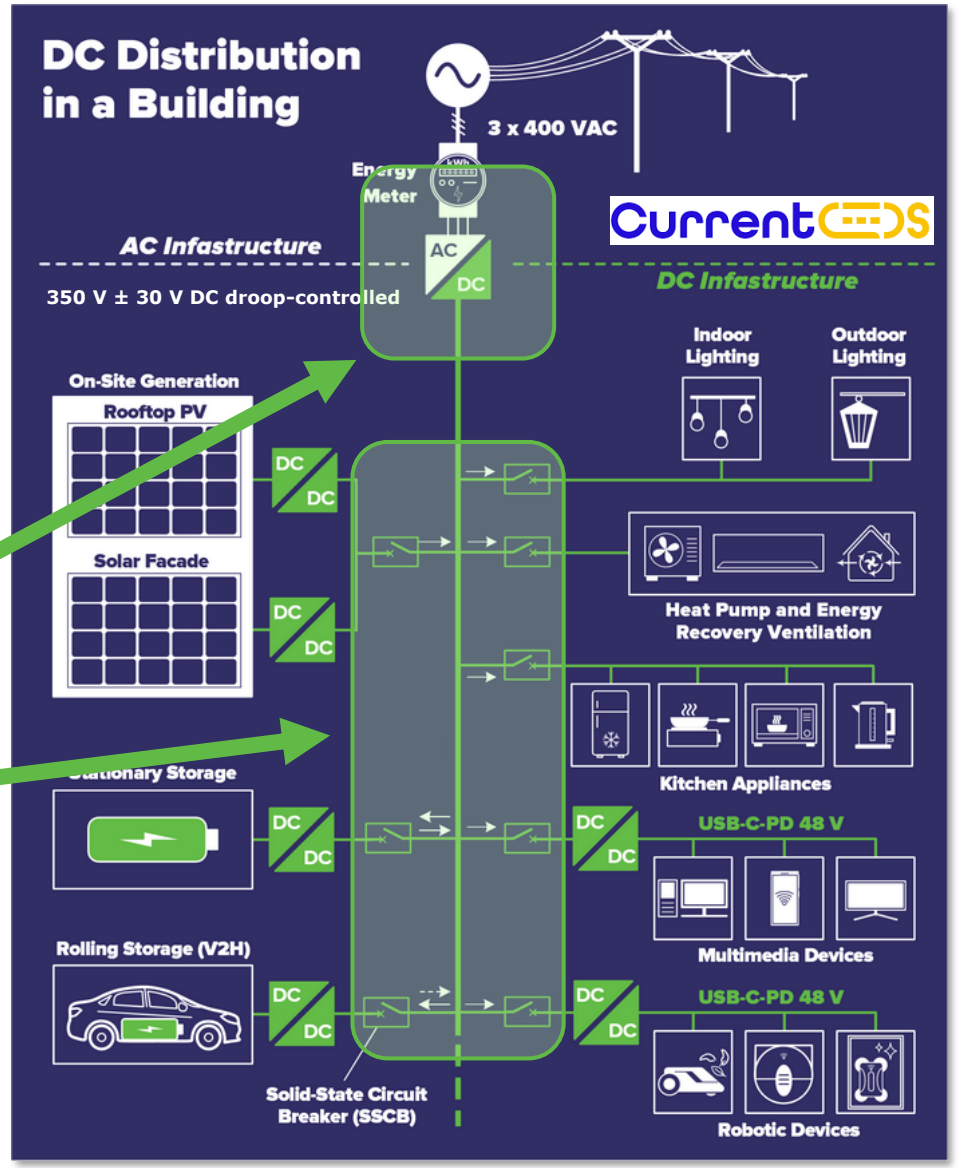


OTHER IMPORTANT SOLUTIONS FOR DC MICROGRIDS

- Main components of a **DC microgrid**:
  - ✓ Energy sources (PV, wind, etc.)
  - ✓ Energy storage (batteries, BESS, etc.)
  - ✓ Loads (LEDs, EVs, etc.)
  - ✓ Control & energy management (EMS, etc.)
  - ✓ DC–DC converters (voltage conversion)
  - ❖ **AC–DC converter** (grid interface)
  - ❖ **Protection devices** (breakers)









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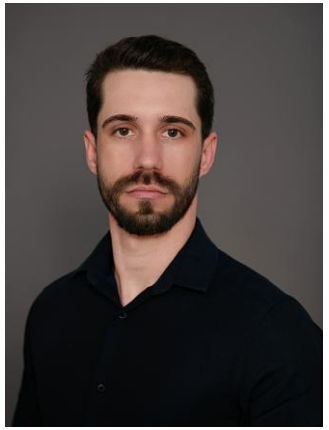
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Dr. Niwton G. Feliciani dos Santos

niwton.feliciani@taltech.ee