DC BUILDINGS

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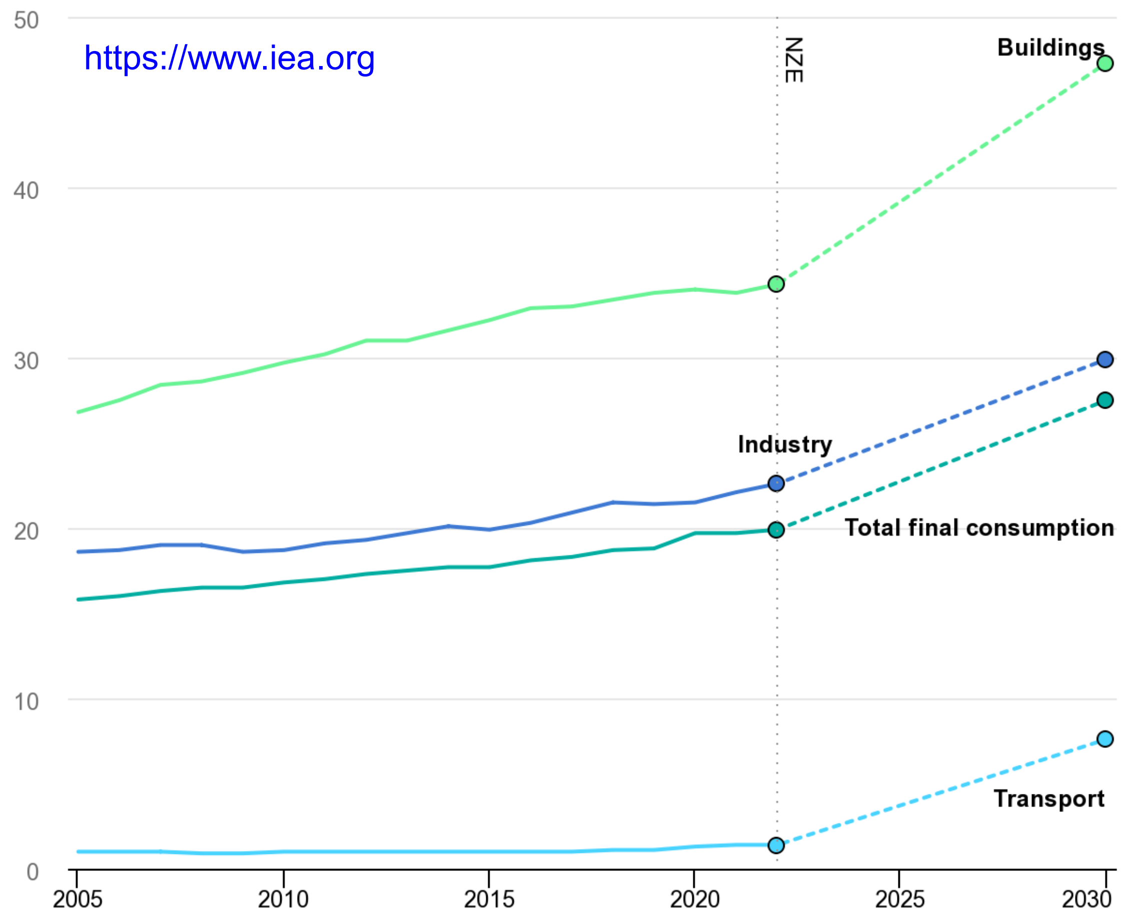
TOWARDS 2050 NZE PATHWAY (EU GREEN DEAL)

- *By 2050 the EU aims to become the* ***world's first "climate-neutral bloc"*** *having an economy with net-zero greenhouse gas emissions (NZE)*
- ***Electrification*** *is considered one of the key strategies to reach NZE goals*
- *The* ***share of electricity*** *in the final energy consumption in 2050 is targeted to be* ***more than 50%***
- *By 2050, almost* ***90%*** *of electricity generation in EU is expected to come* ***from renewable sources****, with wind and solar PV together accounting for nearly 70%*
- *Much of the NZE need will be met by shifting towards* ***electric transport*** *and* ***electrification of heating/cooling demand of buildings*** *using heat pumps*
- *In 2050,* ***electricity will become the dominant energy carrier for the buildings in EU****: the prognosed growth in demand by 2030 is 12% and 35% by 2050*



Share of electricity in total final energy consumption in the NZE scenario (2005-2030)

DECARBONIZATION OF BUILDING STOCK IN EU

- ***Buildings*** *are responsible for approximately* ***40% of EU energy consumption****,* ***more than half of EU gas consumption*** *(mainly through heating, cooling and domestic hot water), and 36% of the energy-related greenhouse gas emissions*
- ***Roughly 75% of buildings*** *in the EU are not energy efficient, yet 85–95% of today's buildings will still be in use in 2050*
- *To* ***boost decarbonization*** *the EU requires all new buildings from 2021 to be nearly zero-energy buildings (nZEB)*
- ***nZEB (or class A building)*** *means a building with a very high energy performance where the very low amount of energy should be covered to a* ***very significant extent by energy from the renewable sources***
- *In practice,* ***nZEB consumes up to 4 times less energy*** *than the traditional „old school" building*
- *Recently, the EU proposed to move from the current nZEB to zero-emission buildings (****ZEB, A+ or*** A_0*) from January 1, 2030. In ZEB the very low amount of energy still required must be* ***fully covered by energy from the renewable sources and without on-site carbon emissions from fossil fuels.*** *All new buildings become all-electric.*

Table 2. Estonian energy labels for the three categories of detached houses D1, D2, and D3; EPC (kWh/(m²a)).

En. Label	D1 (EPC)	D2 (EPC)	D3 (EPC)
A	≤145	≤120	≤100
B	146–165	121–140	101–120
C	166–185	141–160	121–140
D	186–235	161–210	141–200
E	236–285	211–260	201–250
F	286–350	261–330	251–320
G	351–420	331–400	321–390
H	≥421	≥401	≥391

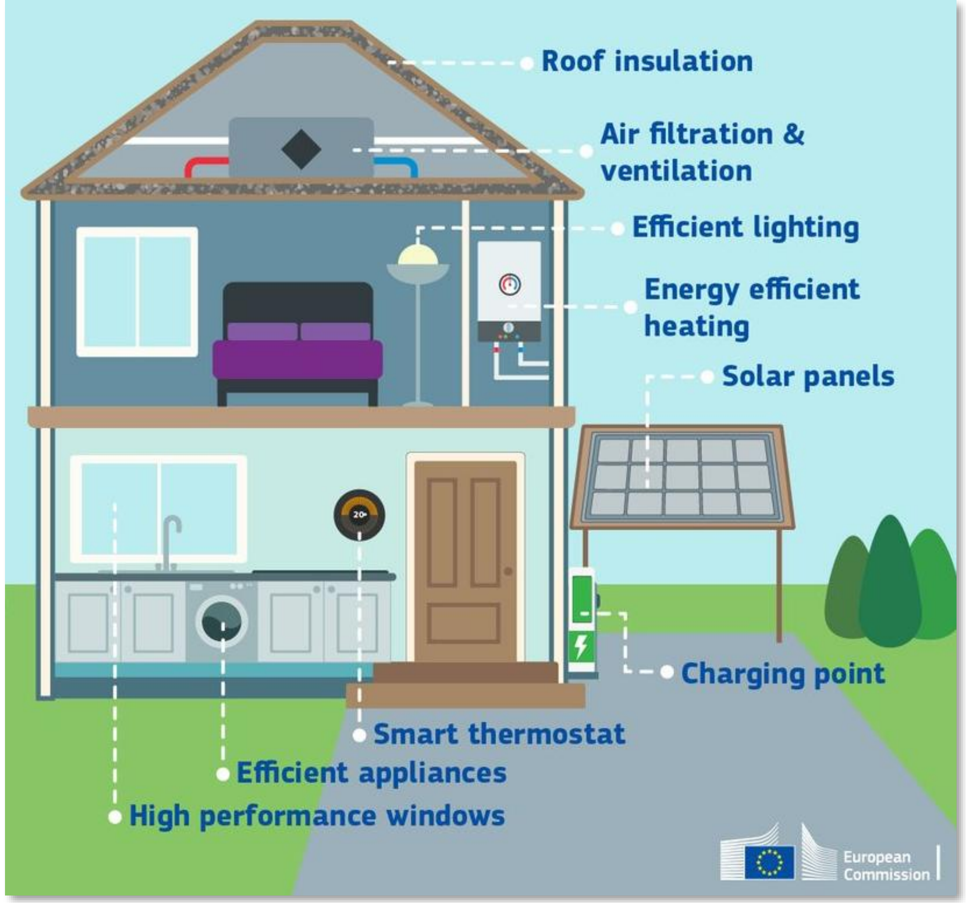
D1, <120 m²
D2, 120–220 m²
D3, >220 m²

https://energy.ec.europa.eu

ZEB AND POWER ELECTRONICS

IT IS ALL ABOUT EFFICIENCY AND ENERGY SAVING

- *ZEB = high energy performance + local renewable energy generation + all-electric lifestyle*
- ***Energy efficiency is the main feature of ZEB** - PV installation (backed up with energy storage), heat pump, heat recovery ventilation, energy-efficient appliances and lighting, smart control of loads, energy arbitrage*
- *Most of the energy saving technologies used in ZEB are **power electronics based***



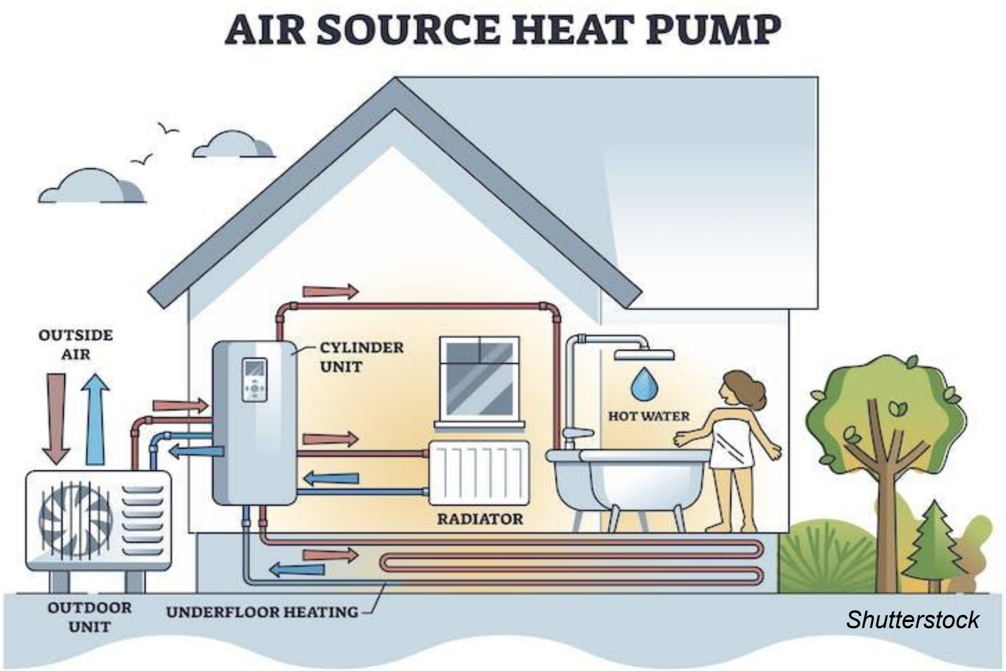
BAPV vs BIPV- RENEWABLE ENERGY SHOULDN'T COME AT THE COST OF AESTHETICS !

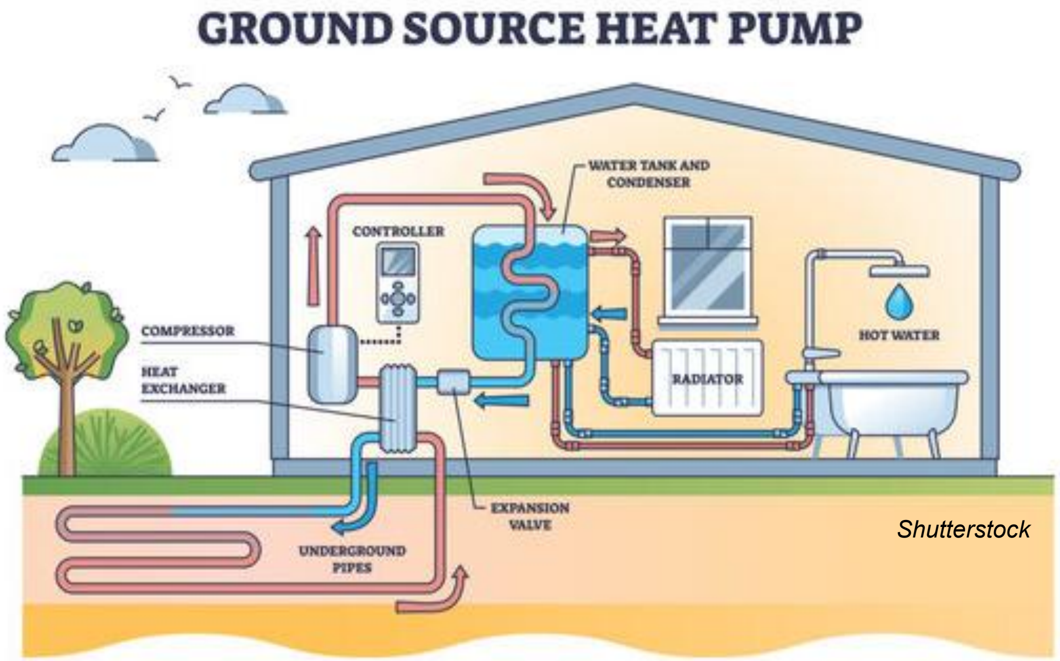
Building-Attached Photovoltaics (BAPV) *lacks full integration into the building, adds additional load, with limited contributions to aesthetics and structural integrity*

Building-Integrated Photovoltaics (BIPV) *is revolutionizing the solar industry by bridging the gap between electricity generation and building design*

ADVANTAGES OF HEAT PUMPS

- *There are* ***two main types of heat pumps*** *– air source and ground source (geothermal)*
- ***Excellent energy efficiency****: can deliver up to 5 times more heat energy to a home than the electrical energy it consumes (see COP – Coefficient of Performance or SCOP – Seasonal Coefficient of Performance)*
- *Used for* ***space heating/cooling*** *and providing* ***domestic hot water*** *for showers and sinks*
- *Can be* ***easily paired with PV*** *installation*
- ***Power electronics enabled smart control*** *– heat pump can be operated as a* ***flexible and grid-responsive resource***

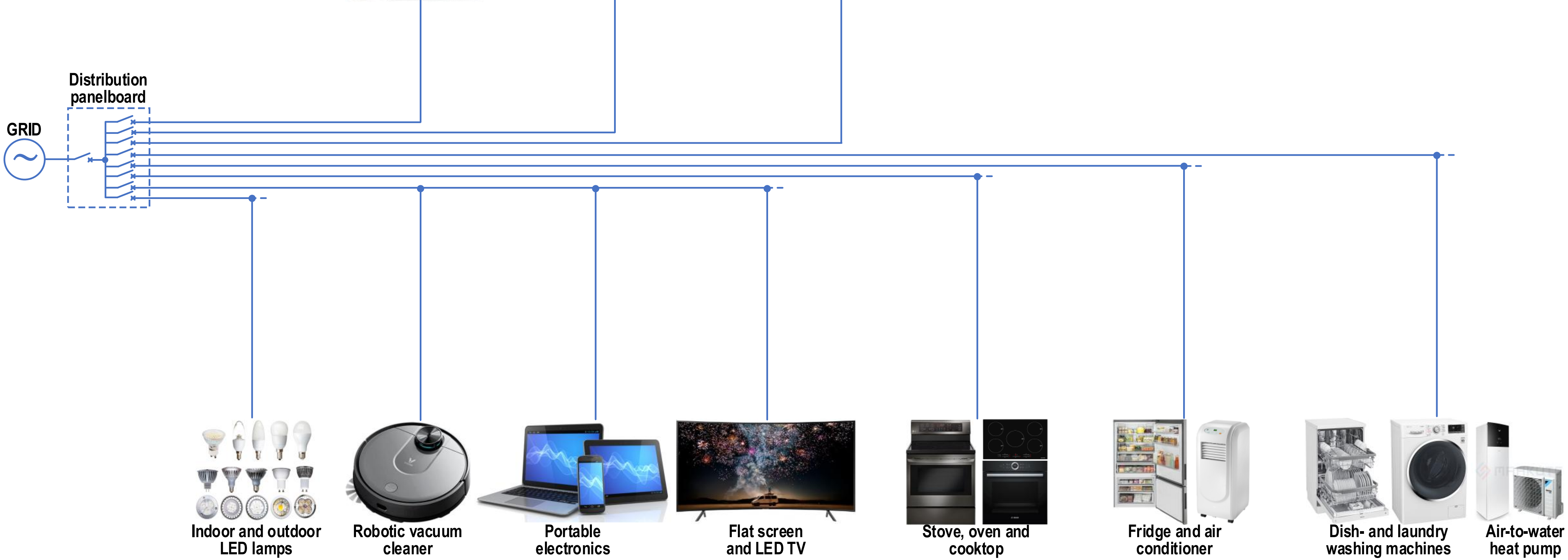




AC-BASED ELECTRICAL SYSTEM OF ZEB TODAY

WE GAIN THE BENEFITS OF AN ALL-ELECTRIC LIFESTYLE!

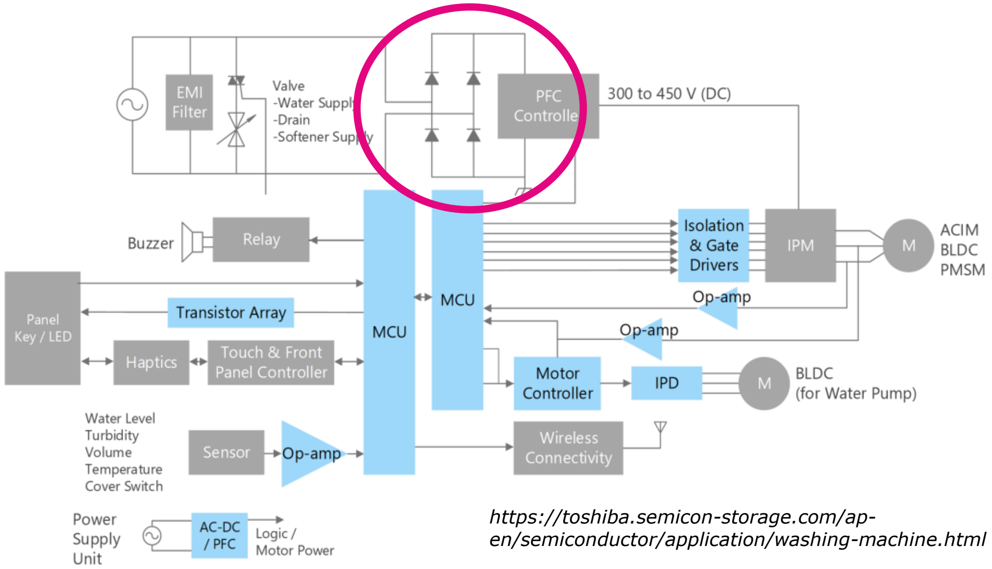
*Look at the **energy label** when buying heat pumps, induction cooktops and other appliances!*



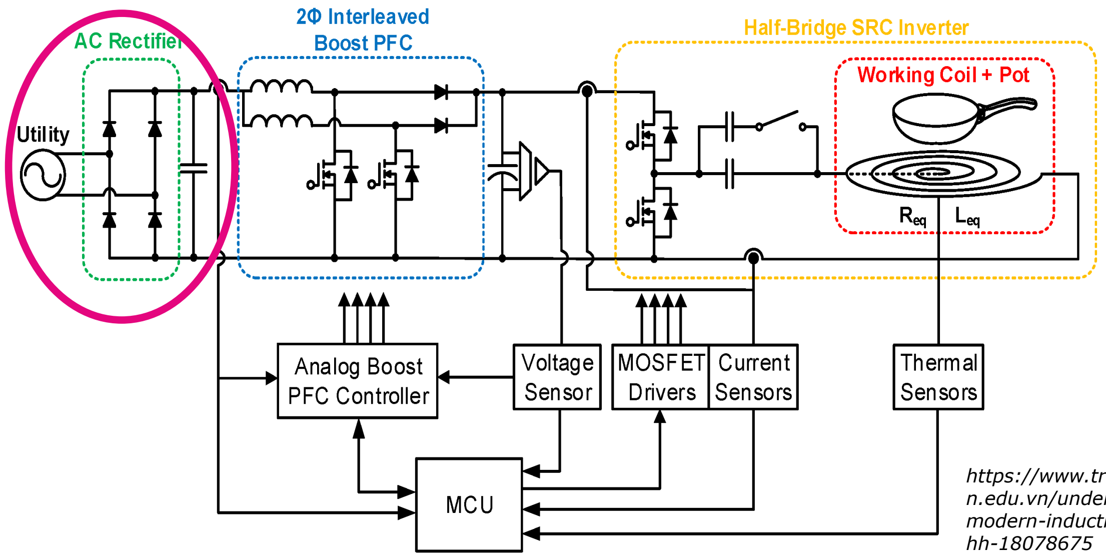
CLASS-A ENERGY-EFFICIENT APPLIANCES

WASHING MACHINES, REFRIGERATORS, INDUCTION COOKTOPS, HEAT PUMPS, ETC.

THEY ALL USE DIRECT CURRENT (DC) FOR OPERATION !!!



https://toshiba.semicon-storage.com/ap-en/semiconductor/application/washing-machine.html



https://www.truongquoctesaigon.edu.vn/understanding-how-modern-induction-cooker-work-hh-18078675

FULL-ELECTRIC LIFESTYLE WITH AC

A CLOSER LOOK AT THE POWER FACTOR ISSUE

PFC stage is required only above 75W - energy efficiency is additionally affected by the non-unity power factor

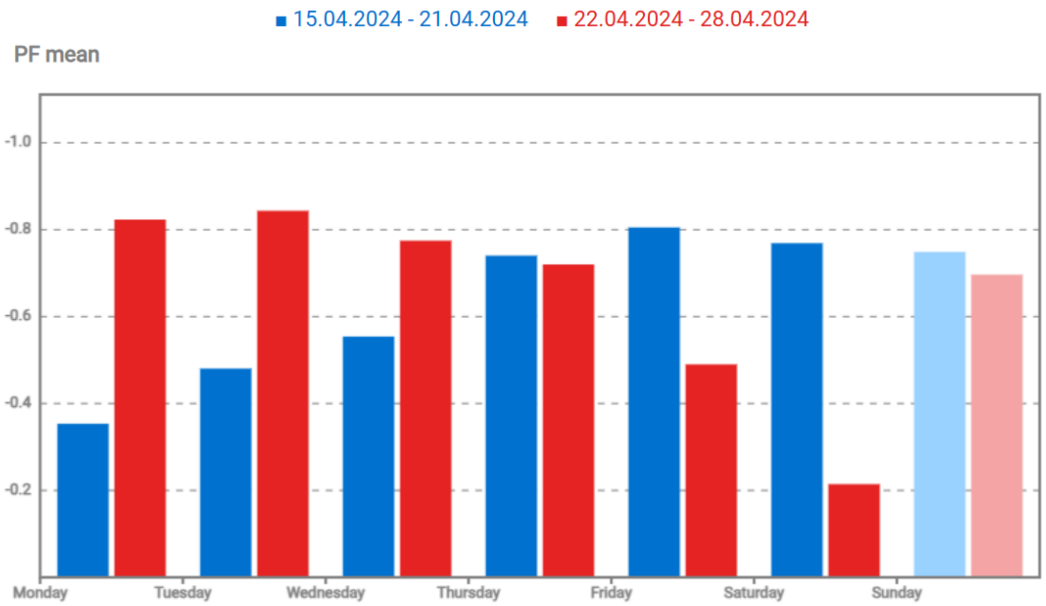
GU10 LED bulb (4.3 W)

1	Urms	1	—	232.40	V
2	Irms	1	—	0.0337	A
3	P	1	—	4.33	W
4	S	1	—	7.83	VA
5	Q	1	—	6.52	var
6	Uthd	1	—	0.964	%
7	Ithd	1	—	74.420	%
8	PF	1	—	0.5534	

Laptop charger (65 W)

