(BI)PV challenges

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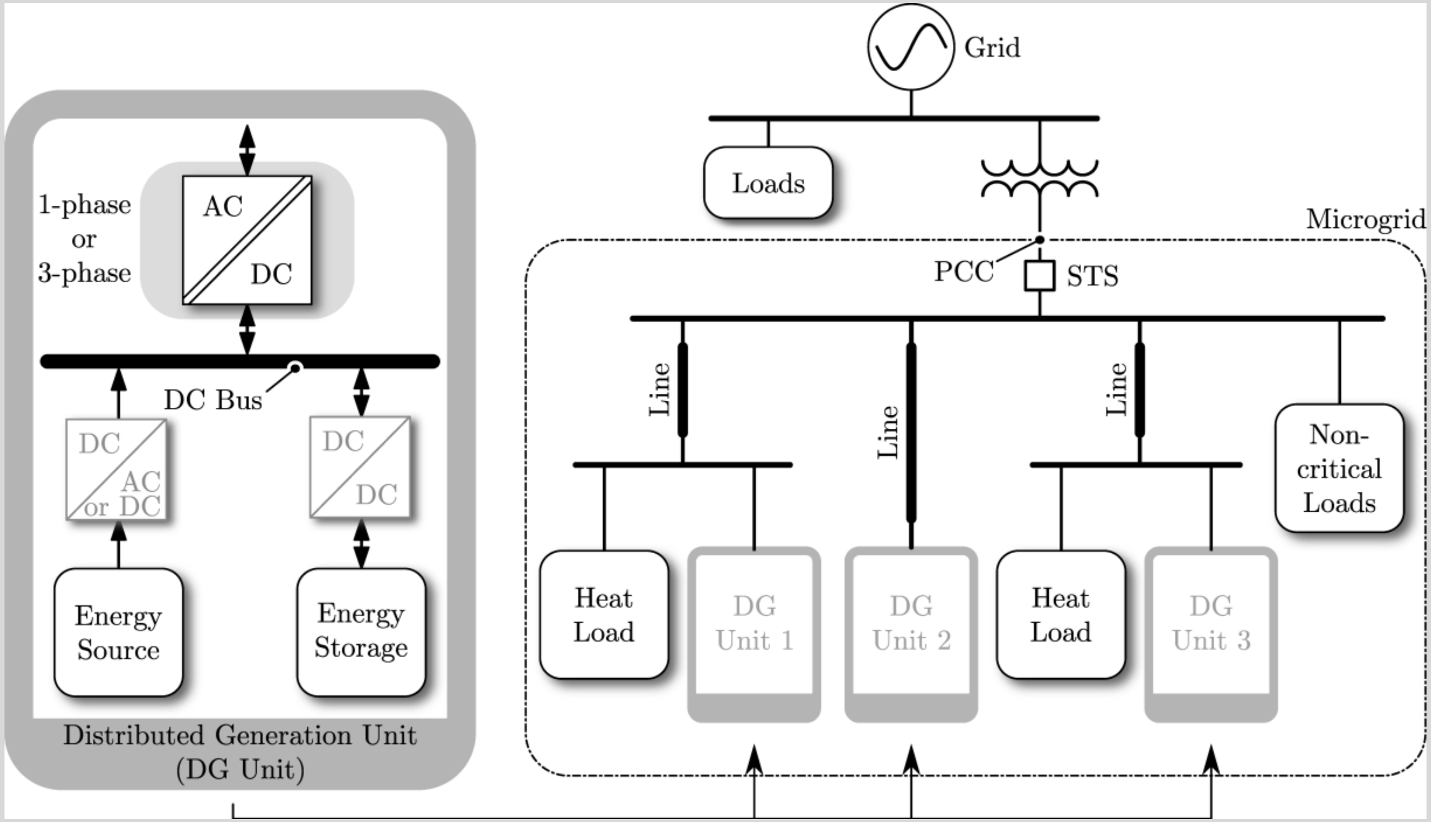
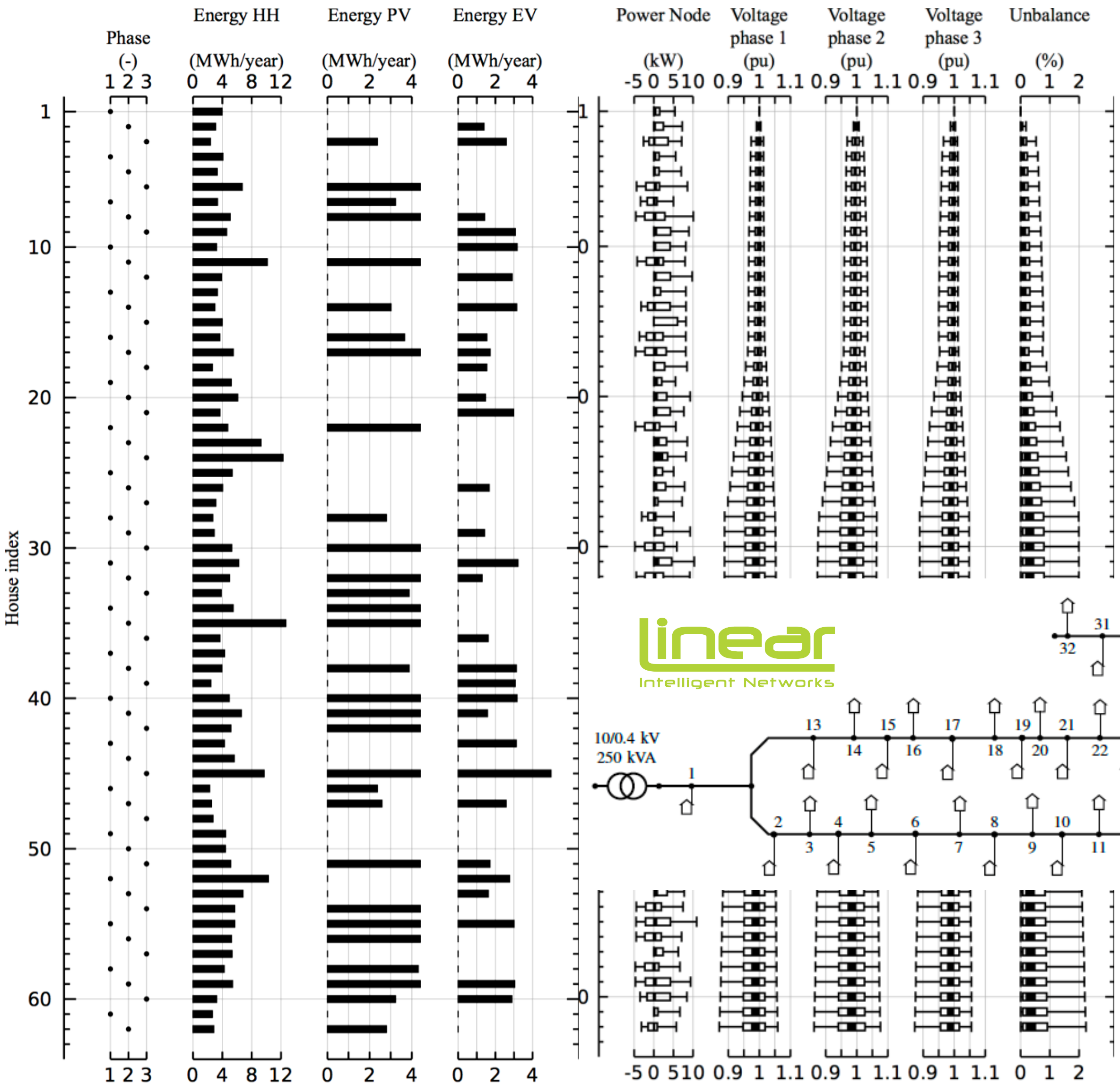