No.	Function	Data	Units
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

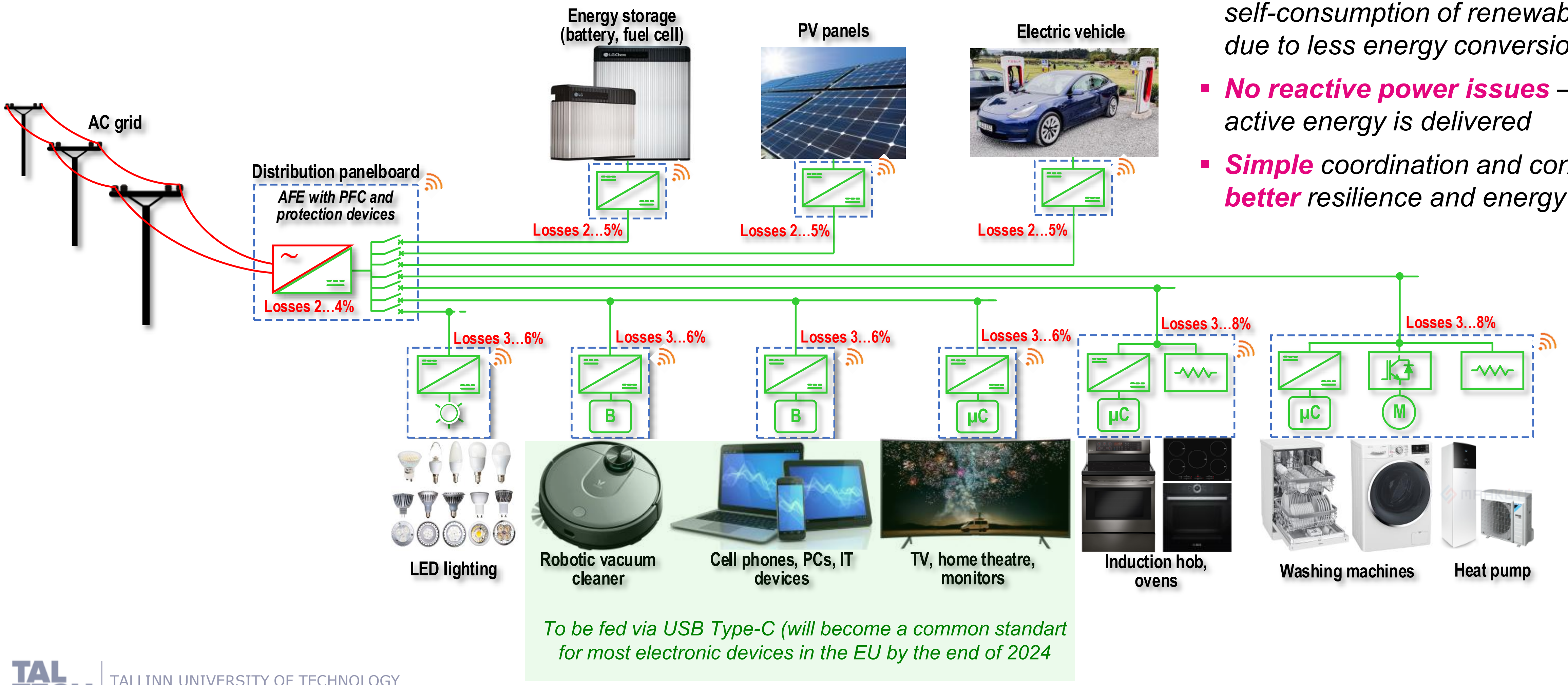
176.7 m² private house



Location	Estonia, Tallinn
Total power of PV	5 kWp
Model of HP	Thermia Atec HP 11
Electric car	BMW i3
COP of HP	COP 3.8 (+7/+45 °C)
Habitants	4

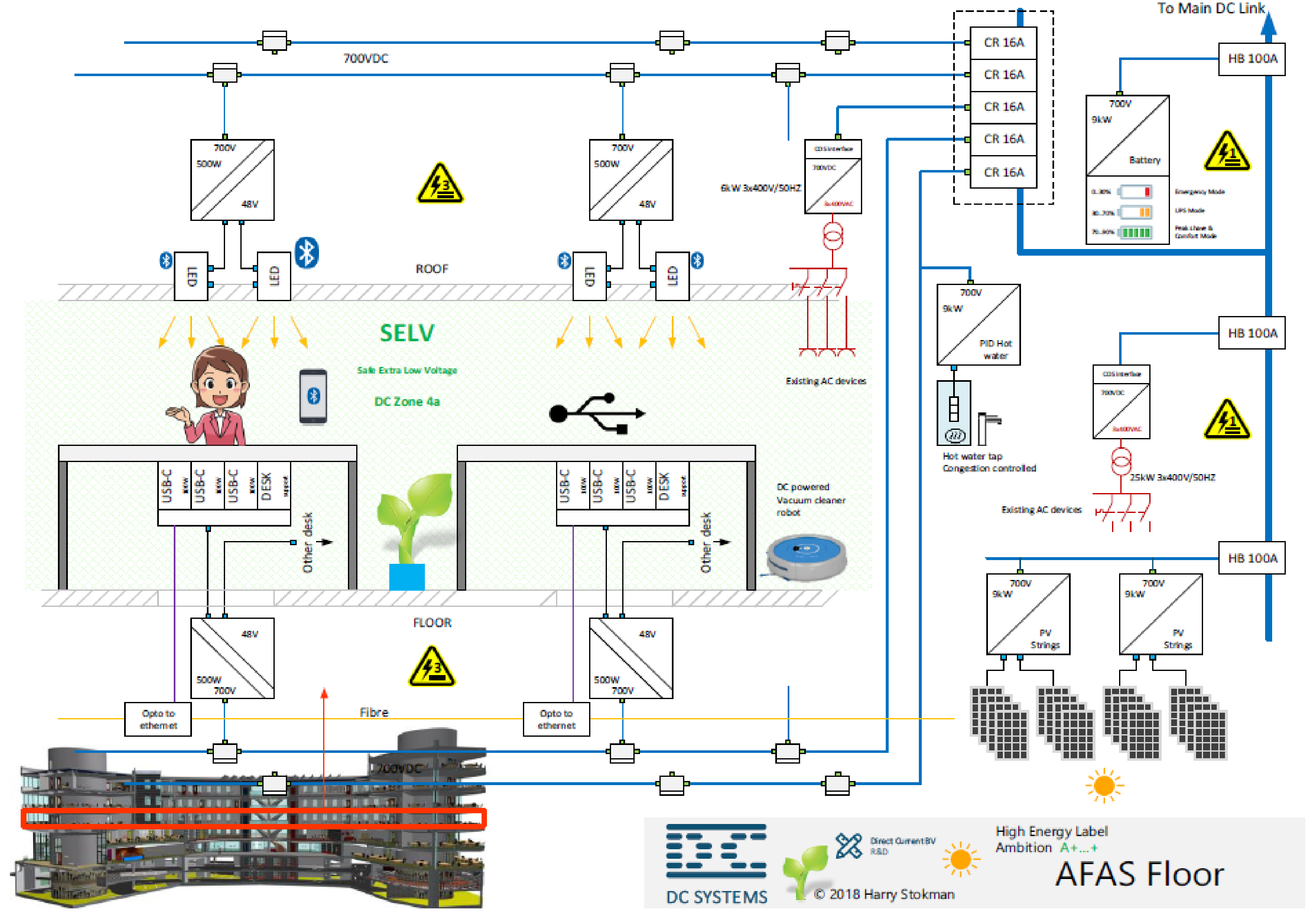
NEXT-GEN ELECTRICAL SYSTEM OF ZEB

DC POWER DISTRIBUTION AND DC-FED APPLIANCES



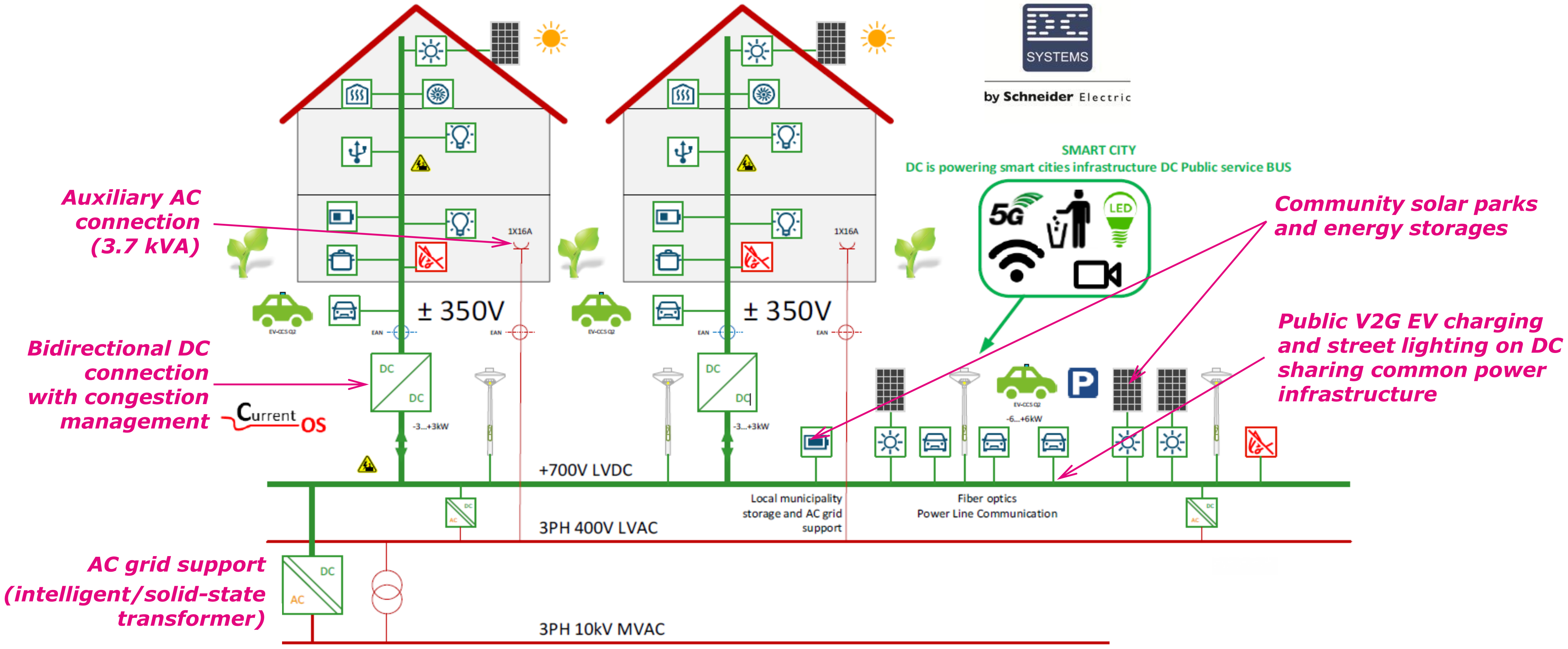
- ***Increased*** *efficiency and* ***maximized*** *self-consumption of renewable energy due to less energy conversion stages*
- ***No reactive power issues*** *– only active energy is delivered*
- ***Simple*** *coordination and control,* ***better*** *resilience and energy security*

ENERGY NEUTRAL DC WORKSPACE



USB Type-C *is used as universal connector for power and data transfer - direct DC connection avoiding numerous AC wall chargers and* ***reducing e-waste***

DC ELECTRIFICATION OF NEIGHBOURHOODS

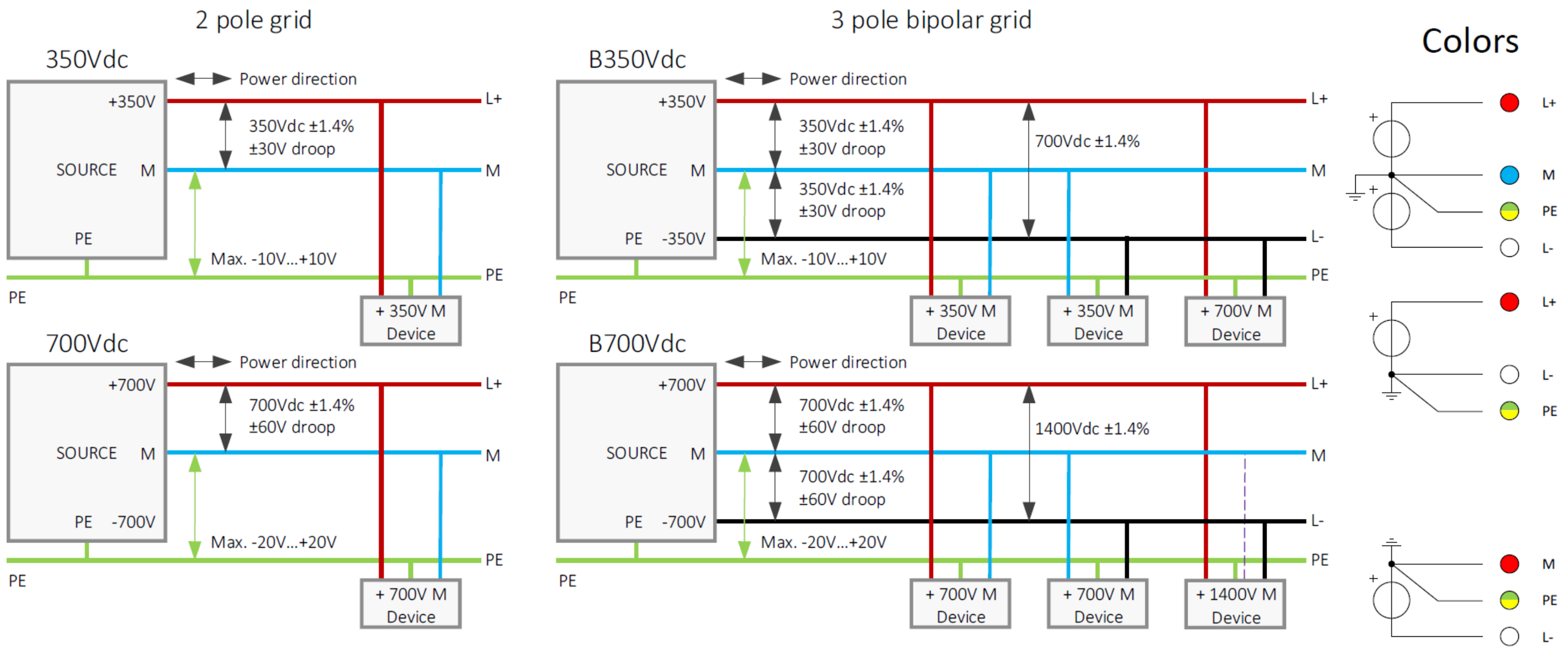


HISTORICAL CHOICE: FROM 230 VAC TO 350 VDC

NPR9090: THE FIRST PRACTICAL GUIDELINE FOR DC INSTALLATIONS

- *The Netherlands has a leading position in the global consultation on international standards for DC installations*
- *In 2018 the 350 V DC has been implemented formally in the Dutch standardization in the NPR9090 (Dutch Practical Guideline for the installations up to 1500 V DC)*
- *The new core colors for DC installations are red, blue and white*

DC Voltages	350V DC / 700V DC / 1400V DC



SYSTEMS

by Schneider Electric

CurrentOS

https://currentos.foundation

E. L. Carvalho et al., "Grid Integration of DC Buildings: Standards, Requirements and Power Converter Topologies," in IEEE Open Journal of Power Electronics, vol. 3, pp. 798-823, 2022

DC OPENS A NEW DIMENSION IN ENERGY PERFORMANCE OF BUILDINGS

RESIDENTIAL DC DISTRIBUTION IS A POWER ELECTRONICS-ENABLED TECHNOLOGY, WHICH

- *can reduce electricity consumption of a building **by up to 30%***
- *can enhance the energy performance class of a building **from A to A+***
- *offers interoperability, easy integration and interaction of the the main electrical components of the building*
- *enables ultimate control flexibility, higher efficiency, power density and reliability*
- *facilitates energy communities and other collective initiatives and business models (energy hubs, EaaS, VPPaaS, etc.)*
- *supports the main grid and provides grid ancillary services (power consumption curtailment, phase balancing, etc.)*
- *fosters V2X adoption via DC charging thus unlocking the untapped potential of EVs as „mobile energy storages“*

** V. Vossos, S. Pantano, R. Heard, and R. E. Brown, "DC appliances and DC power distribution: A bridge to the future net zero energy homes," Lawrence Berkeley National Laboratory, Berkeley CA, USA, Technical Report LBNL-2001084, Sep. 2017.*

350 VDC TECHNOLOGY IS VERY FAST DEVELOPING

RECENTLY IS A TECHNOLOGY VALIDATION AND DEMONSTRATION PHASE (2020-2025)

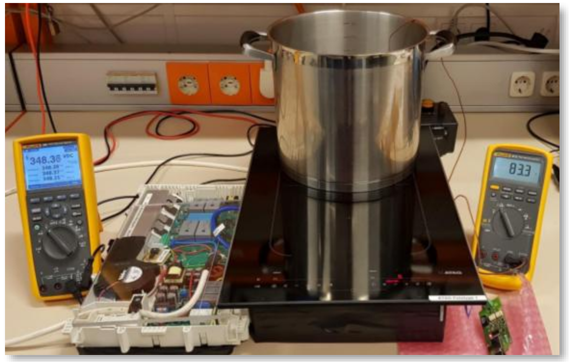
- *Big players (Schneider Electric, EATON, ABB, etc.) strongly support the technology development and innovation*
- *Solid state circuit breakers (DC Systems B.V., Blixt, DC Opportunities B.V.)*
- *USB-C PD (power delivery) 100W wall socket outlet (DC Systems B.V.)*
- *30/60/90 W public light LED drivers (DC Systems B.V.)*
- *Induction cooktop (ATAG Benelux)*
- *Hood fan (ATAG Benelux)*
- *Refrigerator (ATAG Benelux)*
- *Heat pumps (NRGtec)*
- *Under development: coffee machine, oven, microwave, washing machines, etc.*

SYSTEMS

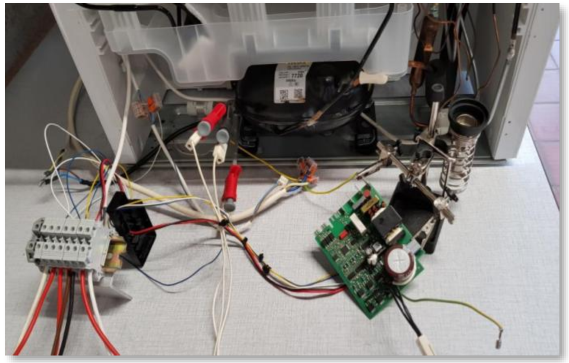
ATAG BENELUX

DC)pportunities

BL!XT

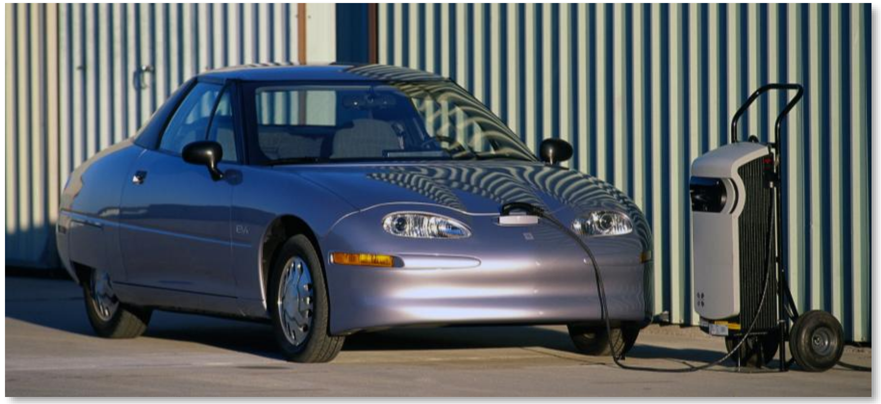


https://gelijkspanning.org/
https://www.dc.systems/
https://blixt.tech//



MAIN CHALLENGES OF DC TODAY

- *Lack of public awareness (remember the appearance of the first mass-produced EV in 1996, the EV1 from GM)*
- *Lack of international standardization and mature technology*
- *Lack of market-ready power electronic systems (PV converters, energy storage interfaces, EV chargers, energy routers, etc.)*



*i*³ DC INITIATIVE: *i*nform *i*nspire & *i*nnovate (est. 2020)

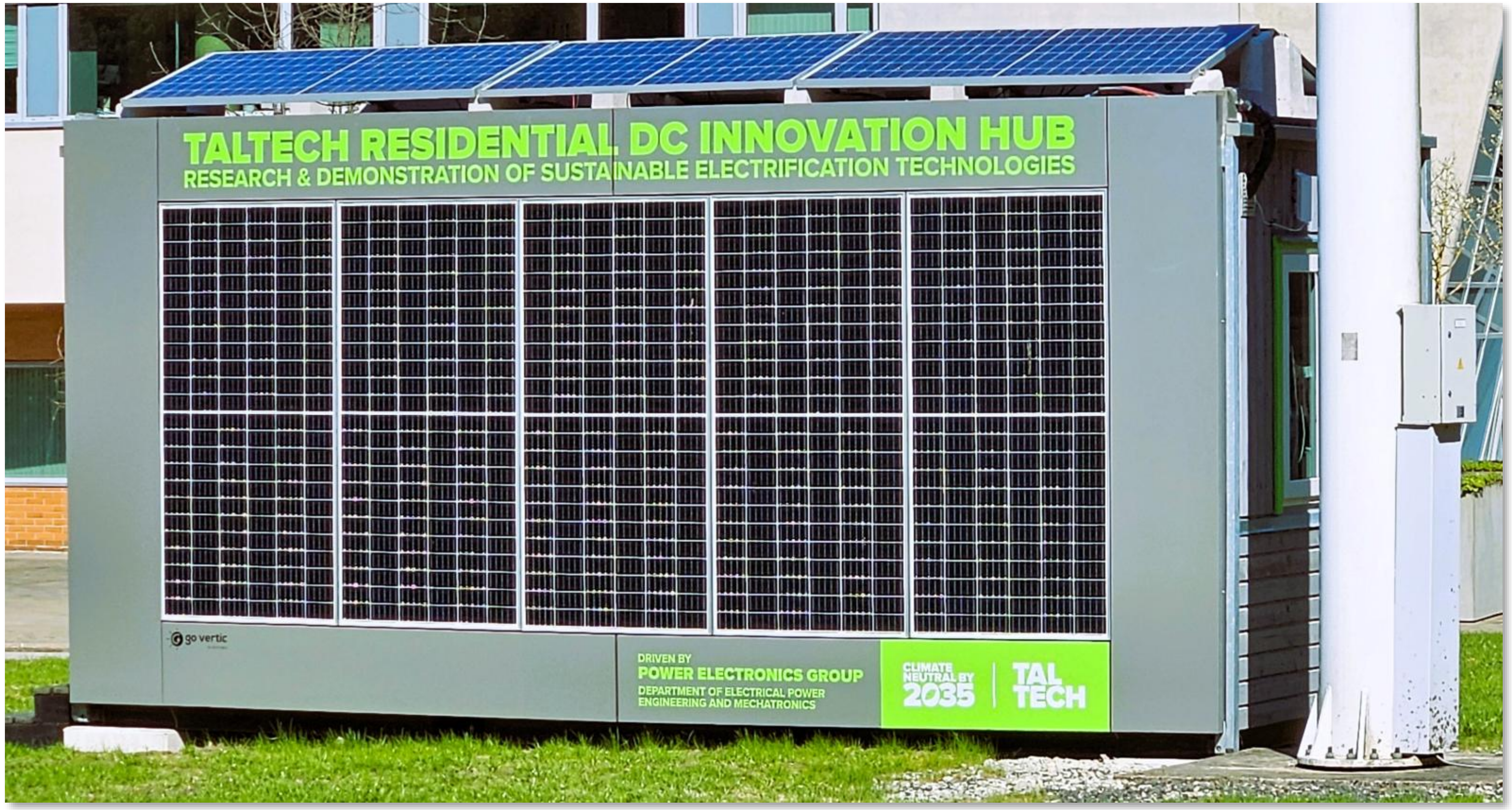
Non-profit joint venture of TalTech aimed at increasing the awareness, pushing forward the innovation and acceleration of the industrial uptake of the residential DC nanogrid technology in Estonia, Baltic states and Northern Europe

- ✓ *organization of national and international seminars and workshops on residentilal DC nanogrids, DC buildings and districts*
- ✓ *research, development and showcasing of innovative technologies*
- ✓ *development of public policies and standards for DC buildings*
- ✓ *creation of new cleantech ventures and joint seeking for funds*

i³ DC
Accelerates Energy Transition

TALTECH RESIDENTIAL DC INNOVATION HUB

THE FIRST DC EXPERIENCE CENTER IN NORTHERN EUROPE

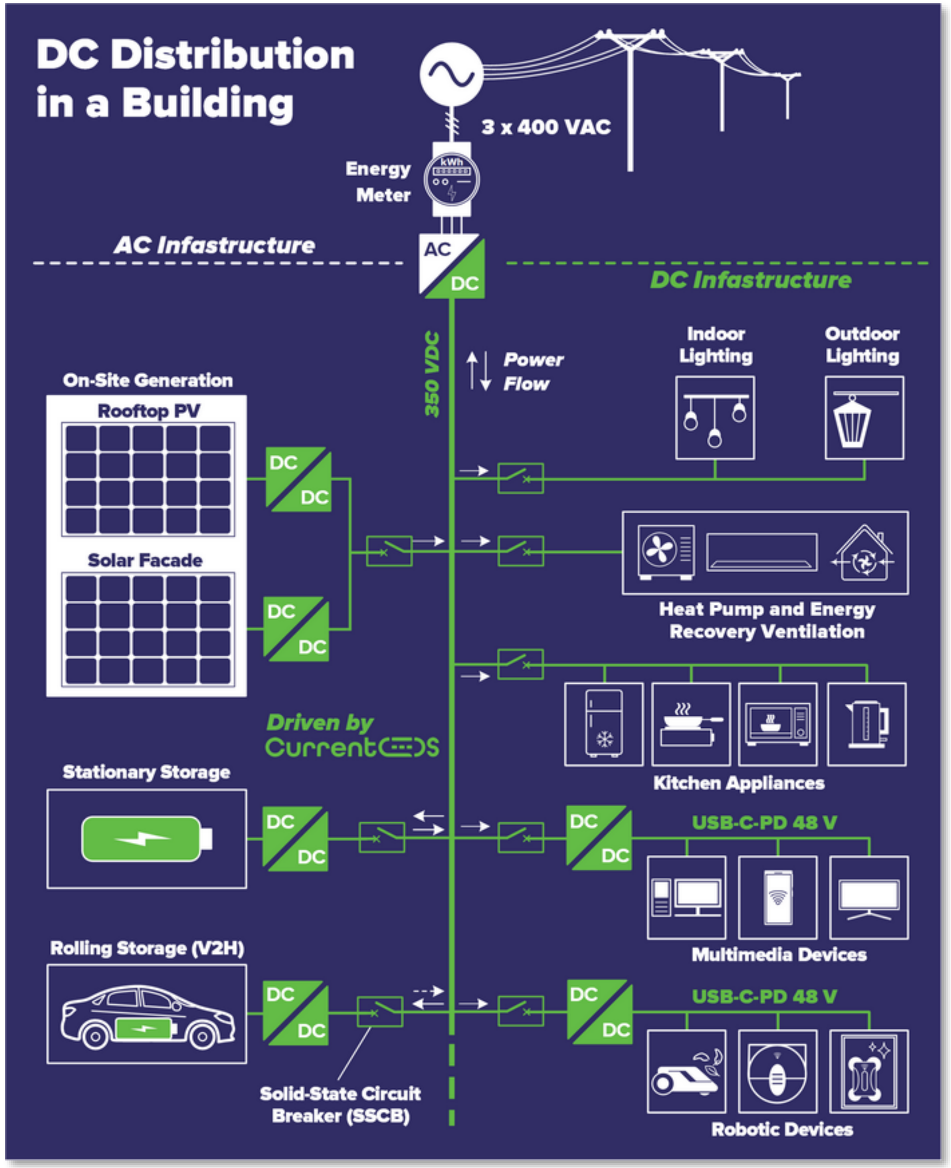


- ***First academic member of Current OS Foundation***
- ***International open platform*** *for research and demonstration of residential DC power distribution technologies*
- *Validation of the* ***net-zero-energy solutions*** *(workplace, space heating and cooling, ventilation, etc.)*
- ***Living lab*** *allows for blending the everyday real-life experience of pilot users with academic research to develop future-proof energy saving technologies*
- ***Data collection*** *for the future design of the energy-neutral TalTech campus*
- ***https://taltech.ee/en/i3dc-initiative***

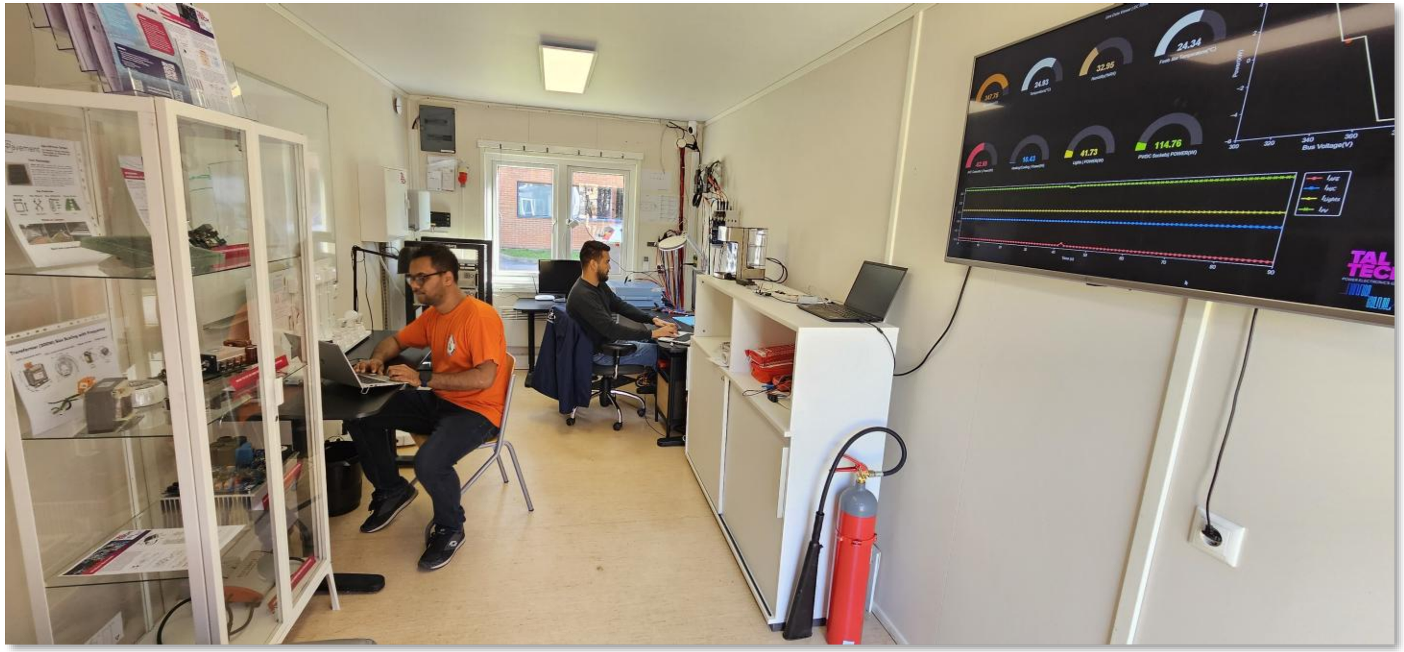
TAL TECH · CLIMATE NEUTRAL BY 2035 · i³ DC Accelerates Energy Transition · VOOL · DCpportunities · Estonian Research Council · CurrentOS · ENERGIA PARTNER · Schneider Electric · go vertic by ACM Metal · sunly · SYSTEMS by Schneider Electric

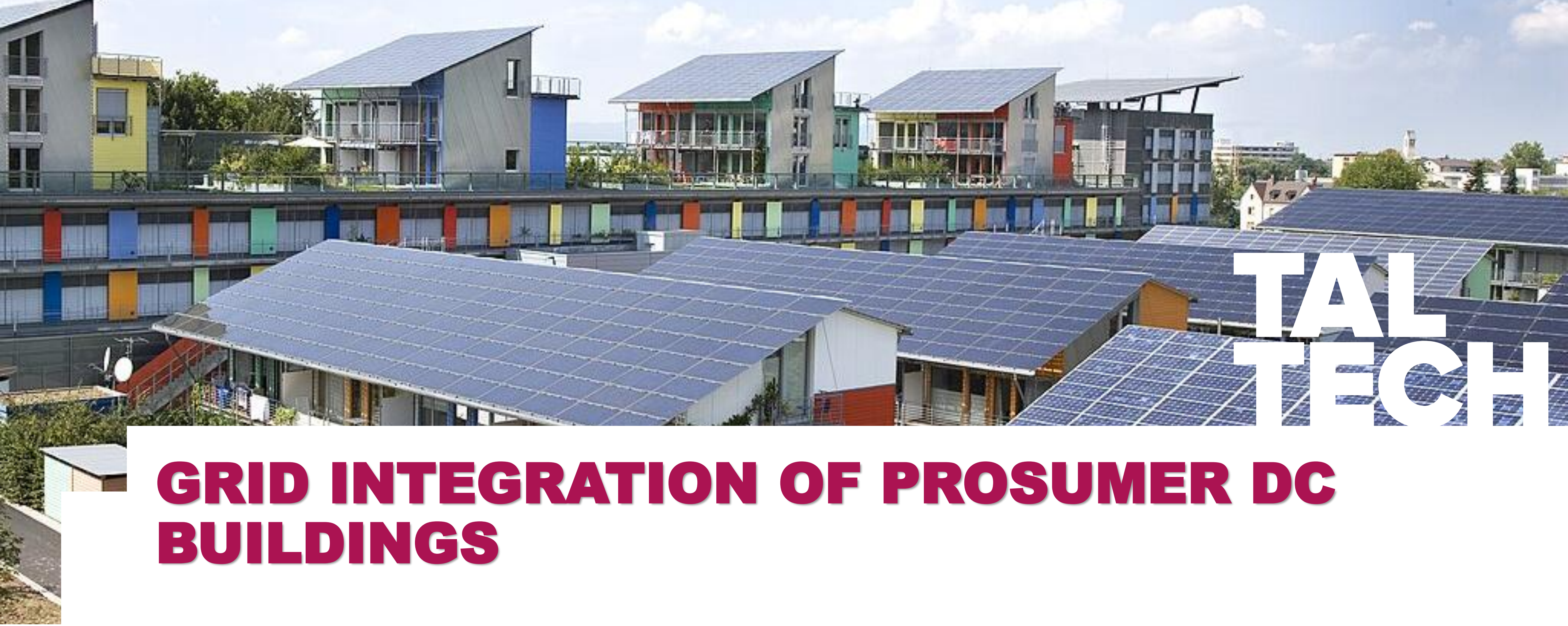
TALTECH RESIDENTIAL DC INNOVATION HUB

THE FIRST DC EXPERIENCE CENTER IN NORTHERN EUROPE



- *Thermally insulated for year-round operation*
- *2 energy neutral working places for researchers*
- *350V±30V DC droop-controlled microgrid (operating system Current/OS)*
- *Solar facade composed of 5 c-Si PV modules*
- *Solar roof with 3 south-facing and 3 north-facing c-Si PV modules*
- *Battery energy storage*
- *LED lighting and heat pump fed from DC (both are energy neutral)*
- *Solid-state protection (both commercial and research samples)*
- *DC appliances (continuous development)*
- *Data logging and visualization (online access soon)*



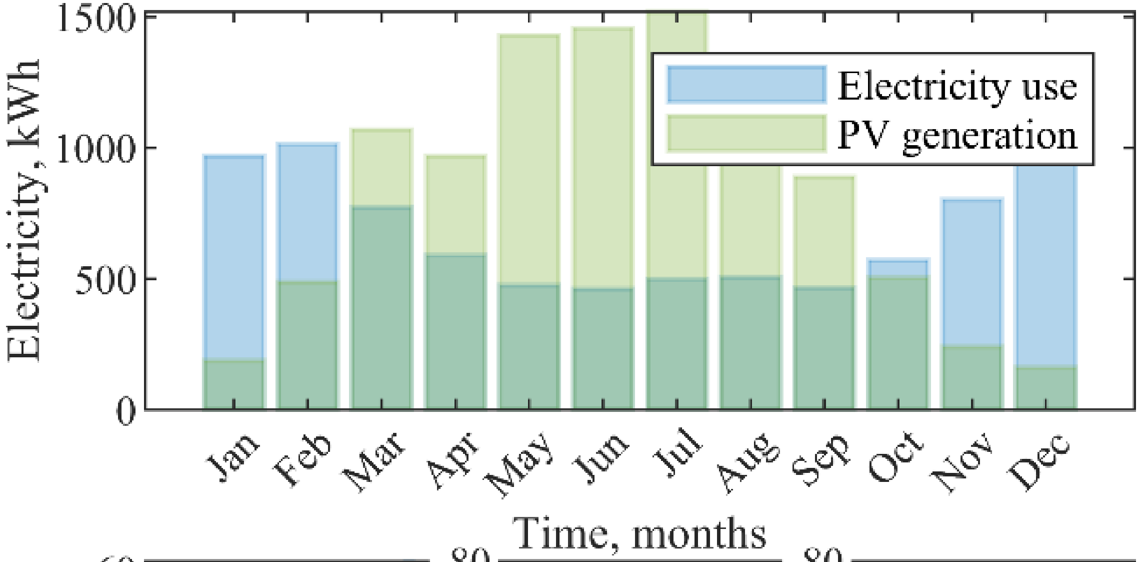


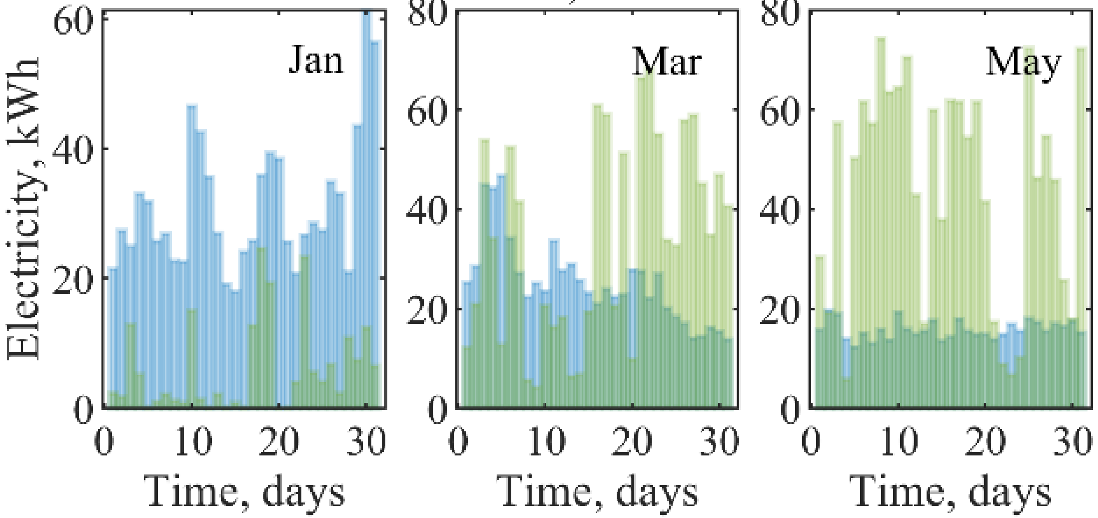
GRID INTEGRATION OF PROSUMER DC BUILDINGS

PROBLEMS OF EXISTING INSTALLATIONS

ENERGY CONSUMPTION AND PRODUCTION BALANCE

Parameter	Value
Location	Estonia, Tallinn
Heated area	176.7 m^2
Total power of PV	5 kWp
Model of HP	Thermia Atec HP 11
COP of HP	COP 3.8 (+7/+45 °C)
Habitants	4

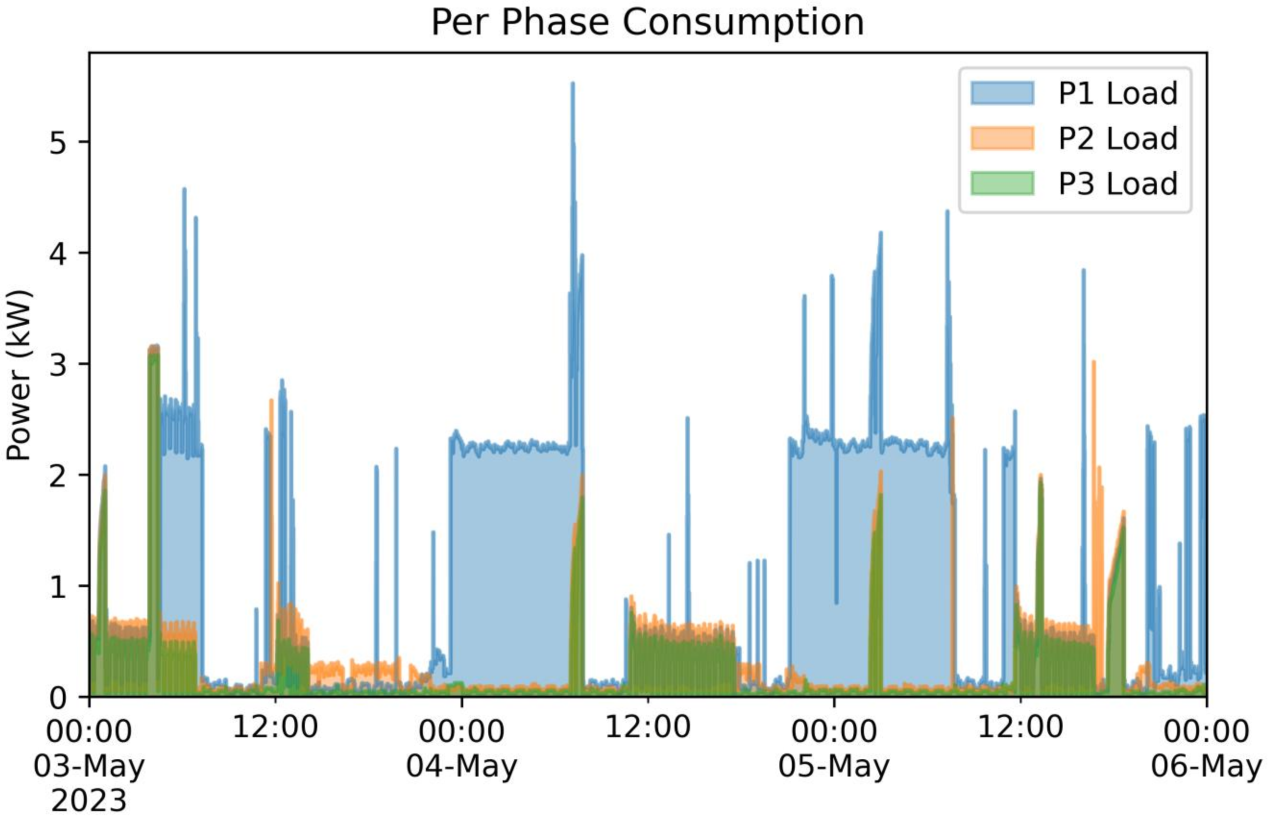




PROBLEMS OF EXISTING INSTALLATIONS

UNEQUAL PHASE LOAD

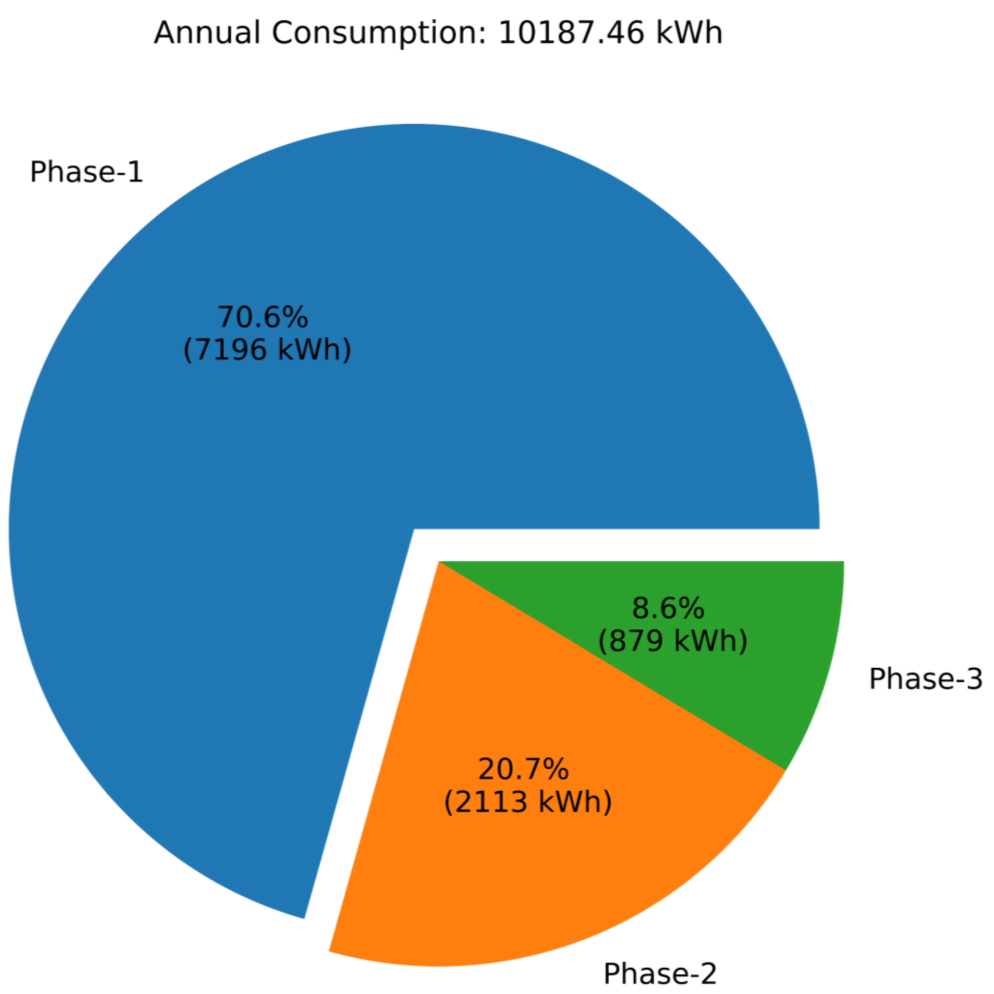
Single-phase AC charger

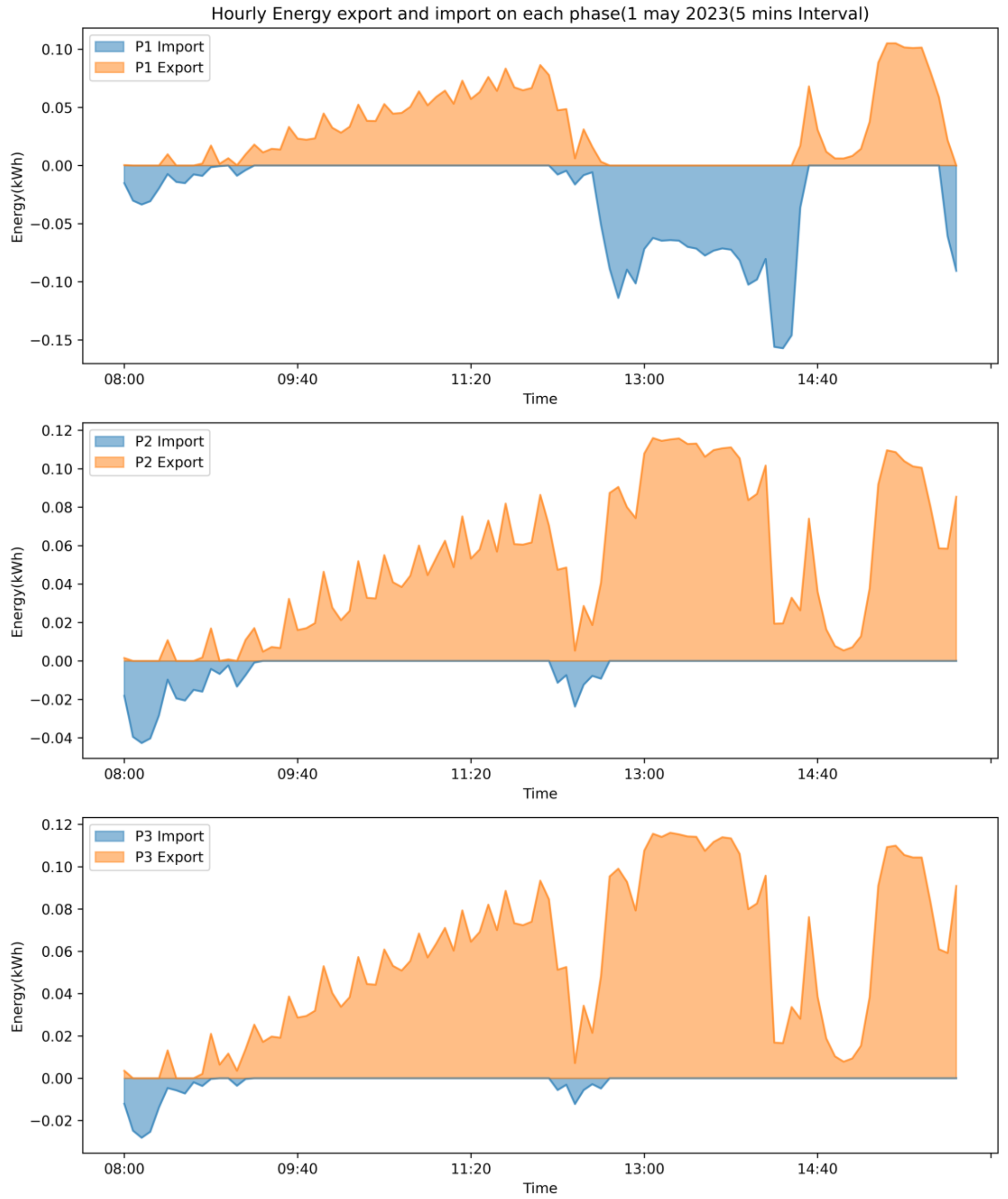


Hasan, S.; Blinov, A.; Chub, A.; Vinnikov, D. “PV Generation and Consumption Dataset of an Estonian Residential Dwelling”, Dataset; DOI:10.48726/6hayh-x0h25 [Online]:https://data.taltech.ee/records/6hayh-x0h25

PROBLEMS OF EXISTING INSTALLATIONS

PHASE CONSUMPTION IMBALANCE



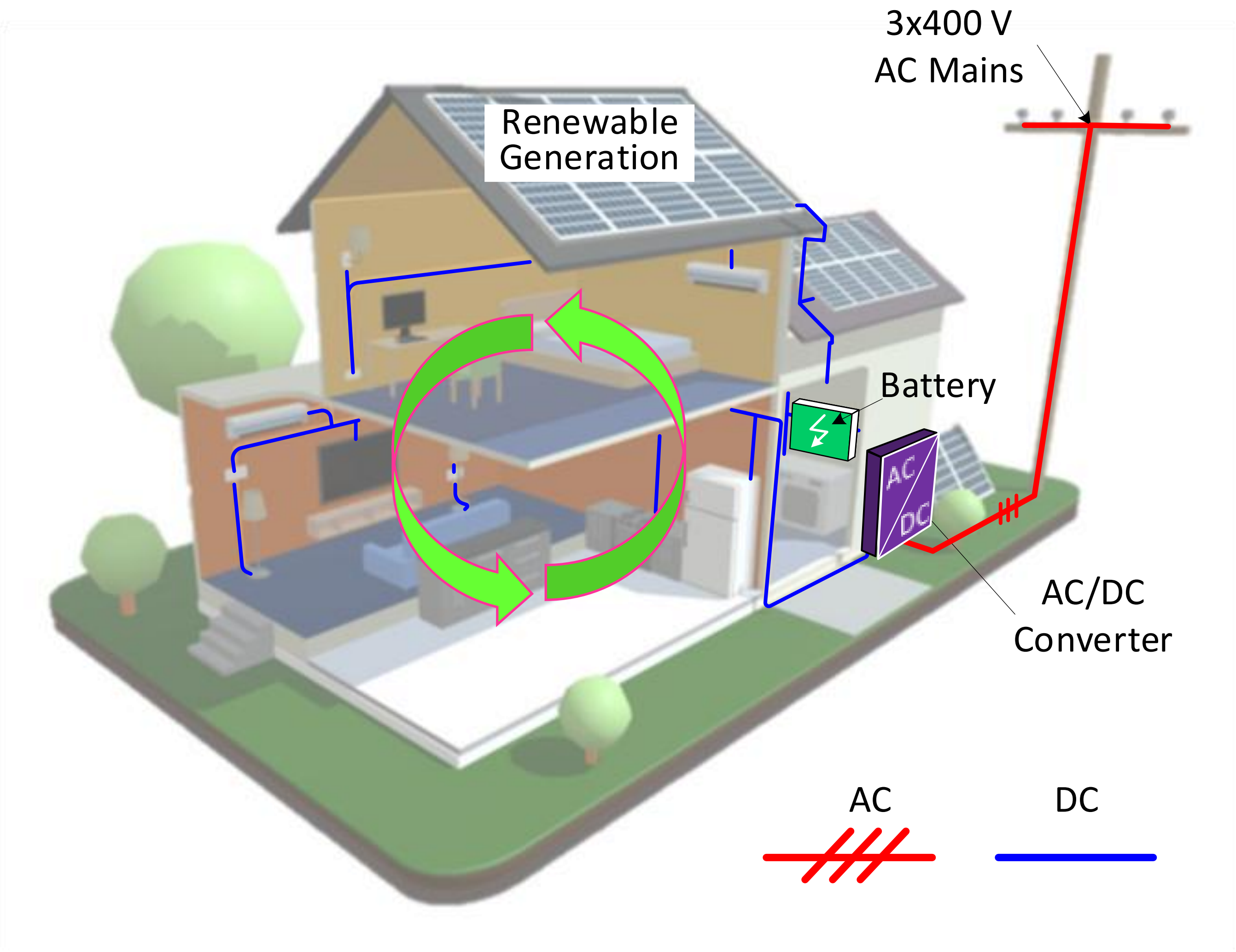


ZERO EMISSION BUILDING CHALLENGES

- ***Seasonal imbalance** of daily production and consumption due to weather*
- ***Unequal phase consumption** – high single-phase consumers*
- ***Excessive energy exchange** – simultaneous import and export*

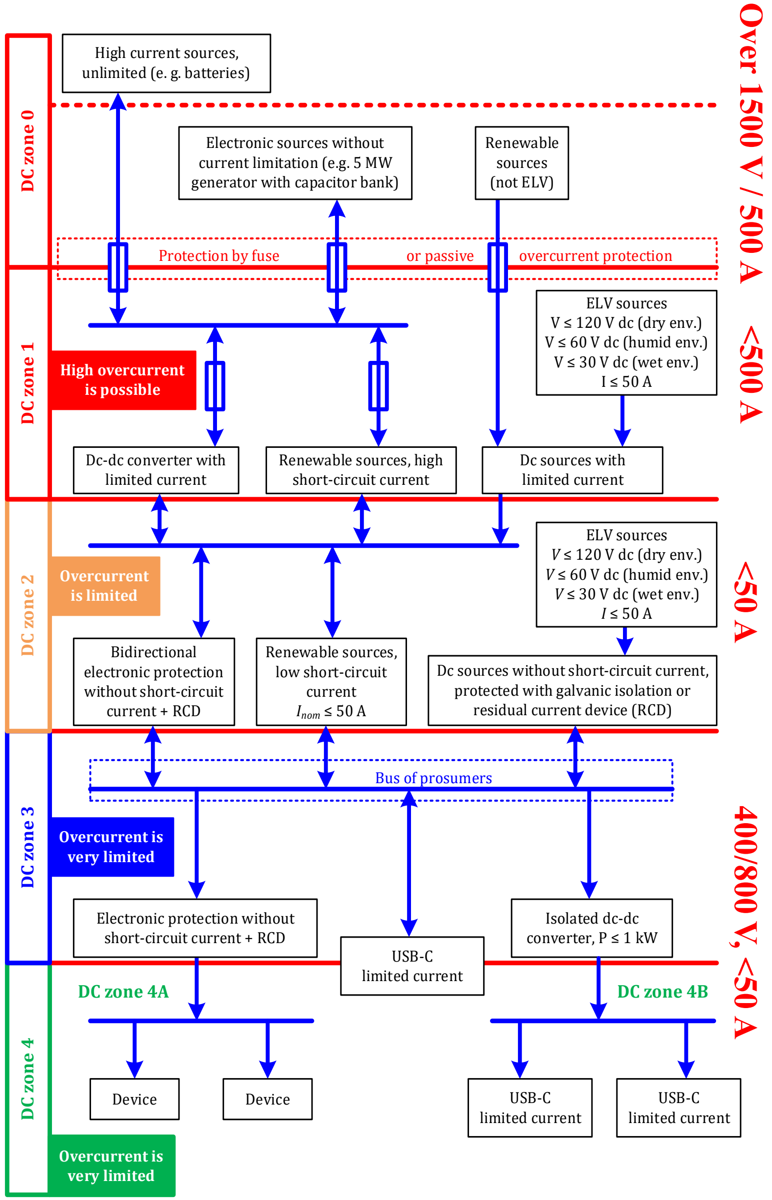
Transition to DC distribution in a building:

- *Reduces number of energy conversion stages*
- *Minimizes energy exchange between AC and DC*
- *Provides active control of own consumption and production*



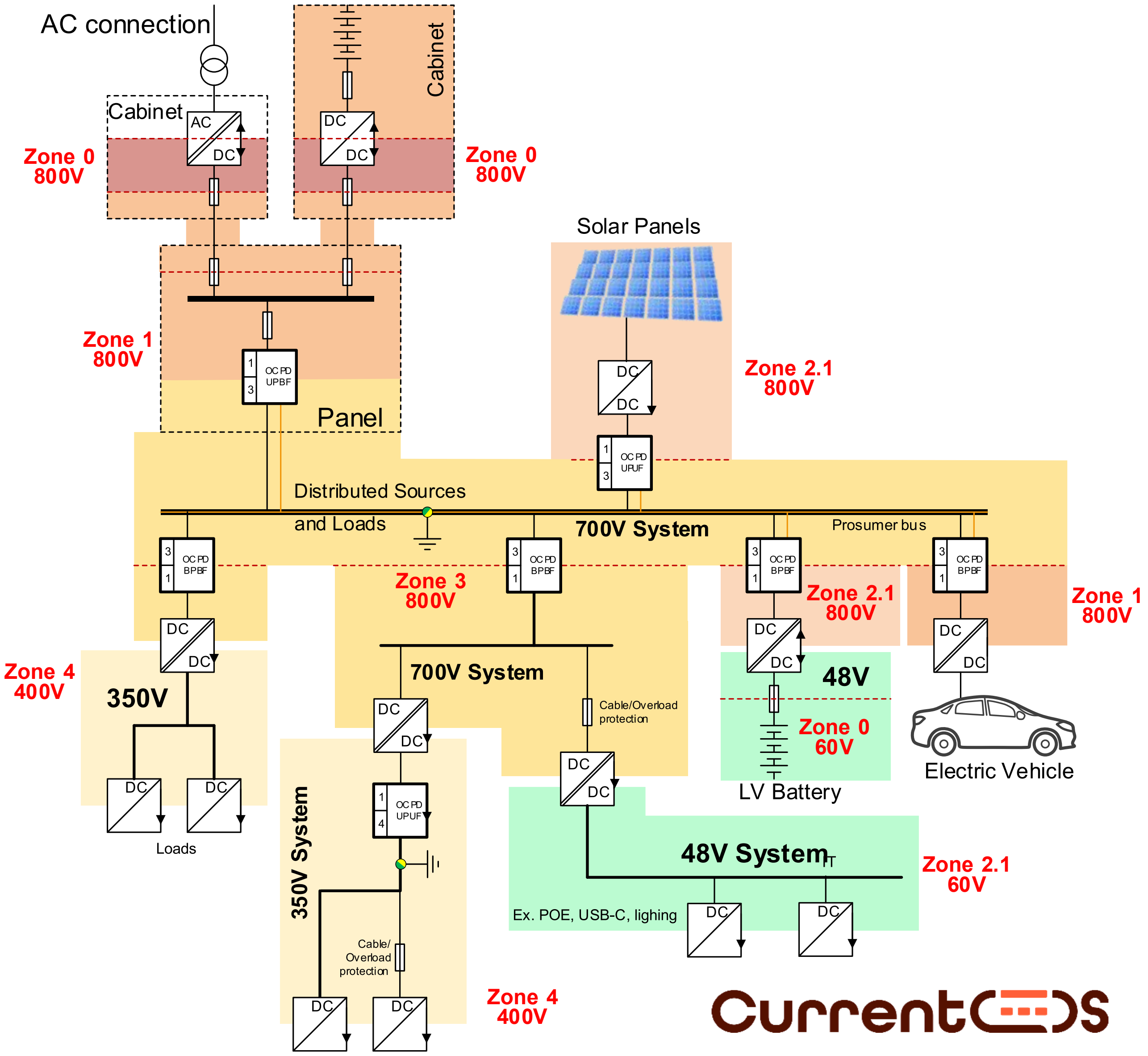
DC GRID CONCEPTS AND PROTECTION ZONES

NPR9090



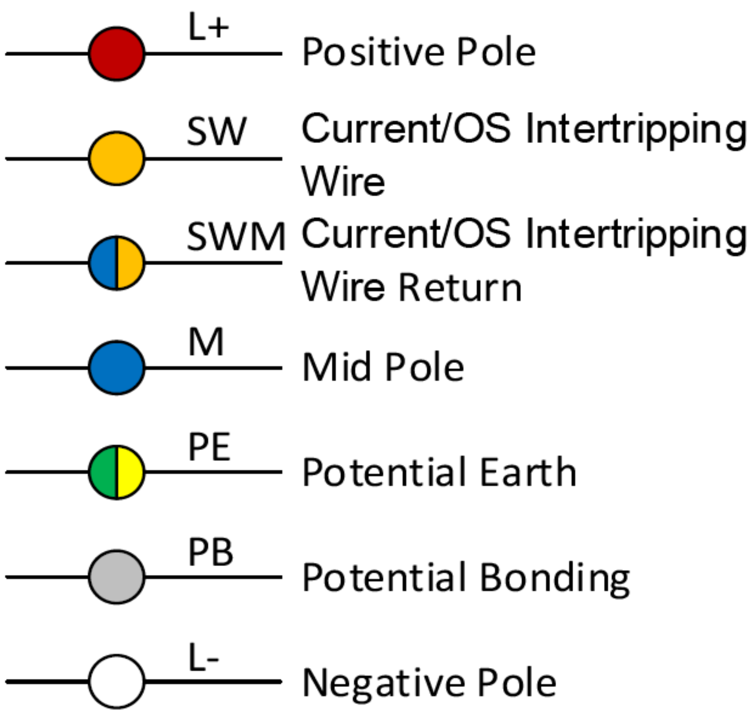
TAL TECH

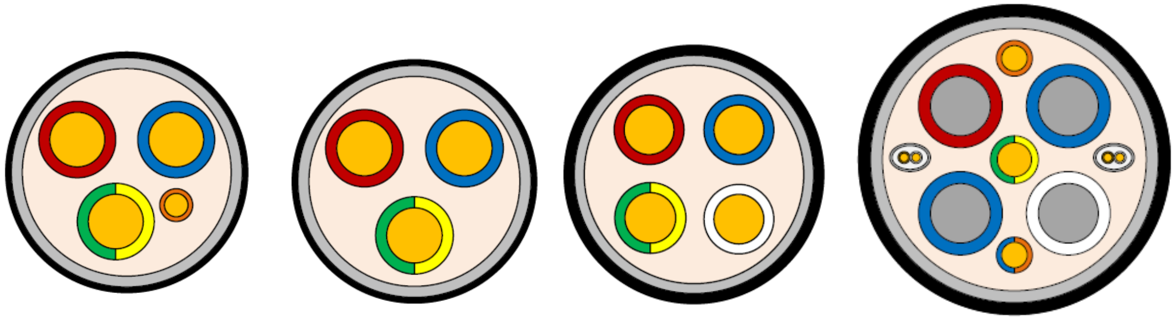
CurrentOS



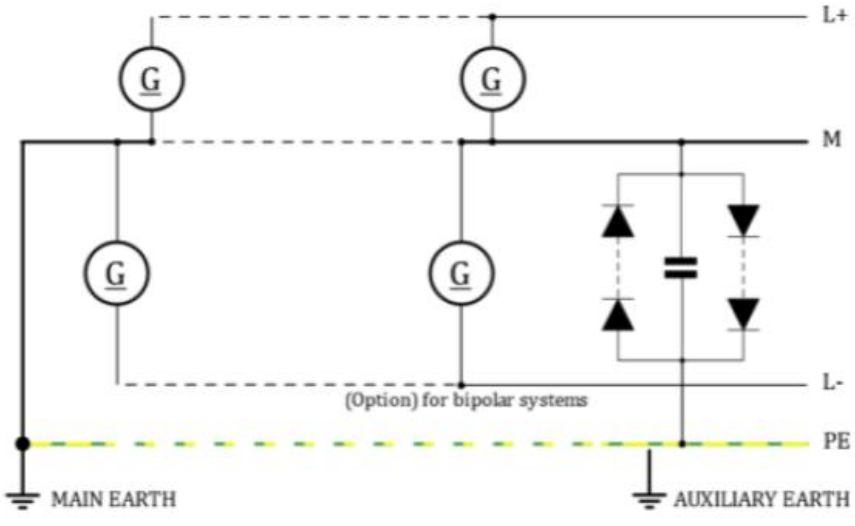
CurrentOS

DC GRID WIRE COLOURS AND EARHING

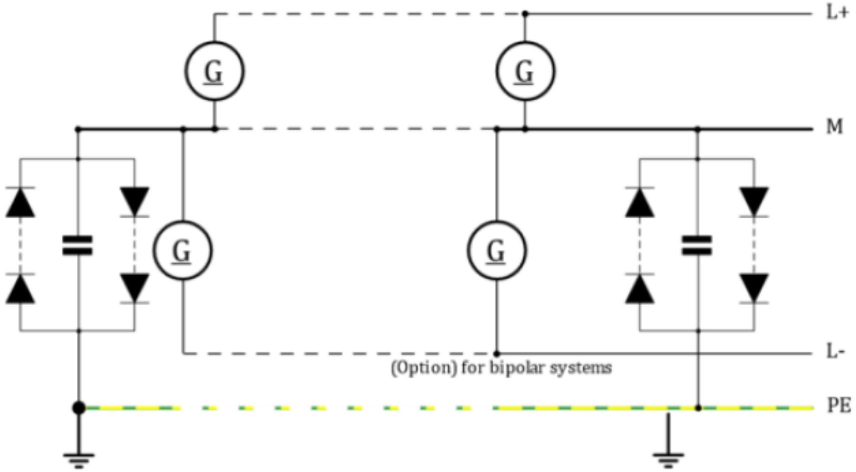




Unipolar *Bipolar*



TN-SCD

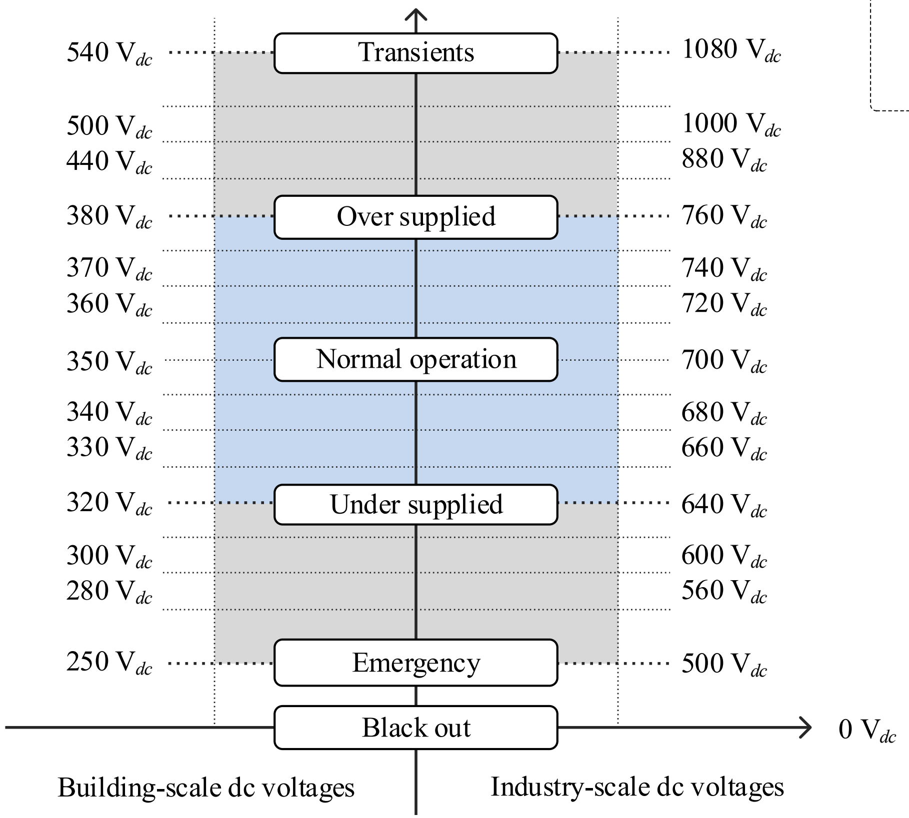


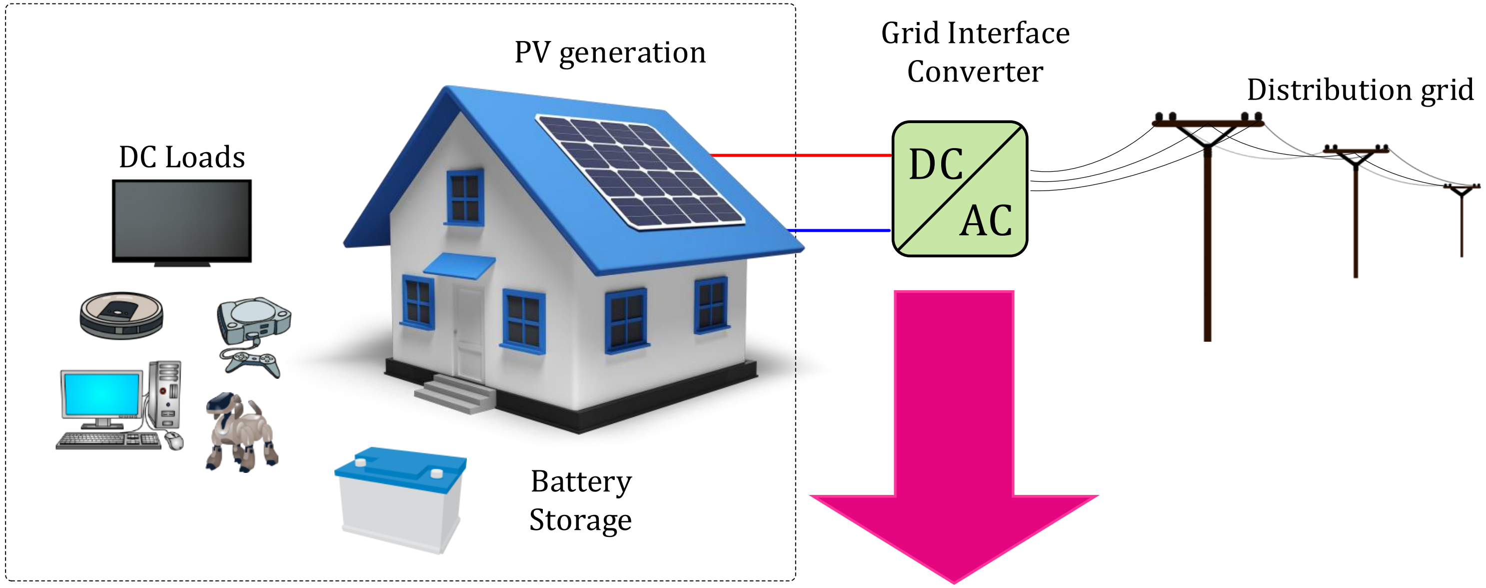
TN-SCDD

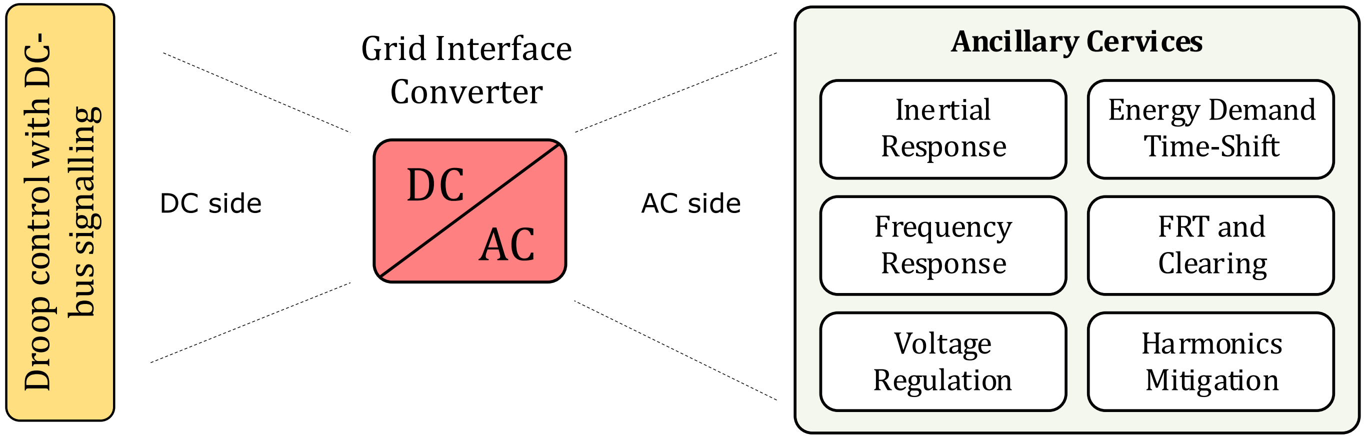
DC GRID FORMING CONVERTER

MAIN FUNCTIONS

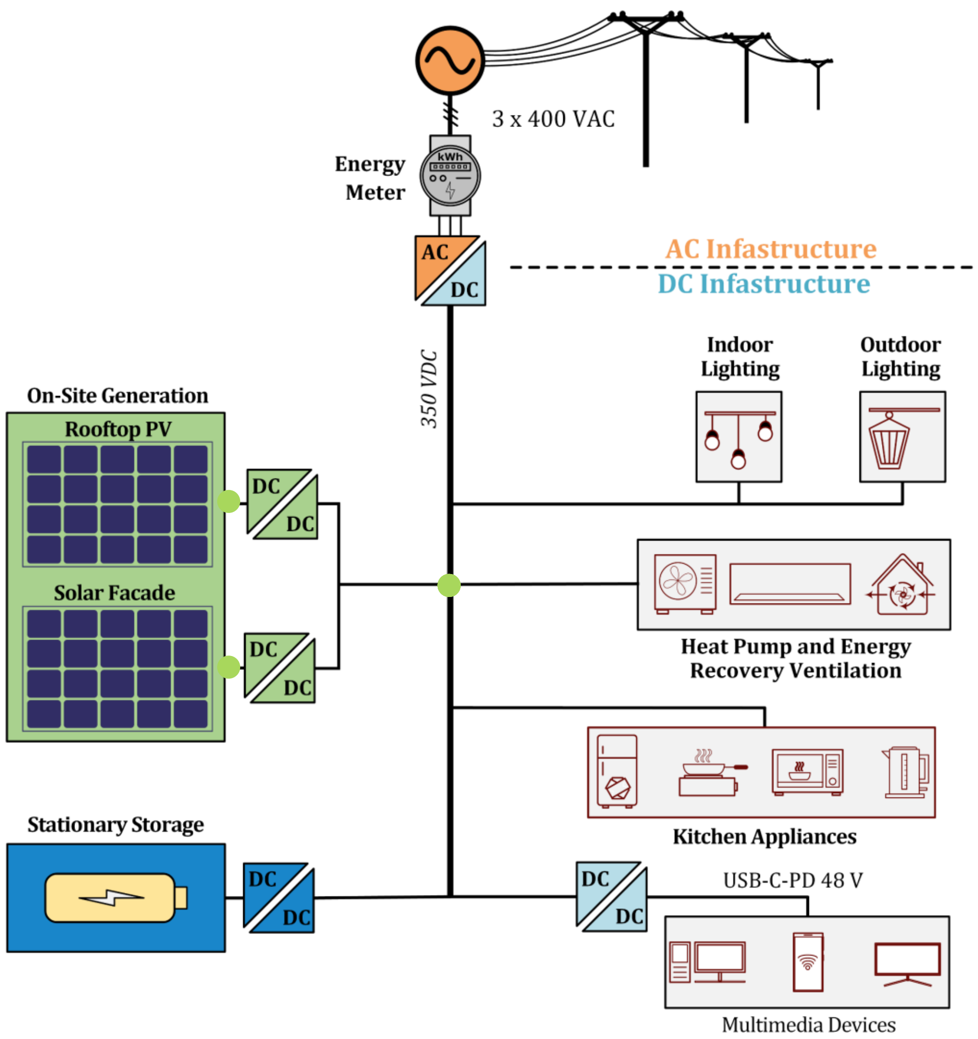
- *Bidirectional power transfer*
- *AC grid support (like smart PV inverter)*
- *DC grid forming and droop control*

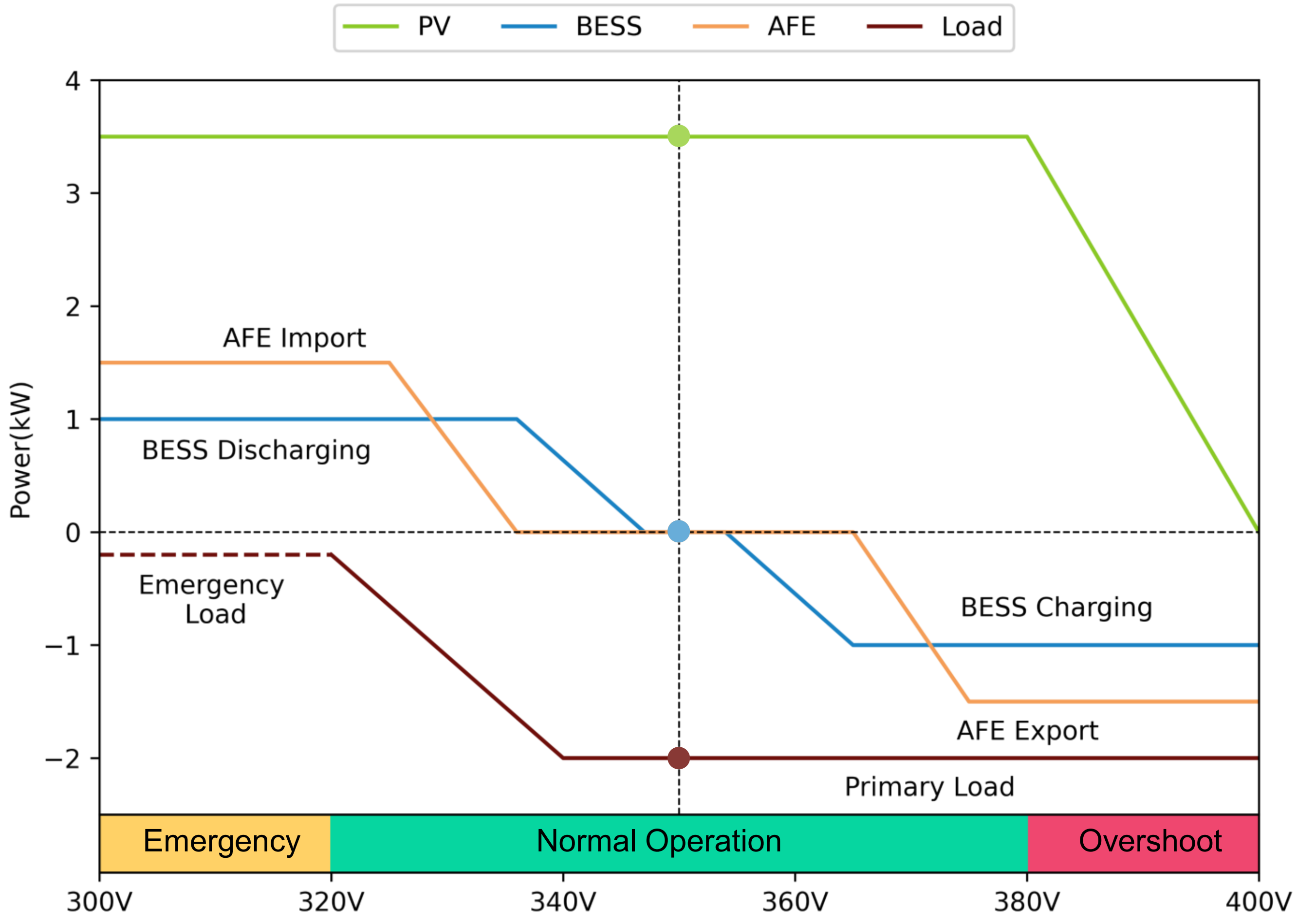






Full Irradiation

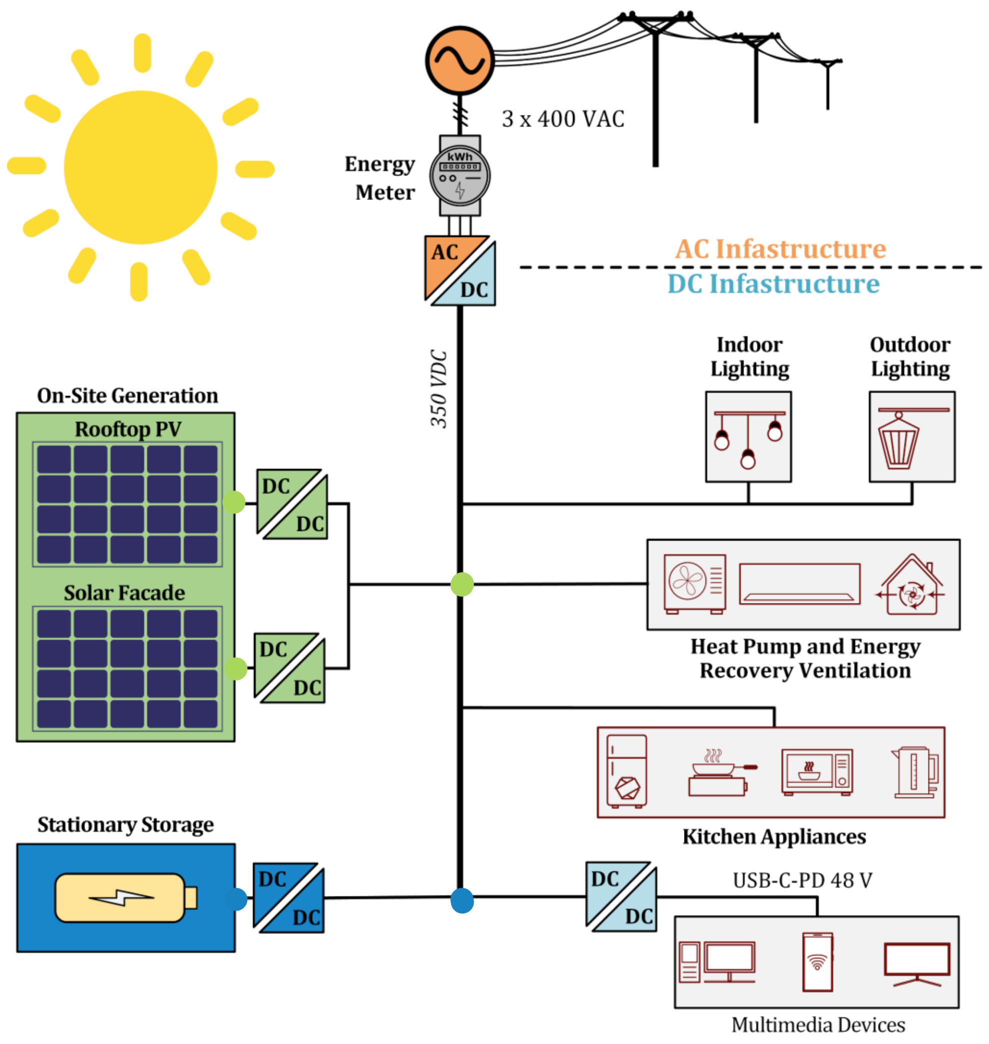


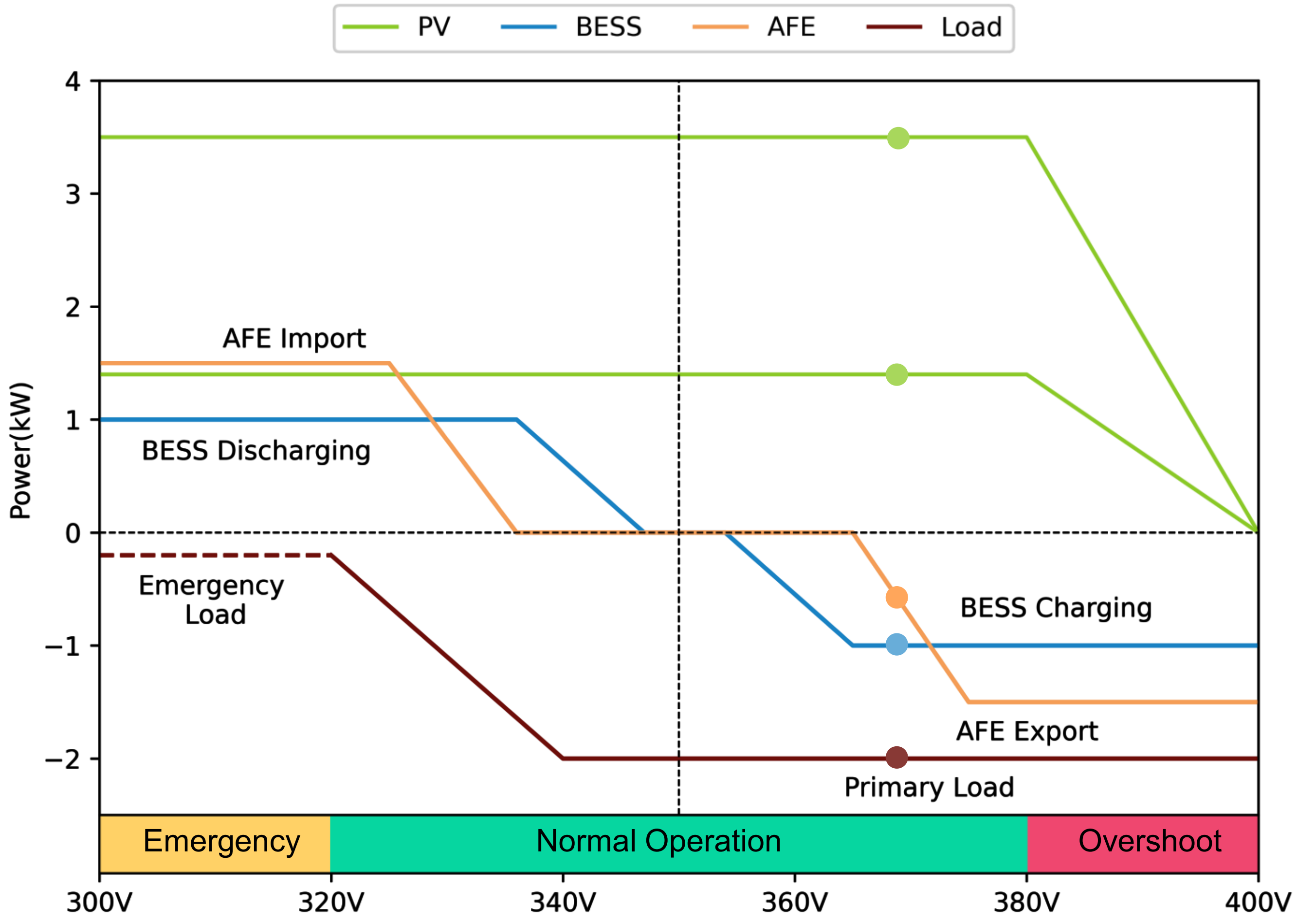


The example DC system is connected to AC grid through active front end (AFE) full-power converter and incorporates PV generation, battery storage and droop-controlled loads

The sun is shining, and the PV generation is high enough to supply all loads, provide power to battery charging and even export part of the energy to the AC grid.

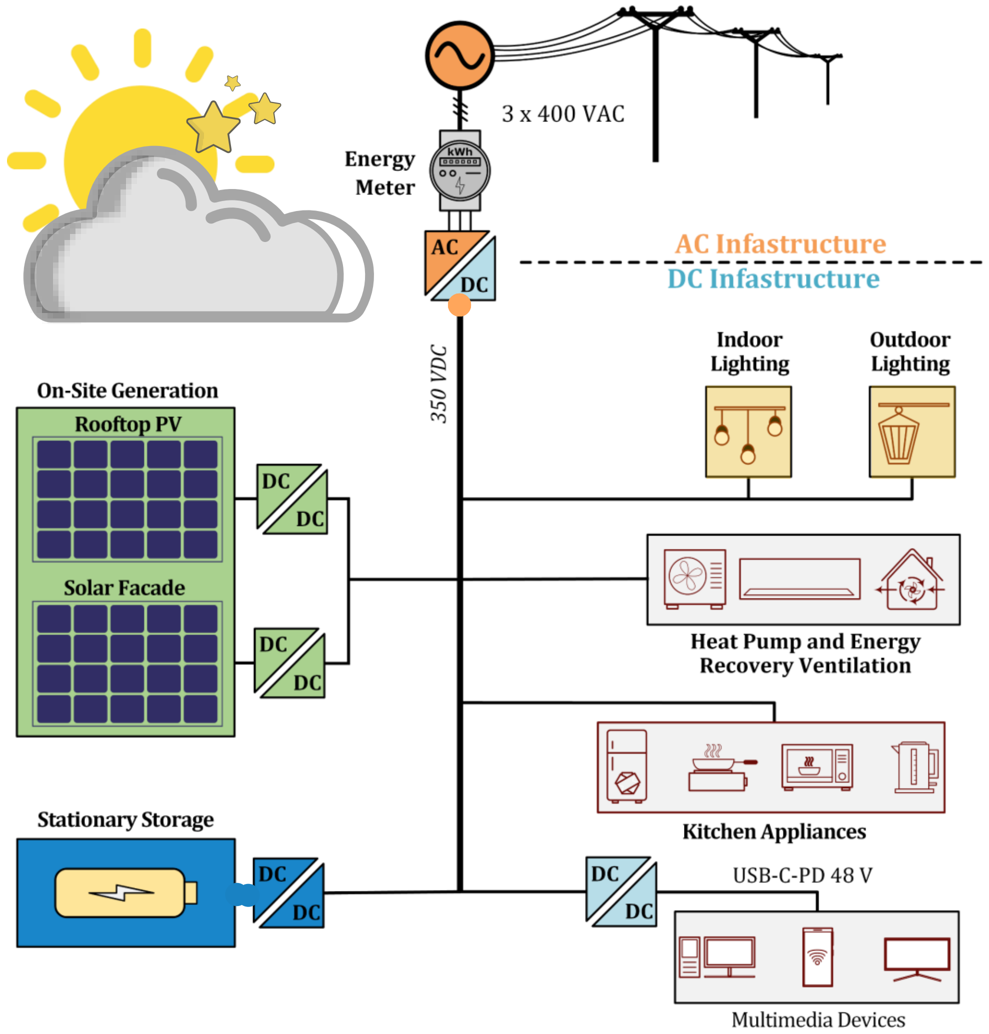
Partial Shading

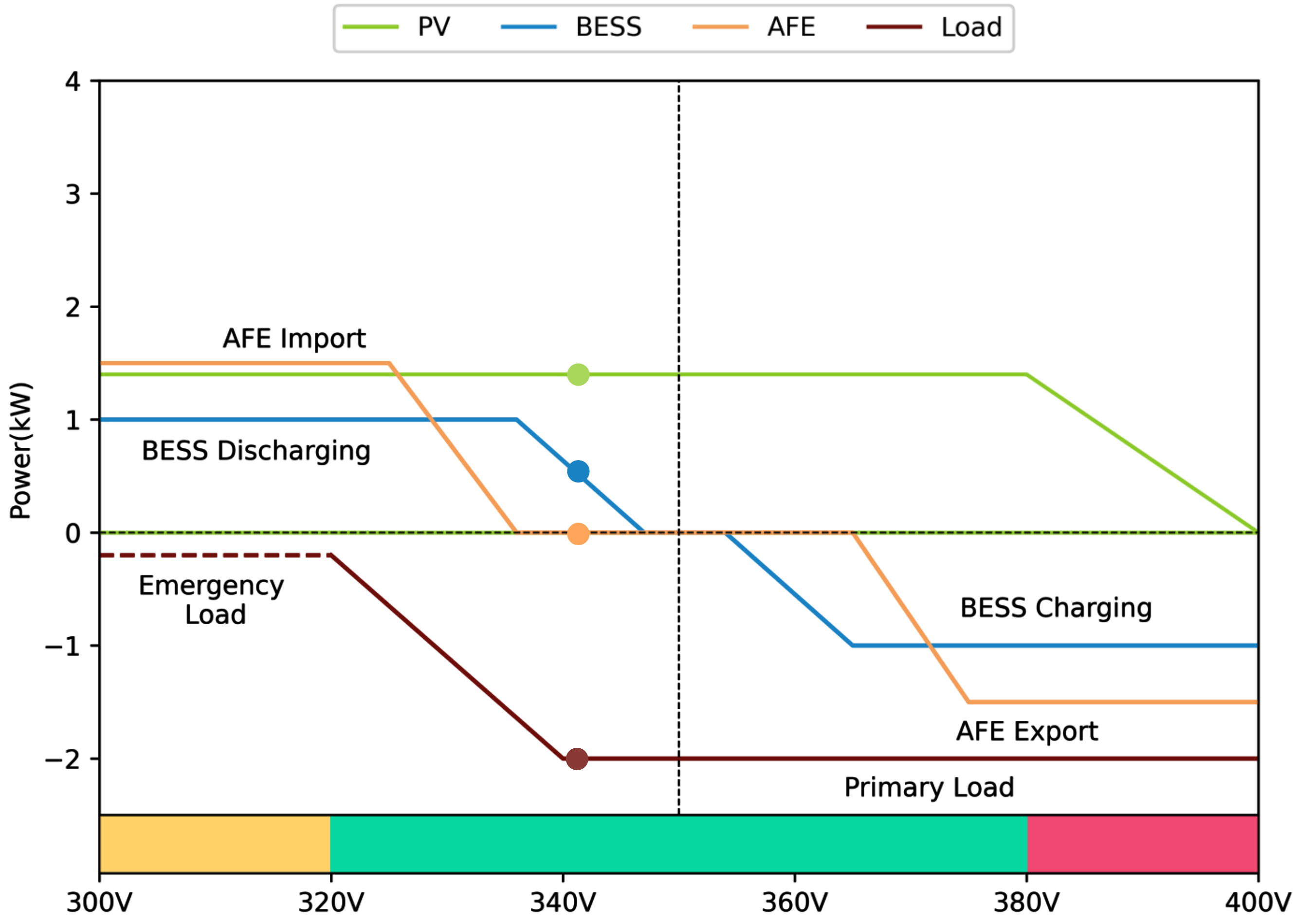




The clouds appear and the PV energy production falls. The battery now discharges to cover the load demand.

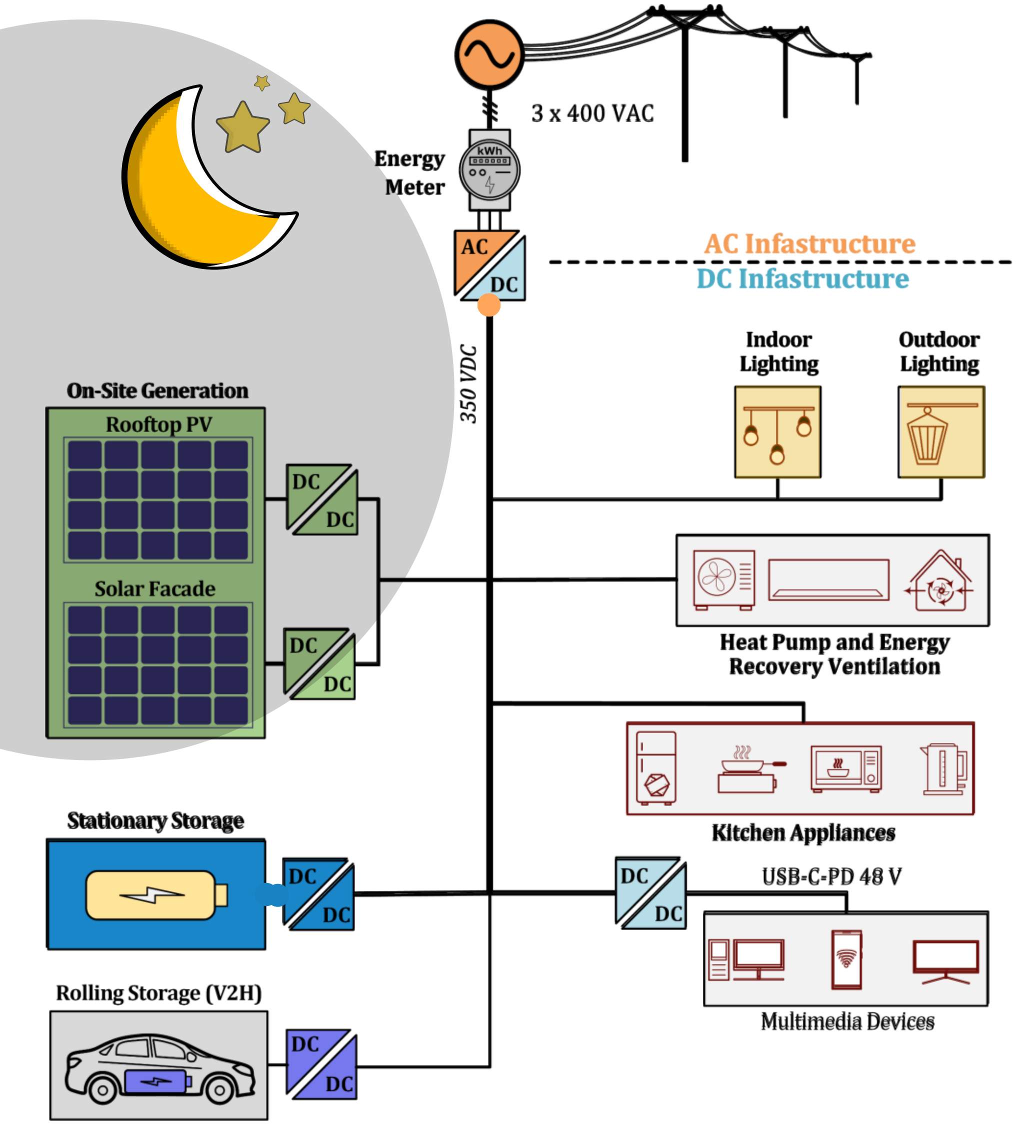
Night

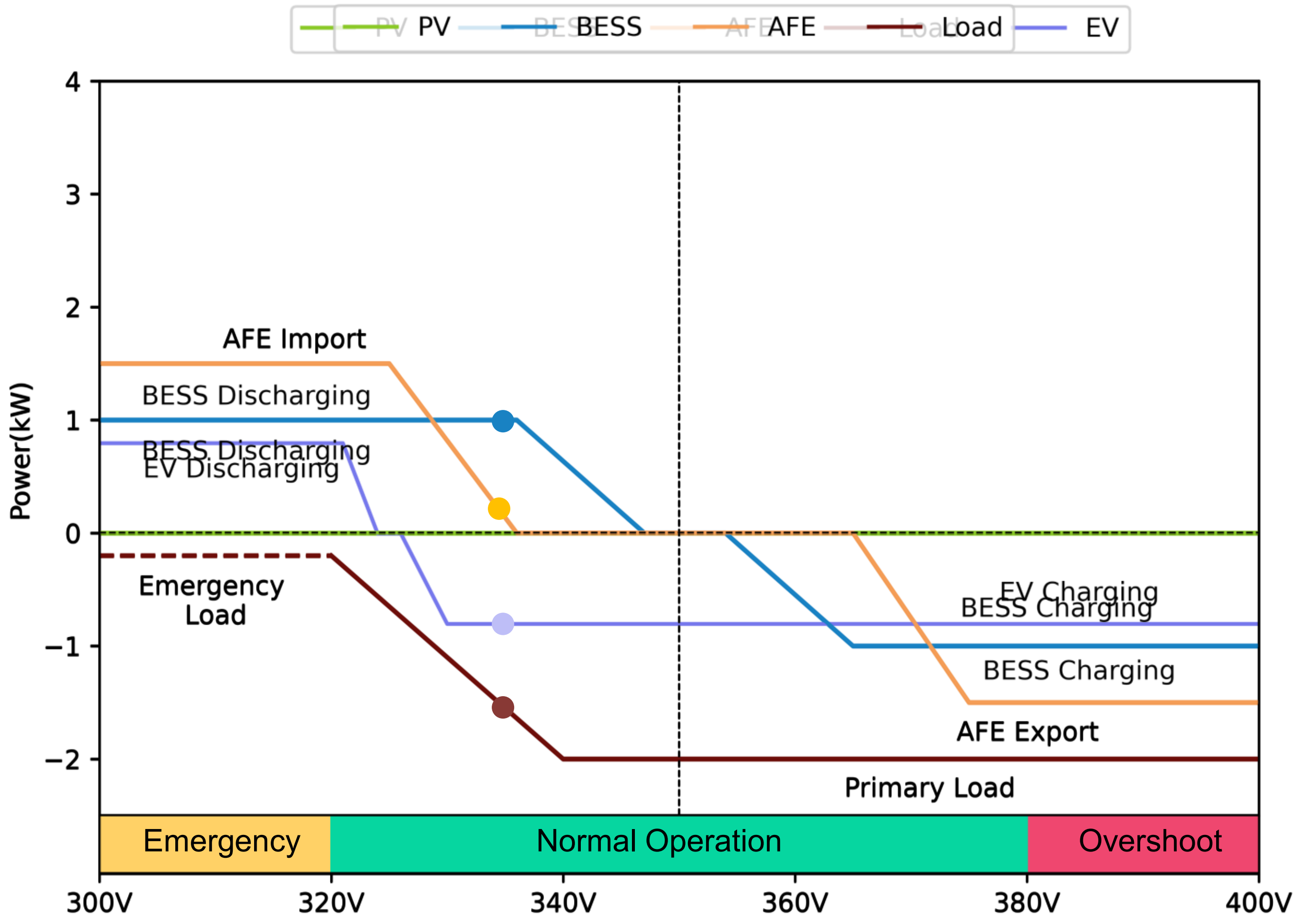




The nighttime starts and the PV production falls to zero. The battery operates at full power to supply the load. To attain energy balance, part of the energy is also imported from the AC grid by AFE, while the consumption of the non-critical loads is reduced

EV Charging



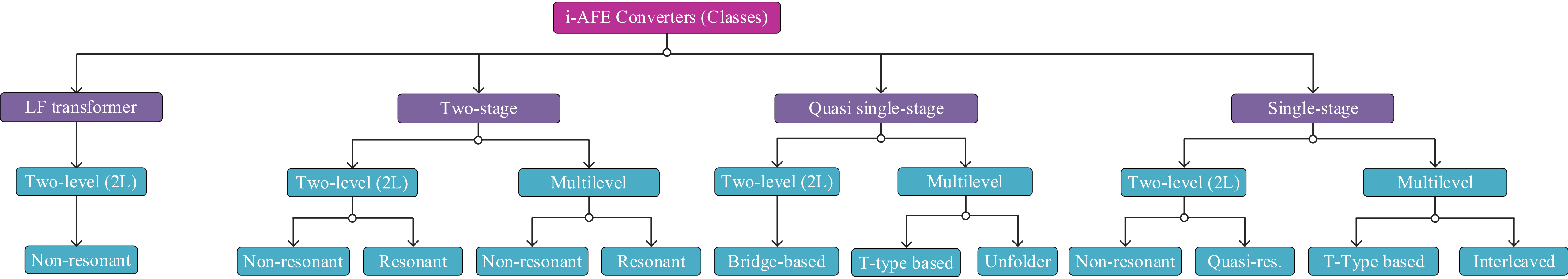


The addition of other components into the system results in changes in its behaviour and the droop profile needs to be re-evaluated. For example, the addition of EV with priority charging requires further reduction of primary load to attain energy balance.

ACTIVE FRONT-END (AFE) AC-DC CONVERTERS

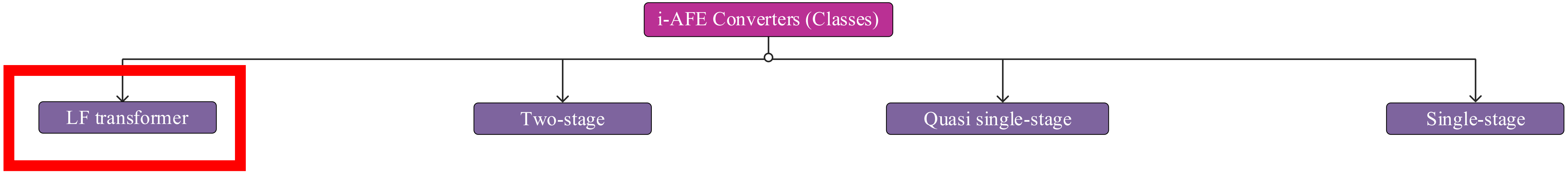
CLASSIFICATION ACCORDING TO THE NUMBER OF POWER PROCESSING STAGES

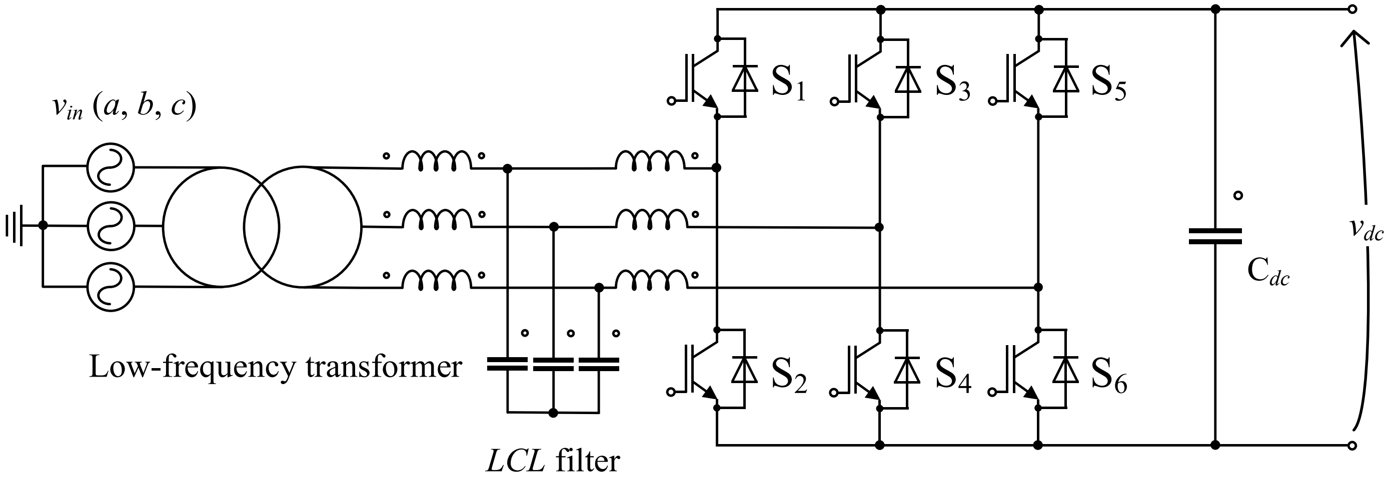
"Faults and disturbances in the DC grid shall not propagate or cause malfunctions in the AC grid. In Current/OS this is ensured with galvanic isolation of the two grids. {…}
Therefore, in Current/OS installations ***only galvanically isolated converters*** shall be used for interfacing between the AC and the DC grid."



E. L. Carvalho, A. Blinov, A. Chub, P. Emiliani, G. de Carne and D. Vinnikov, "Grid Integration of DC Buildings: Standards, Requirements and Power Converter Topologies," in IEEE Open Journal of Power Electronics, vol. 3, pp. 798-823, 2022, doi: 10.1109/OJPEL.2022.3217741.

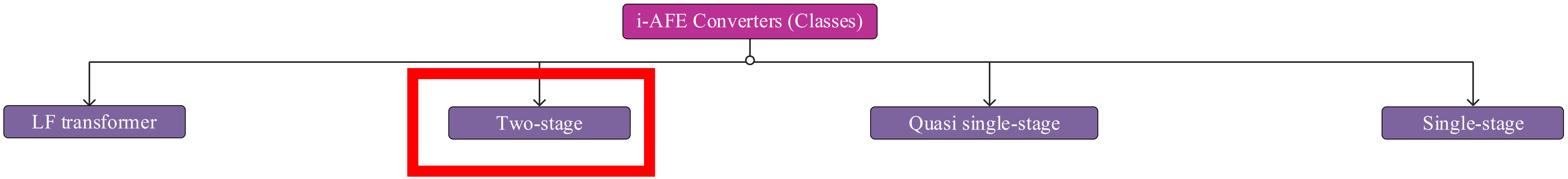
LOW FREQUENCY TRANSFORMER BASED APPROACH

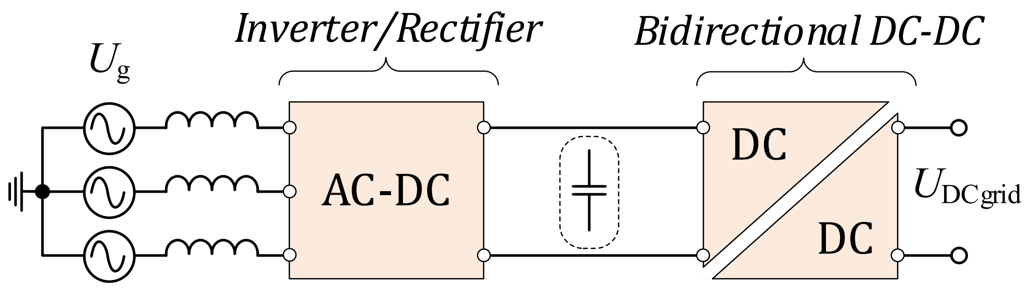


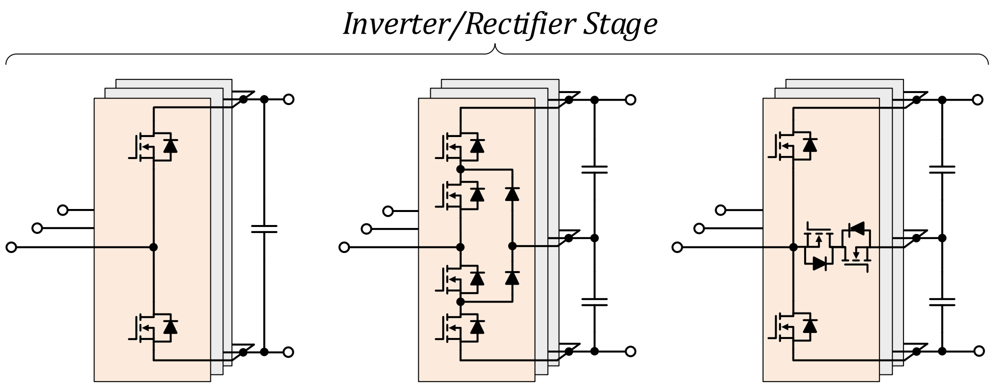


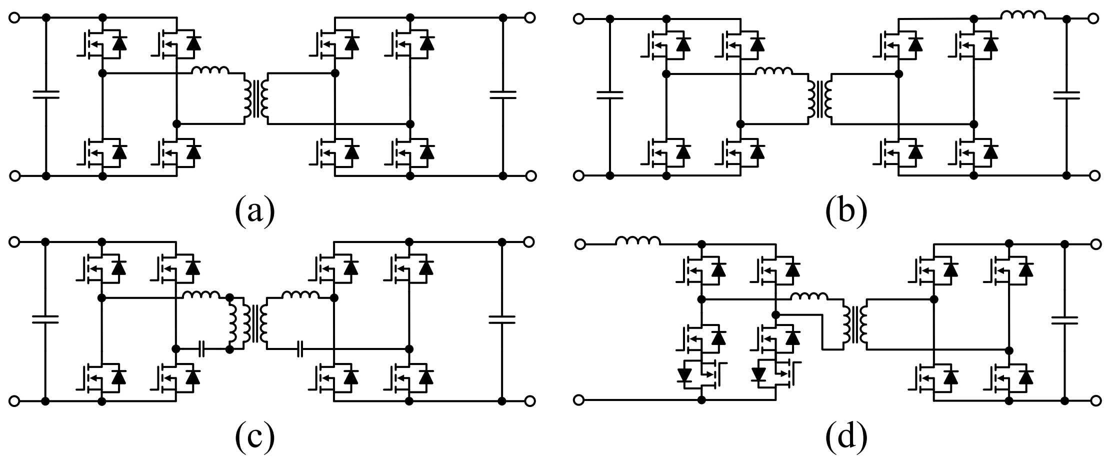
- *Bulky and heavy*
- *High use of materials*
- *Possible acoustic noise*

TWO-STAGE CONVERSION

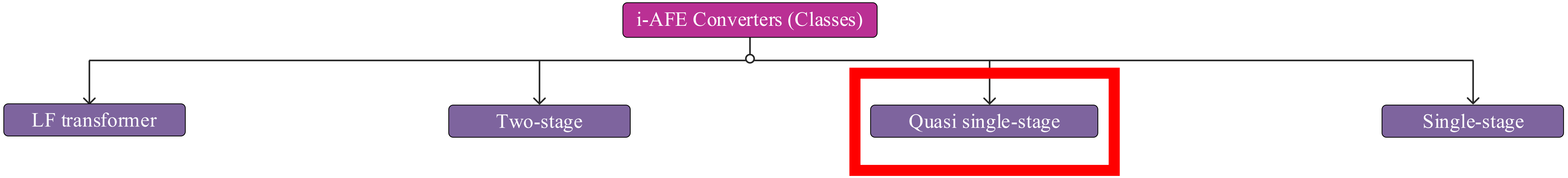


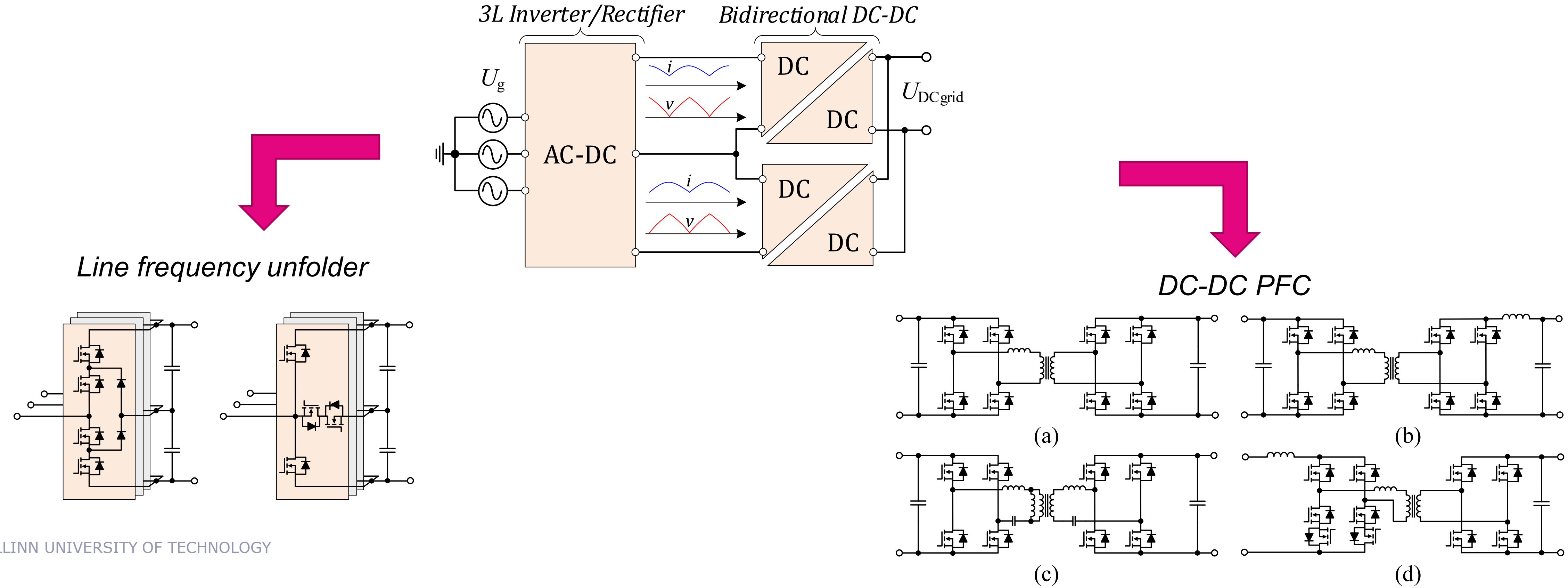




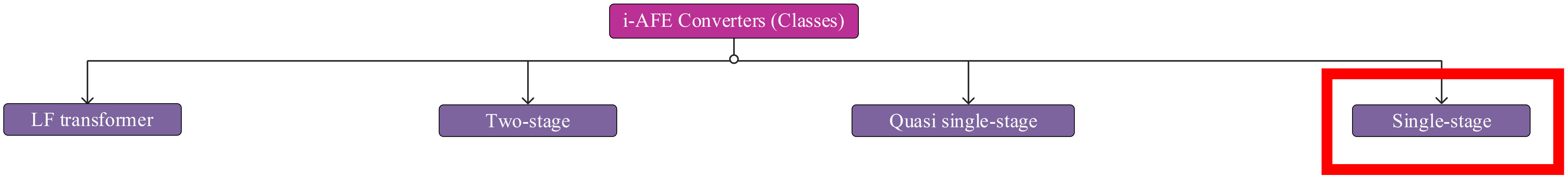


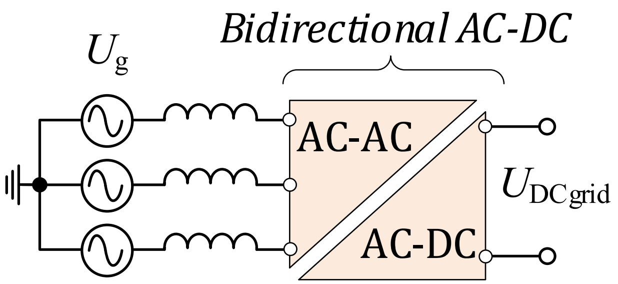
QUASI SINGLE-STAGE CONVERSION

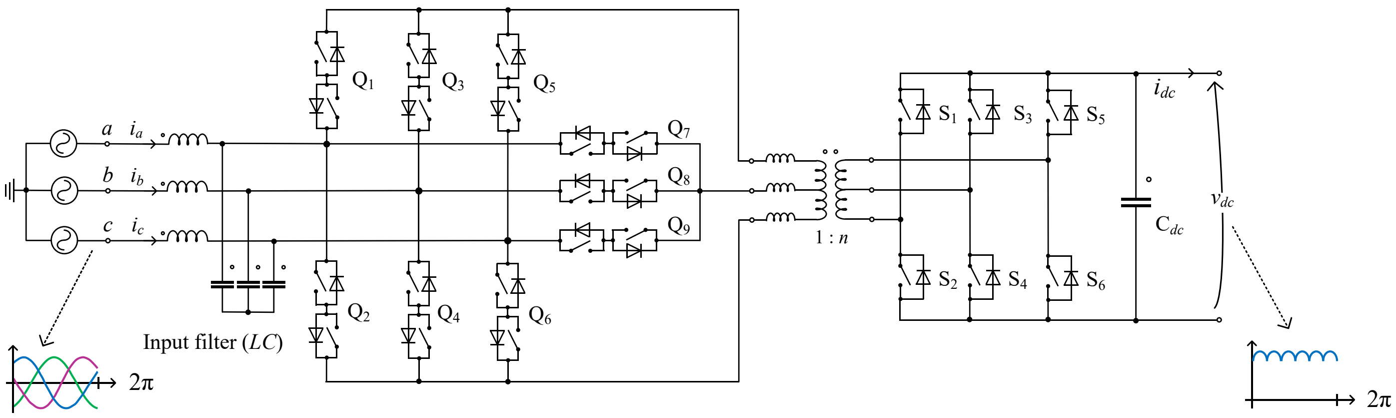


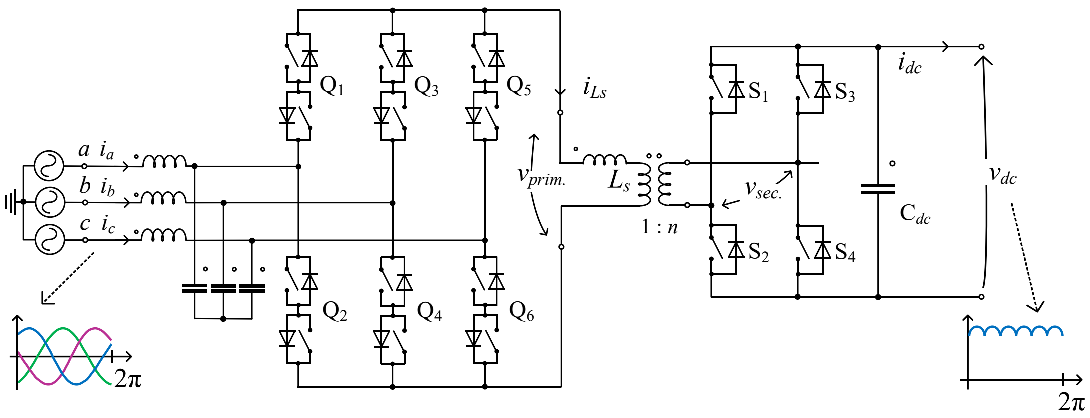


SINGLE-STAGE CONVERSION



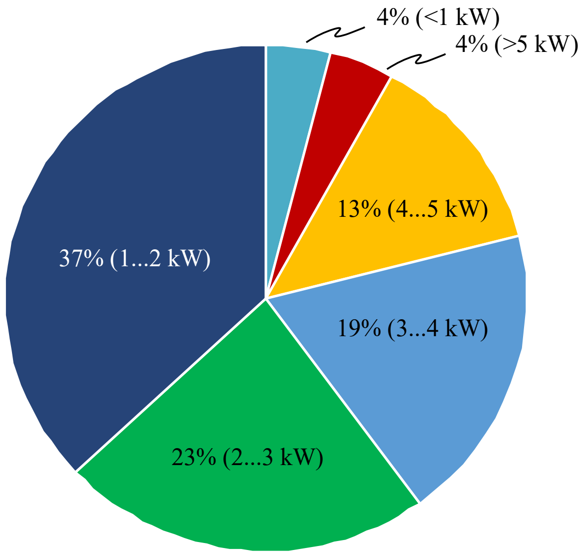




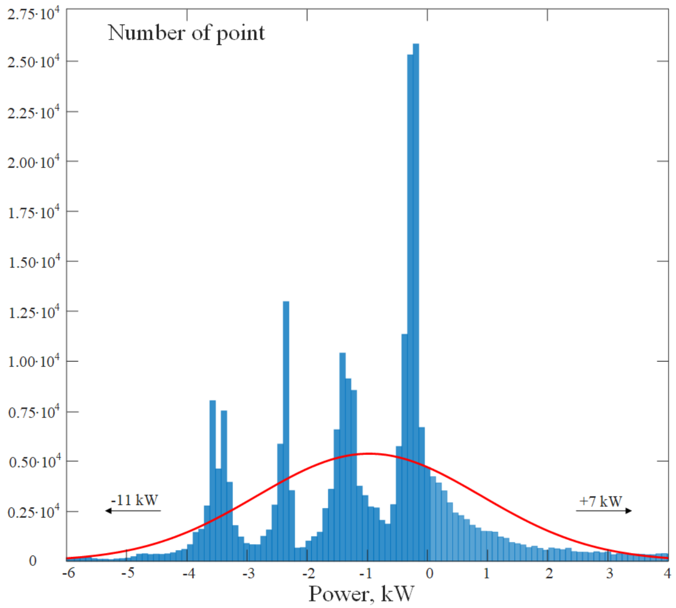


DC GRID FORMING CONVERTER DESIGN ASPECTS

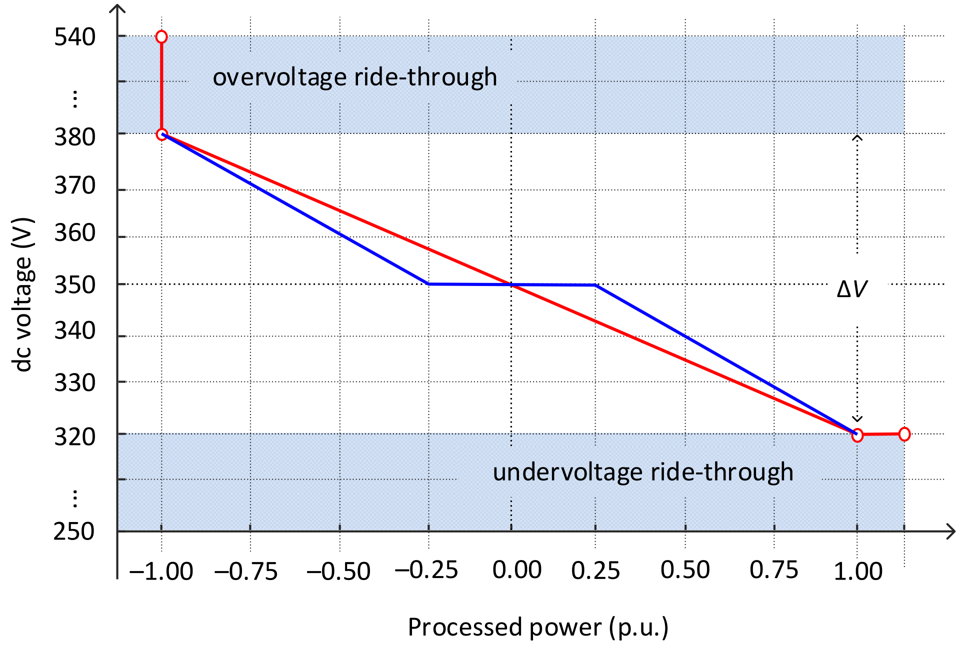
Energy consumption profile



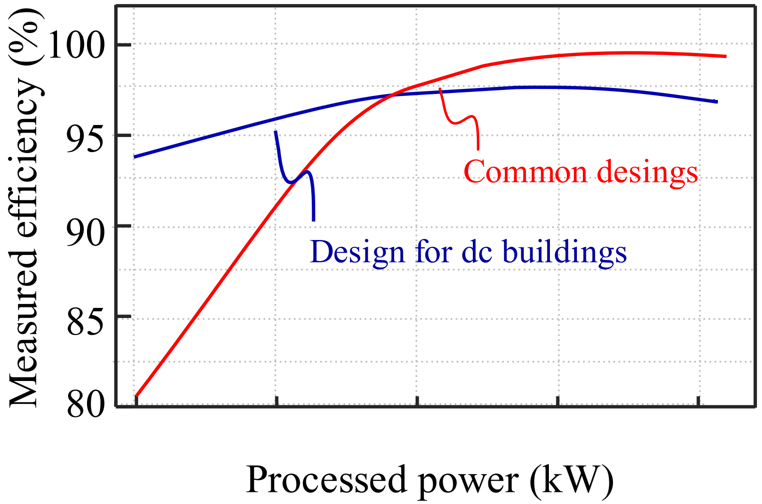
Load profile



Droop profile



Efficiency profile

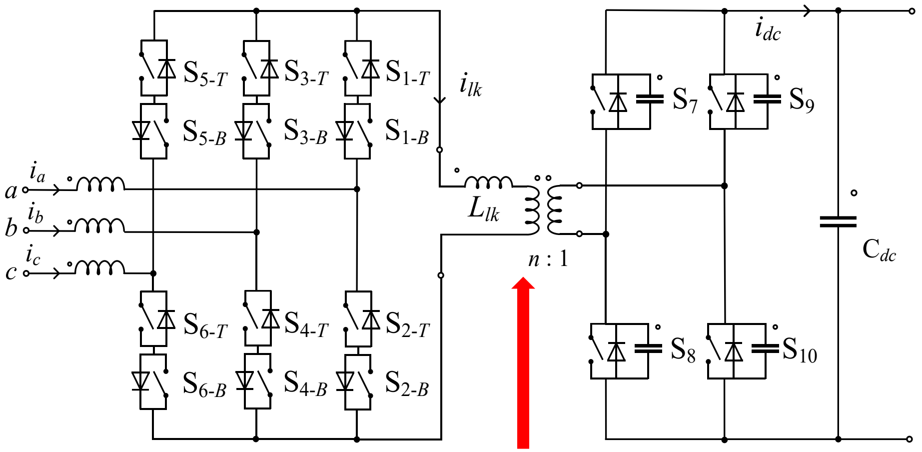


Design targets and priorities

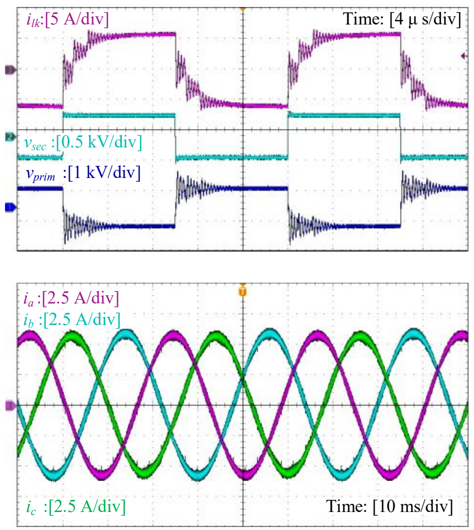
- *Investigate actual operational profile*
- *Indicate most probable working conditions*
- *Optimize the design considering the droop curve*

E. L. Carvalho, A. Sidorova, A. Blinov, A. Chub and D. Vinnikov, "Design Considerations of Dual-Active Bridge DC Grid-Forming Converter for DC Buildings," in *IEEE Transactions on Industrial Electronics*, doi: 10.1109/TIE.2023.3331125.

EXAMPLE DESIGNS: AC-DC MATRIX-CONVERTER



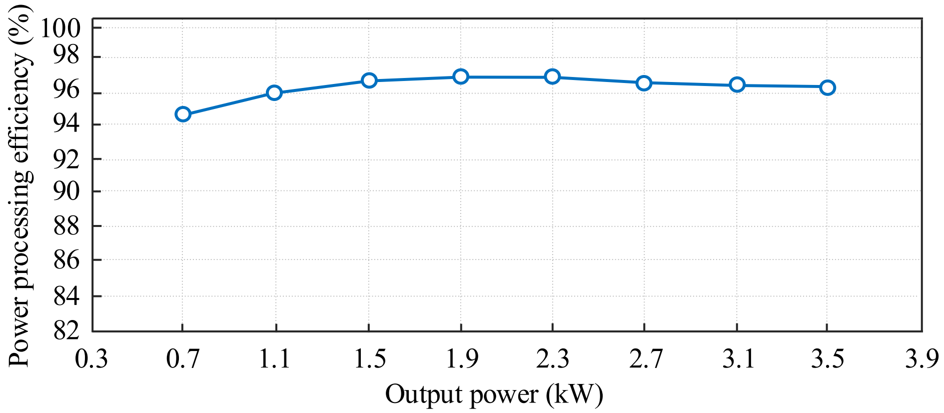
High-Frequency AC Link



Single-stage isolated matrix converter

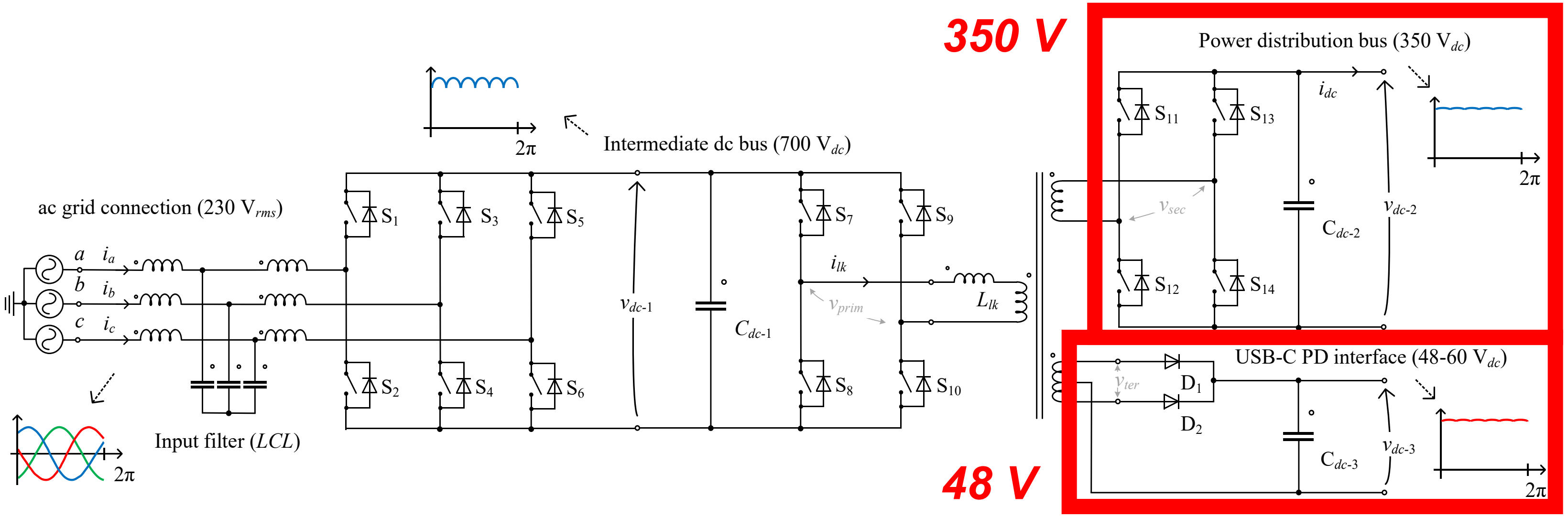
- *Peak efficiency 96.7%*
- *High efficiency at low power thanks to soft switching*
- *No intermediate DC*

Parameter/component	Value/Specification
Input voltage (*ac*)	230 V_{rms} (phase-neutral)
Nominal power (*P*)	3.5 kW
ac filter (*L*)	1.3 mH
Allowed *THD*	5 %
Primary side switches (S_1-S_6)	IMW120R220M1H (1200 V/9.5 A)
Secondary side switches (S_7-S_{10})	C3M0120065k (1200 V/22 A)
Switching frequency (f_s)	50 kHz
HF transformer	Pri: 31 turns Sec: 17 turns Turns ratio (*n*:1): 1.82: 1 Core: 2 × TDK EPCOS N87 Leakage inductance: 8 µH
Output voltage (*dc*)	350 V_{dc} (following NPR9090)
Output current (i_{dc})	10 A
Output capacitance (C_{dc})	60 µF
Driver circuits	UCC21521



E. L. Carvalho, A. Blinov, P. Emiliani, A. Chub and D. Vinnikov, "Three-Phase Bidirectional Isolated AC–DC Matrix-Converter With Full Soft-Switching Range," in *IEEE Access*, vol. 11, pp. 119270-119283, 2023, doi: 10.1109/ACCESS.2023.3327224.

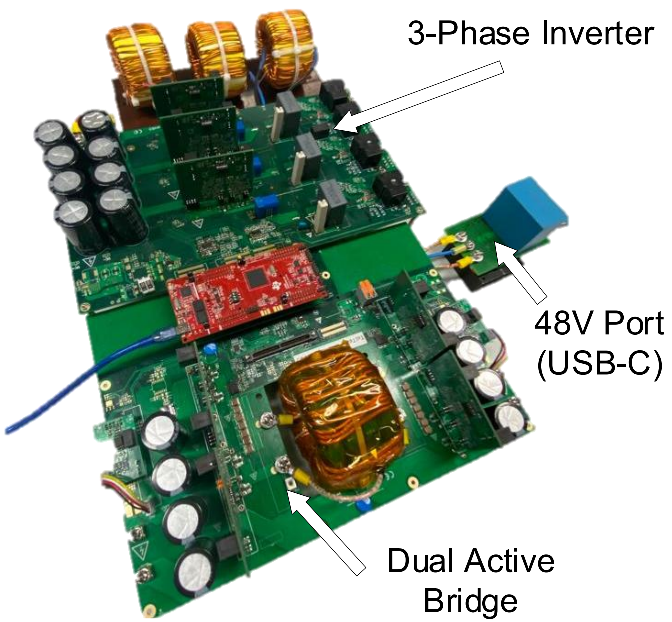
EXAMPLE DESIGNS: TWO-STAGE MULTI-PORT



Parameter/Component	Value/Detail
2L-VSC converter (ac-dc stage)	
ac voltage	230 V_{rms} (phase-neutral)
Nominal power	5.36 kW
LCL filter (ac side)	350 µH – 4.7 µF – 15 µH
Switches (S_1-S_6)	C2M0160120D (1200 V/19 A)
Switching frequency (f_s)	20 kHz
Intermediate dc bus (v_{dc-1})	700 V_{dc}
Main isolated dc-dc stage	
Output voltage (v_{dc-2})	350 V_{dc}
Output power (P_2)	5 kW (nom.)
Modulation method	Phase-shift modulation
Phase-shift range	$-\pi/6 \leq \delta \leq \pi/6$
Switching frequency (f_s)	100 kHz
Input capacitor (C_1)	2 mF
Output capacitor (C_2)	470 µF
Primary side switches (S_7-S_{10})	C2M0160120D (1200 V/19 A)
Secondary side switches (S_{11}-S_{14})	C3M0120065D (650 V/22 A)
USB PD interface	
Output voltage (v_{dc-3})	48-60 V_{dc}
Output power (P_3)	360 W (nom.) / 7.5 A (max.)
Output capacitor (C_3)	60 µF
Diodes (D_1-D_2)	RURG8060
Complementary components	
HF transformer	Pri: 24 turns Sec: 12 turns Ter: 5 turns Turns ratio (*n*:): 2:1:0.21 Core: 4×B64290L0730 (N87) Leakage inductance: 78 µH
Driver circuits	UCC21521

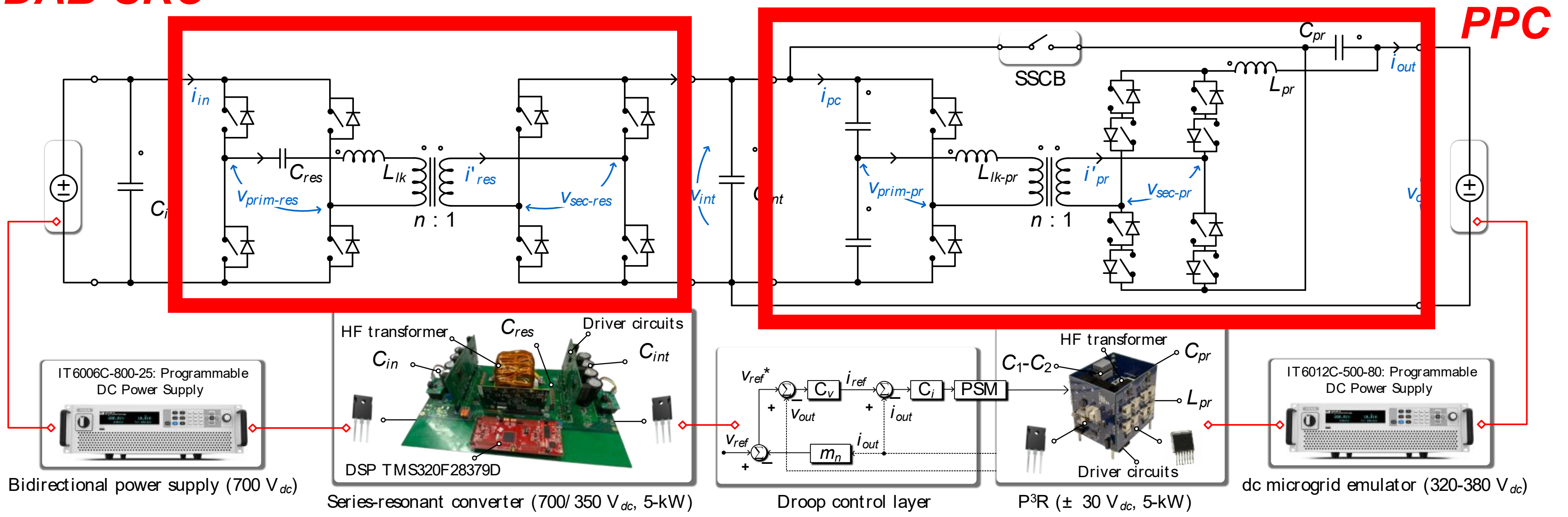
Multiport converter:

- *Utilizes single 3-w transformer*
- *Regulation according to droop curve*
- *95.6% efficiency at 350V port*
- *92.8% efficiency at 48V port*



E. L. Carvalho, A. Blinov, A. Chub, I. Galkin and D. Vinnikov, "Multi-port i-AFE Converter for Grid-Interactive Buildings: Design Requirements and Efficiency Evaluation," 2023 IEEE 8th Southern Power Electronics Conference and SPEC/COBEP, Florianopolis, Brazil, 2023, doi: 10.1109/SPEC56436.2023.10408230.

EXAMPLE DESIGNS: P³R CONVERTER

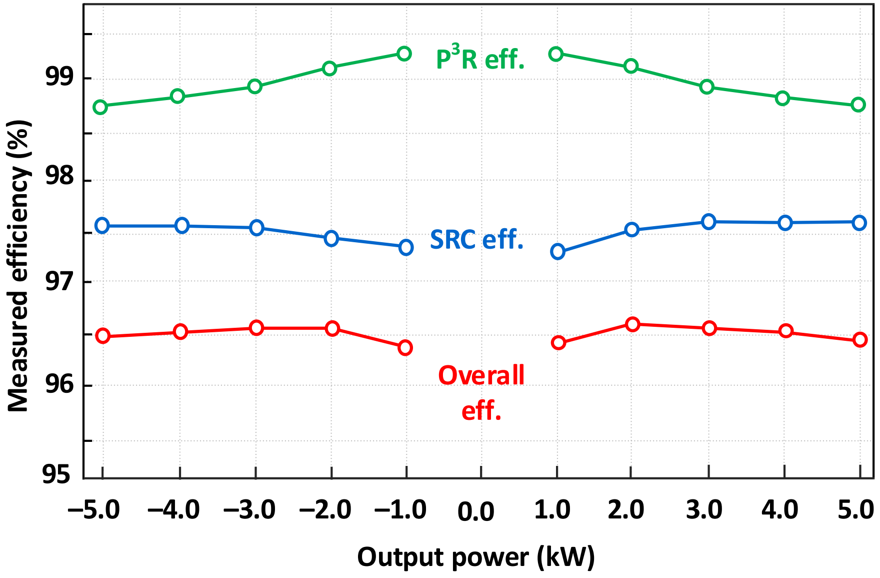


Parameter/Component	Value/Detail
Rated power (P_o)	5 kW
Input dc voltage (v_{in})	700 V$_{dc}$
Output dc voltage (v_{int})	350 V$_{dc}$
Output current (i_{out})	14.29 A
Switching frequency (f_s)	100 kHz
Quality factor (Q)	$0.1 < Q < 0.6$
Input capacitor (C_{in})	220 µF
Intermediate capacitor (C_{int})	470 µF
Primary side switches	UF3SC120009K4 (1200 V/65 A), 73 mΩ /210 pF
Secondary side switches	UF3SC065007K4 (650 V/120 A), 8.8 mΩ /1190 pF
HF transformer	Pri: 24 turns Sec: 12 turns Turns ratio (n:1): 2:1 Core: 4×B64290L0730 (N87)
Leakage inductance (L_{lk})	90 µH
Series capacitor (C_{res})	28 nF (1 kV)

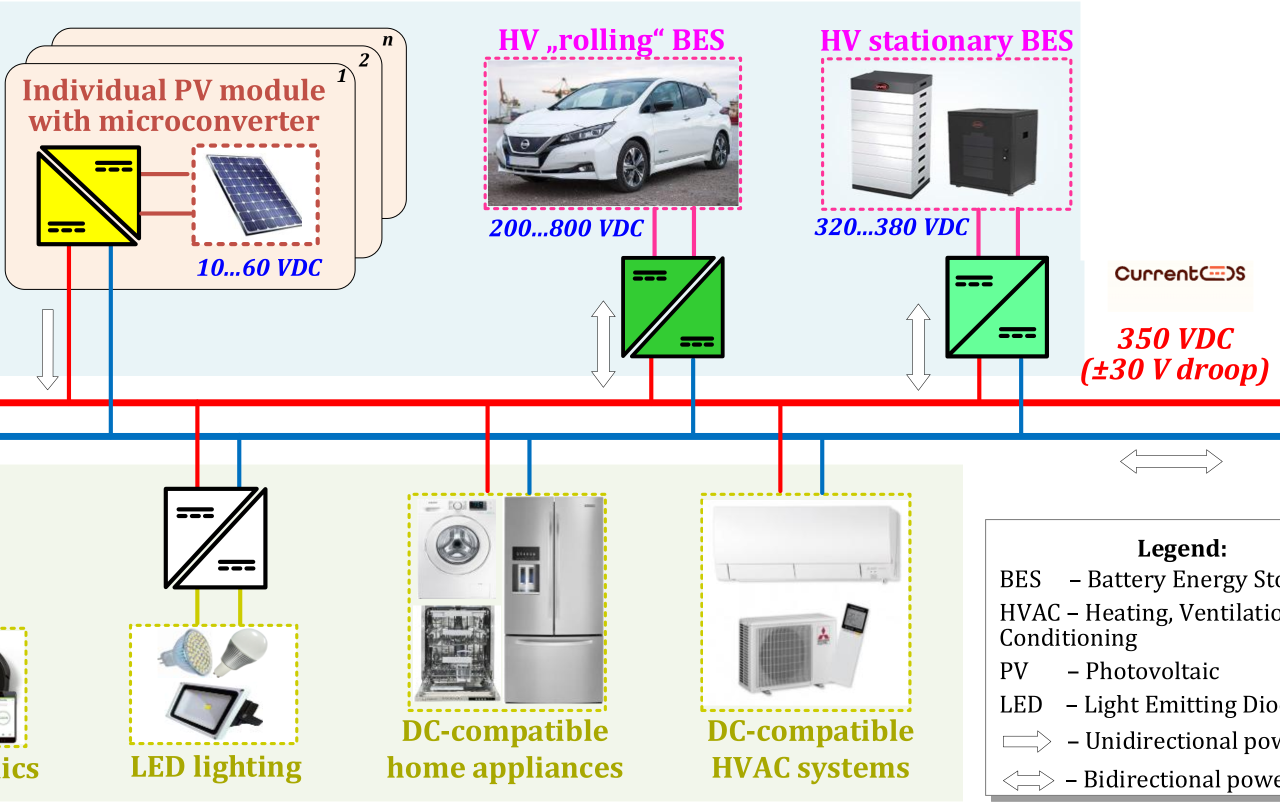
Parameter/Component	Value/Detail
Rated power (P_o)	5 kW
Output current (i_{out})	14.29 A
Output dc voltage (v_{out})	320…380 V$_{dc}$
Switching frequency (f_s)	50 kHz
HF transformer	Pri: 23 turns Sec: 10 turns Turns ratio (n:1): 2.3: 1 Core: ETD54/28/19/3C97 Leakage inductance: 0.85 µH
Output capacitor (C_{pr})	100 µF
Output capacitor (L_{pr})	100 µH
Primary side switches	C3M0120090J (900 V/22 A) 170 mΩ /48 pF
Secondary side switches	BSC0403NS (40 V/98 A) 2.5 mΩ /500 pF
SSCB switches	G3R60MT07D (750 V/43 A) 60 mΩ /98 pF
Driver circuit	UCC21521

P³R converter:

- *Utilizes SRC in open loop*
- *Regulation according to droop curve by PPC*
- *Flat 96.5% efficiency characteristic*



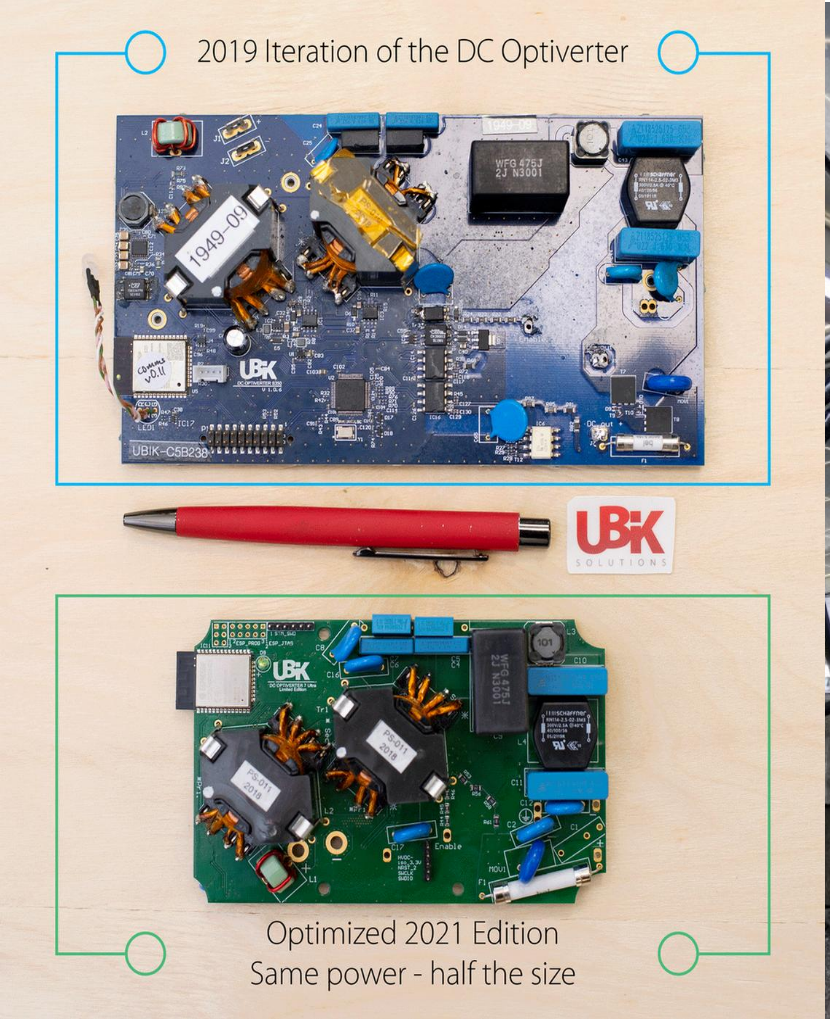
E. L. Carvalho, A. Chub, N. Hassanpour, A. Blinov, A.K. Rathore and D. Vinnikov, "P3R – Partial Power Post-Regulated Grid Forming Converter for Prosumer DC Buildings," in *IEEE Transactions on Industrial Electronics* // Accepted, in press //.



DC DEVICES

POWER ELECTRONICS TECHNOLOGIES FOR RESIDENTIAL DC

OPTIVERTER – A Hybrid of Photovoltaic OPTImizer and MicroconVERTER

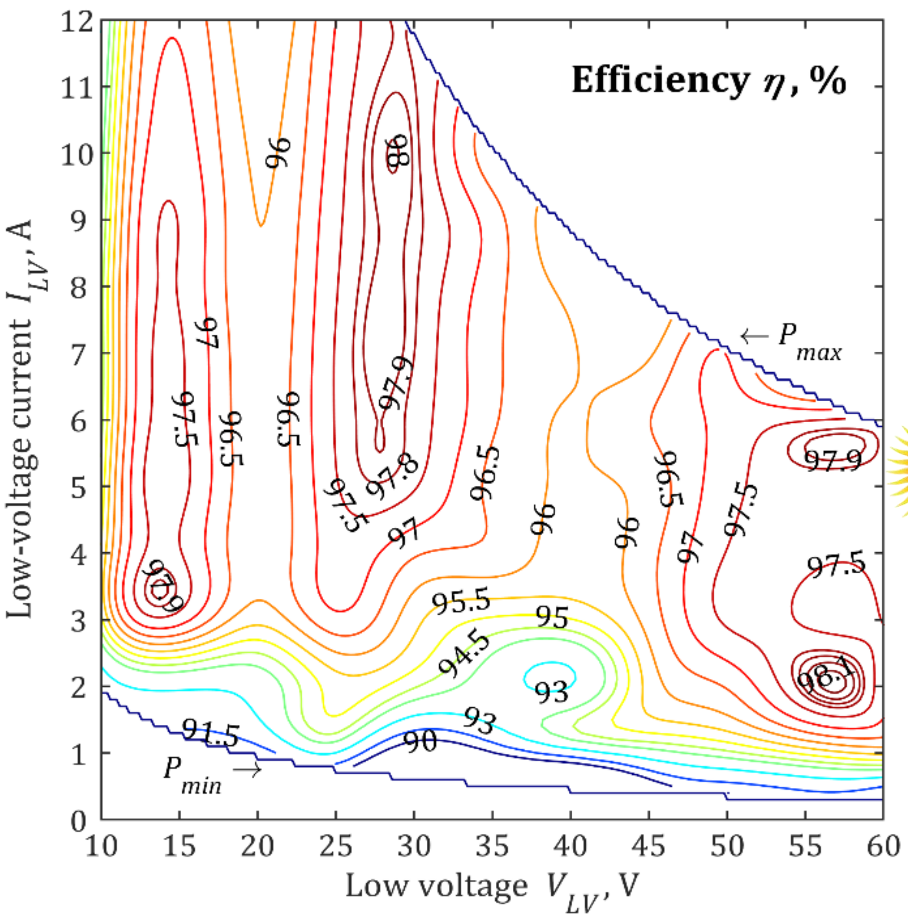


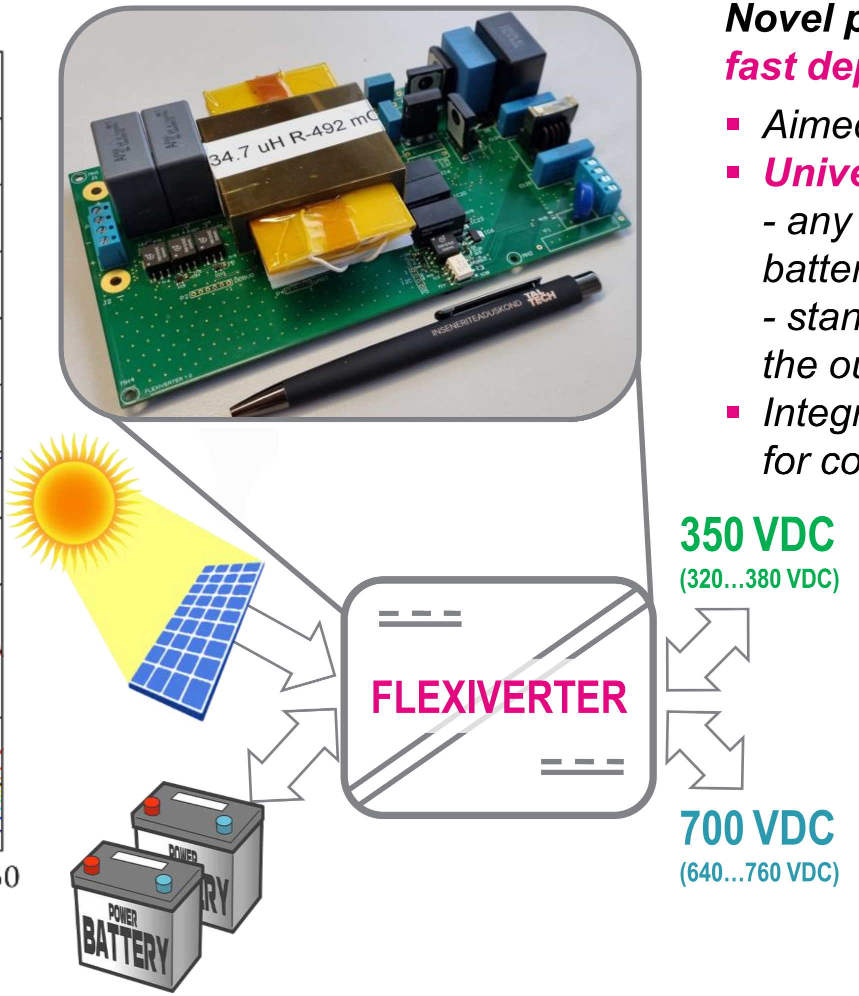
- *An entirely* ***novel PV MLPE technology***
- *Can be paired with all commercial* ***60- and 72-cell*** *PV modules*
- ***Fast GMPPT*** *and ultimate shade tolerance resulting in up to 30% better energy harvest*
- *Can be plugged either in* ***the 350 VDC or in 700 VDC*** *microgrids*
- ***Fully compatible*** *with emerging NPR9090 standard and Current OS DC microgrid protocol*
- *Supports the* ***droop control*** *functionality and features the integrated* ***solid state protection*** *circuitry for ensuring the highest level of fire and electric shock safety*
- ***All-in-One approach*** *with integrated gateway*
- *Integrates* ***2.4 GHz WiFi*** *and* ***BLE*** *for effortless cloud monitoring and on-site commissioning*

D. Vinnikov, A. Chub, E. Liivik, R. Kosenko and O. Korkh, "Solar Optiverter—A Novel Hybrid Approach to the Photovoltaic Module Level Power Electronics," in IEEE Transactions on Industrial Electronics, vol. 66, no. 5, pp. 3869-3880, May 2019, doi: 10.1109/TIE.2018.2850036.

FLEXIVERTER – FLEXIble conVERTER

Power electronics “LEGO” for next-gen DC homes





Novel power electronic building block for fast deployment of residential DC systems:

- *Aimed at nano-producers (<800W)*
- ***Universal compatibility:***
  - *any residential PV module and 24V or 48V batteries at the input*
  - *standard 350±30V or 700±60V microgrid at the output*
- *Integrated soft-start and solid-state protection for compatibility with **CurrentOS** protocol*

Features:

- *Peak efficiency **>98%***
- *Input source type **identification***
- *DC microgrid ready – **droop control** for battery and **power clipping** for PV*
- ***Global** maximum power point tracking verified*
- ***Integrated** design*
- *Generic **off-the-shelf components** used*

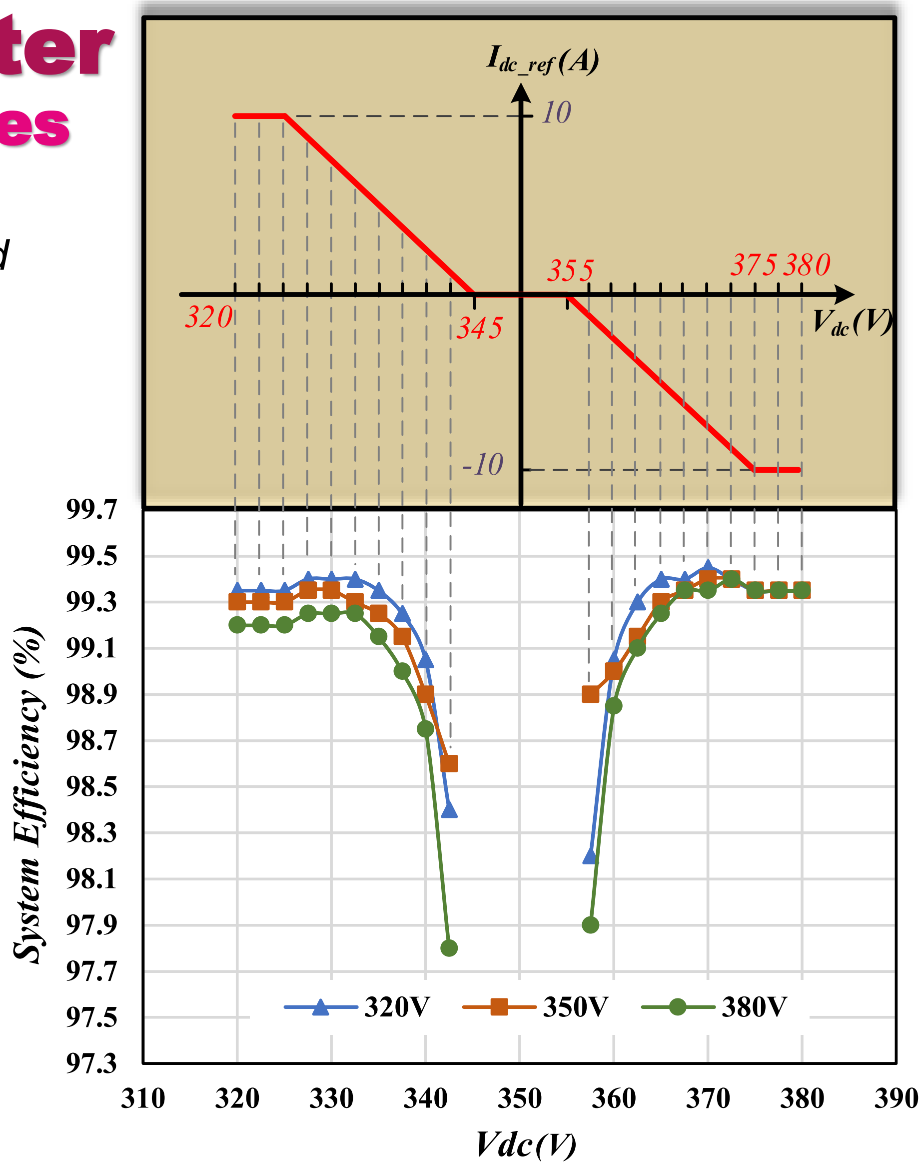
TAL TECH | TALLINN UNIVERSITY OF TECHNOLOGY

V. Sidorov, A. Chub, D. Vinnikov and A. Lindvest, "Novel Universal Power Electronic Interface for Integration of PV Modules and Battery Energy Storages in Residential DC Microgrids," in IEEE Access, vol. 11, pp. 30845-30858, 2023.

FORCE – Fractional pOweR ConvErter

For efficient integration of second-life batteries

- *Ultra-efficient – **over 99%** for 25%+ load*
- *Optimized for **350±30V** residential DC microgrids*
- *Designed for **second-life** LFP battery stack of 109 cells, approx. capacity ~8 kWh (depends on degradation)*
- ***Patented control** with soft-switching in the entire range*
- ***Soft-start** and embedded solid-state **protection** for compatibility with **CurrentOS** DC microgrid protocol*
- ***Low stress** on components*
- *Ready for emerging bidirectional **monolithic GaN switches** (by Infineon)*

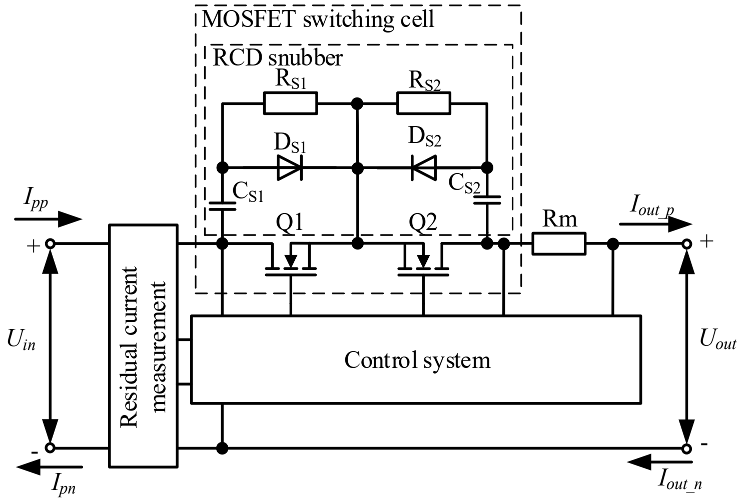


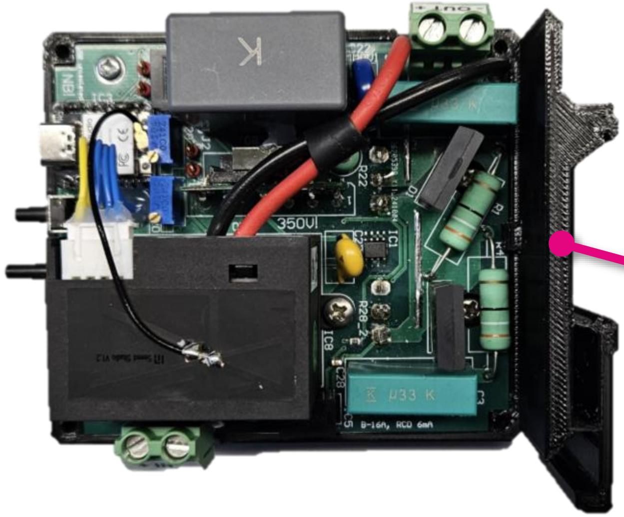
N. Hassanpour, A. Chub, A. Blinov and D. Vinnikov, "Soft-Switching Bidirectional Step-Up/Down Partial Power Converter with Reduced Components Stress," in IEEE Transactions on Power Electronics, vol. 38, no. 11, pp. 14166-14177, Nov. 2023.

SAFEBREAK – SAfe and Fast DC Electronic BREAKer

Multifunctional SSCB for residential prosumer DC nanogrids

- *Optimized for **350 VDC/16A** residential applications*
- *Utilizes SiC JFETs for **low R_{DSon}**, efficiency **99.8% @ 16A***
- ***Fast speed** – short circuit detected within 10 µs*
- *Min. voltage: 100 VDC*
- *Max. input voltage: 440 VDC (overvoltage protection at 380 VDC)*
- *Contains **residual current sensor** for ultimate safety*
- *Max. allowed residual current: 6 mA*
- ***Bidirectional operation** (prosumer-ready)*
- ***Connectivity**: WiFi, USB. **Telemetry**: current, voltage, faults*
- *MQTT smart connection to **Energy Management System***





DEVELOPMENTS IN PROGRESS

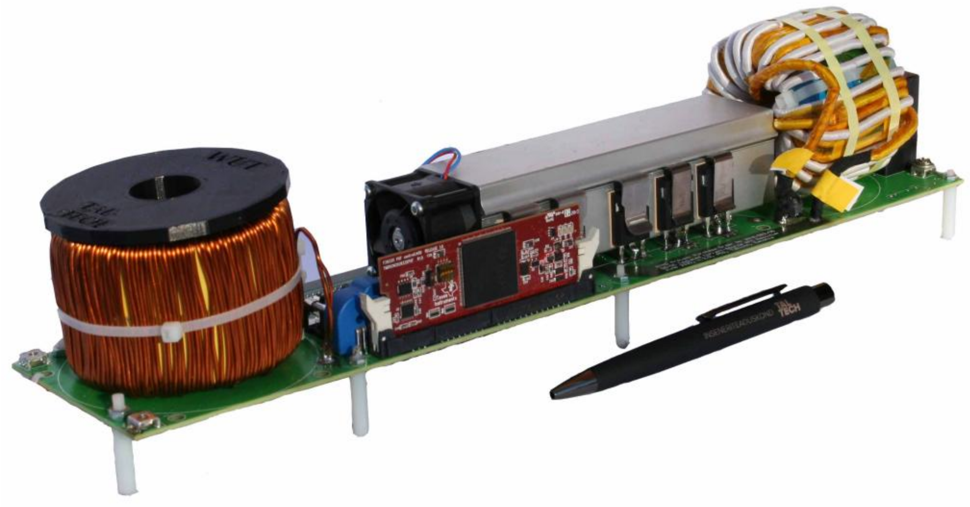
MERGE: Smart energy gateway for DC homes connection to AC grid

- *Bidirectional power router for prosumer DC buildings*
- *High-frequency galvanic isolation*
- *Input 230/400 VAC, output 350 VDC, 5…10 kW*
- *Droop control according to CurrentOS protocol*
- *Efficiency curve optimized for part-load operation based on statistical data (>97 %)*
- *Possible multi-port configuration with USB-PD output*

E. L. Carvalho et al. "Design Considerations of Dual-Active Bridge DC Grid-Forming Converter for DC Buildings," in IEEE Trans. on Ind. Electronics, vol. 71, no. 9, pp. 10601-10611, Sept. 2024

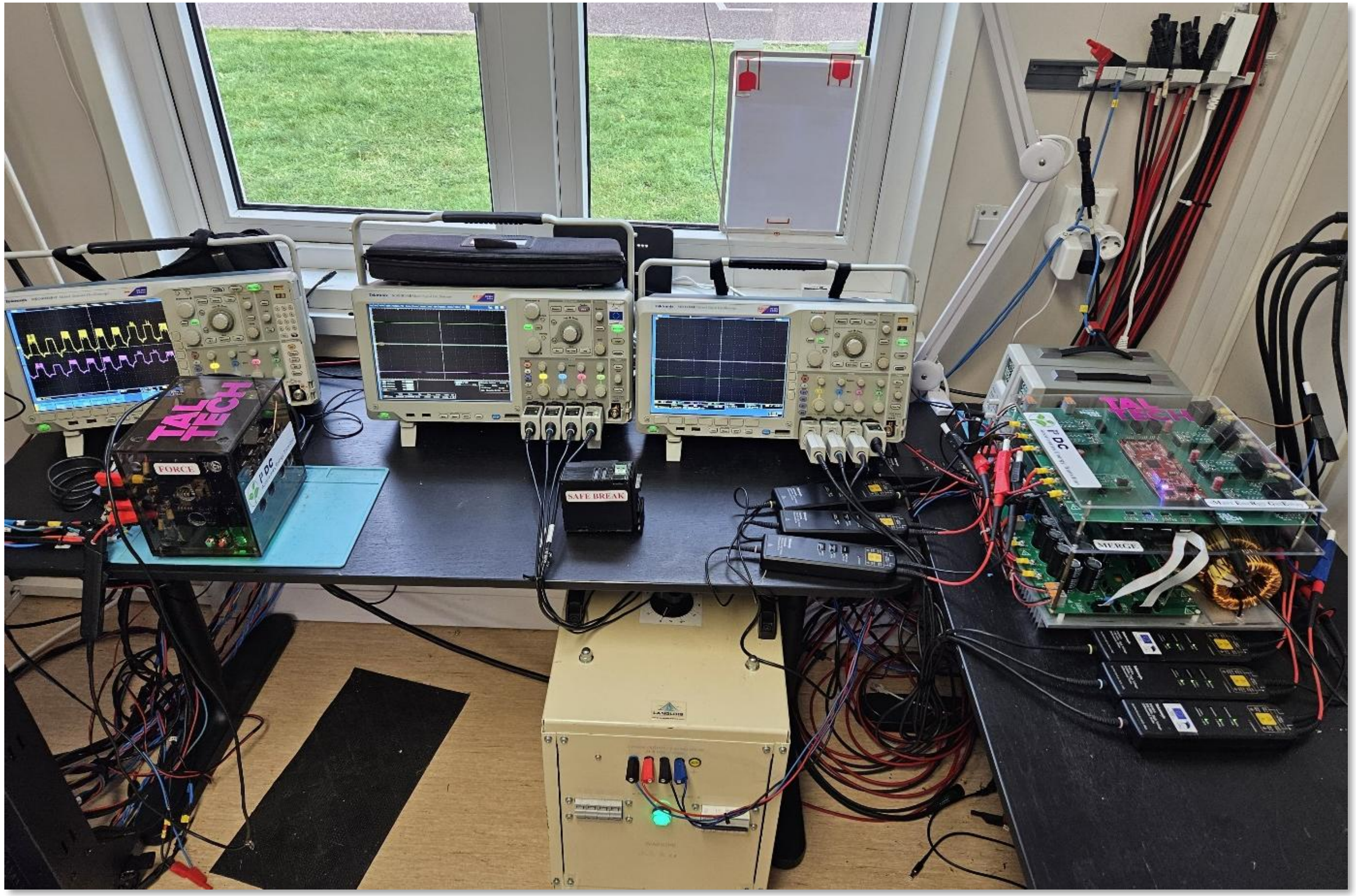
UbiCharge: Ubiquitous low-power EV opportunity Charger

- *Charges EV and employs energy stored in it for the emergency backup power supply of ZEB*
- *High-frequency galvanic isolation*
- *Power 3…7.4 kVA, universal EV-side range of 200…800 VDC*
- *Droop controlled according to CurrentOS (in emergency bands)*
- *High weighted efficiency of >97%*
- *Low-cost single-stage design*



D. Zinchenko et al. "High-Efficiency Single-Stage On-Board Charger for Electrical Vehicles," in IEEE Transactions on Vehicular Technology, vol. 70, no. 12, pp. 12581-12592, Dec. 2021

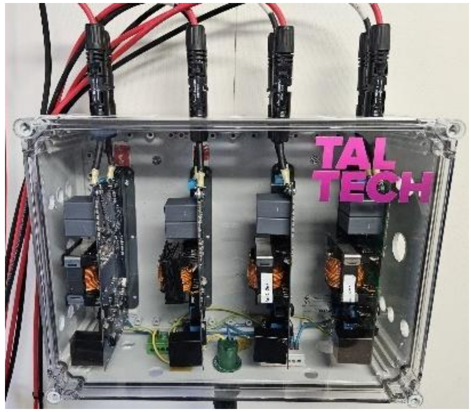
TECHNOLOGIES UNDER TEST IN DC INNOHUB



SAFEBREAK

MERGE

FORCE



FlexiVerter

Visit dcinnohub.com !

PEMC 2026 IN TALLINN – SAVE THE DATE!

THE 22ND IEEE POWER ELECTRONICS AND MOTION CONTROL CONFERENCE (PEMC2026)

CO-SPONSORED BY THE IEEE IES

You can expect:

- *Highly relevant program on power electronics, controls, electrical drives, robotics and their industrial applications*
- *~150 papers to be presented*
- *Tutorials from world-renown experts*
- *Conference venue next to the Tallinn's Old Town – a UNESCO World Heritage Site*
- *Entertaining social events for attendees, special events for students and WiE members*
- *Luncheons and coffee breaks*

IEEE-PEMC 2026

22nd International Power Electronics and Motion Control Conference

October 5 - 7, 2026 – Tallinn, Estonia

SAVE THE DATE!

IEEE-PEMC is the biennial conference initiated by the **Power Electronics and Motion Control (PEMC) Council**, which has been standing strong for over 50 years since the first event in 1970. It is devoted to contemporary research topics of power electronics, control systems, electrical drives, robotics, and related topics. This exciting event connects researchers and industry experts to share ideas and experiences surrounding frontier technologies, breakthroughs, and innovative solutions and applications. It creates an opportunity to meet world-class scientists presenting **keynotes, tutorials, and invited papers**.

Join this event to be among leaders of society's transformations to sustainability.

MAIN TOPICS

- Power Electronics and Drives in Transportation
- Power Electronics in Future Power Grids

TECHNICAL TRACKS

- Power Electronics and Drives in Transportation
- Power Electronics in Power Grids
- Power Electronics in Electrical Energy & Heat Generation
- Power Electronics and Drives in Industry
- Power Supplies and Special Converters
- Semiconductor Devices
- Power Electronic Converter Design and Control
- Electrical Machines and Actuators
- Motion Control, Adj. Speed Drives and Robotics
- Machine Learning in Power Electronics & Drives
- Sensors, Measurement & Observation Techniques
- Education and other related topics
- Multiphase Machines and Drives

TAL TECH

Power Electronics and Motion Control Council

PEMC

IEEE Industrial Electronics Society

IEEE ESTONIA SECTION

SPECIAL SESSIONS

The conference will include special sessions on **topics of focused interest** in particular areas, reporting technical trends and breakthroughs within the conference scope. They are organized at the initiative of 1-4 individuals, who must adhere to the procedure published on the conference website.

PAPER SUBMISSION

Prospective authors are invited to submit **full papers** in English, following instructions on the website. The conference proceedings will be submitted to **IEEE Xplore**.

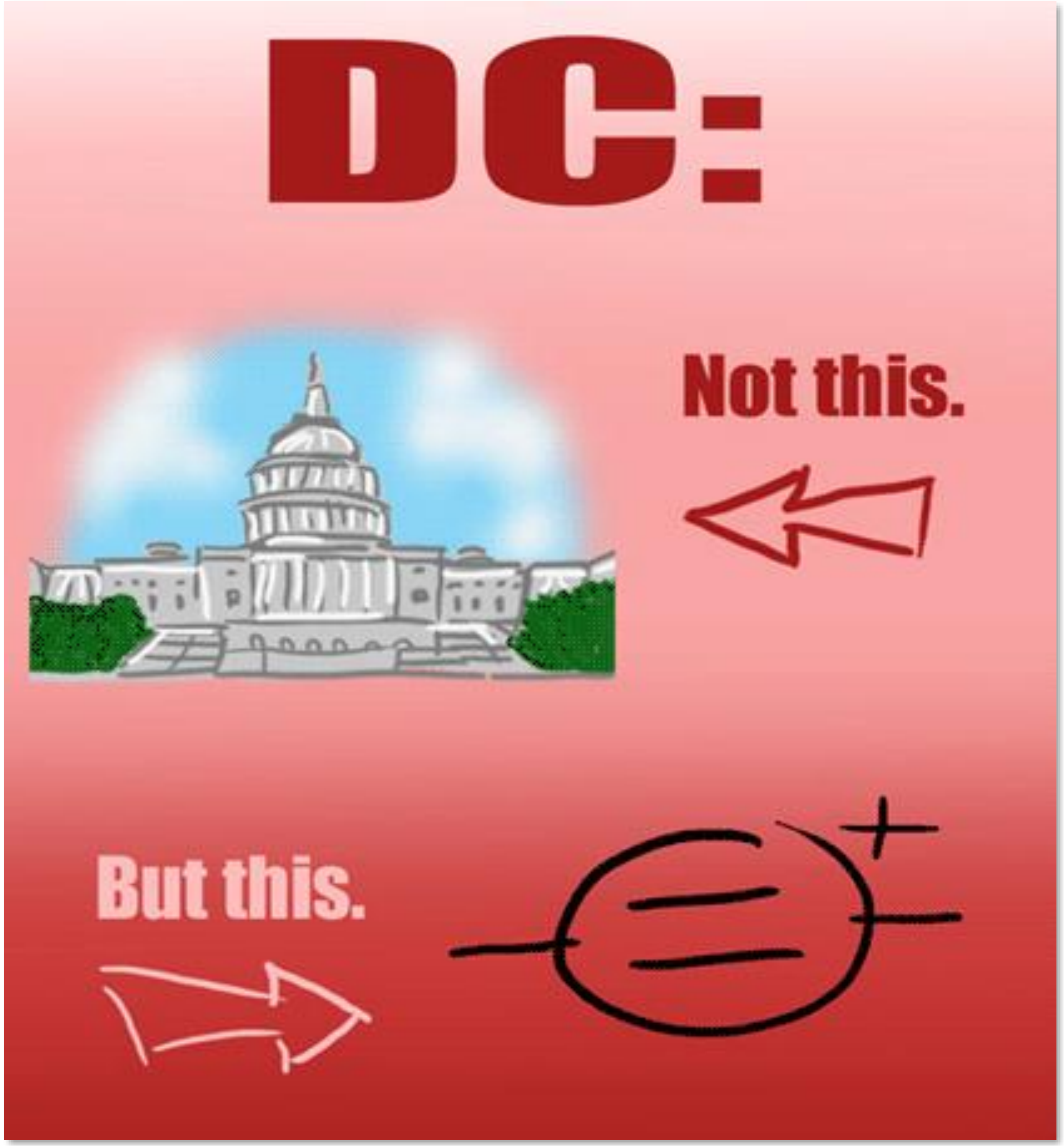
TUTORIALS

Tutorials planned for organization during the conference will be announced on the website. Industrial partners are invited to contribute at the industrial exhibition!

VENUE

The conference will be held at the Original Sokos Hotel Viru.

IEEE-PEMC 2026 Tallinn, Estonia October 5 - 7, 2026



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