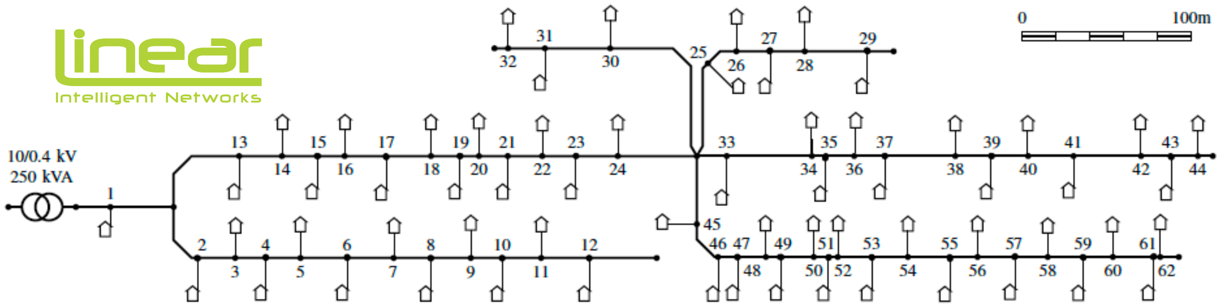
Prosumers in smart grids



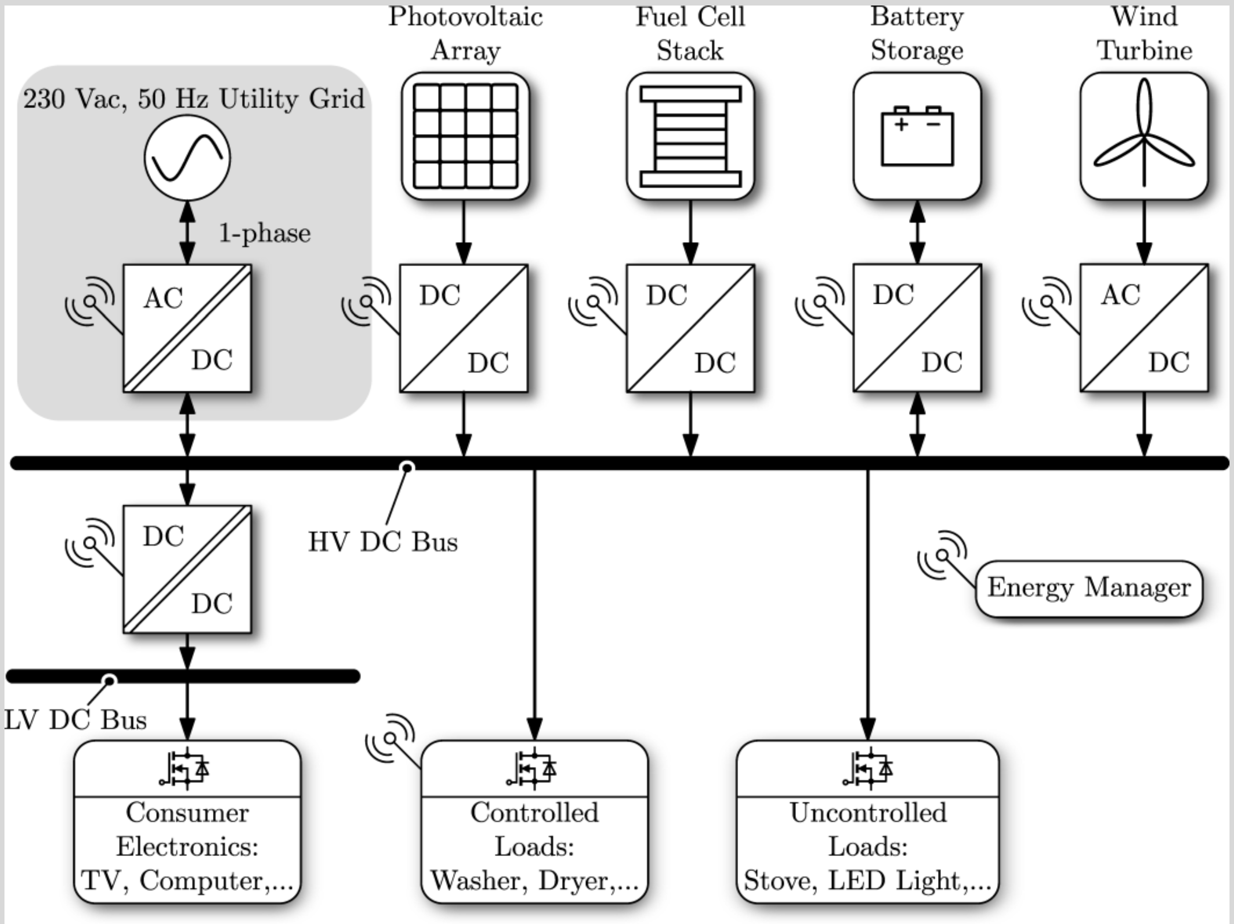
PV & Grid issues





- Power Quality issues
  - Voltage
  - Phase Unbalance
- Self-consumption is low
- Additional loads (EVs, Heatpumps) may worsen the problem

New grid architectures

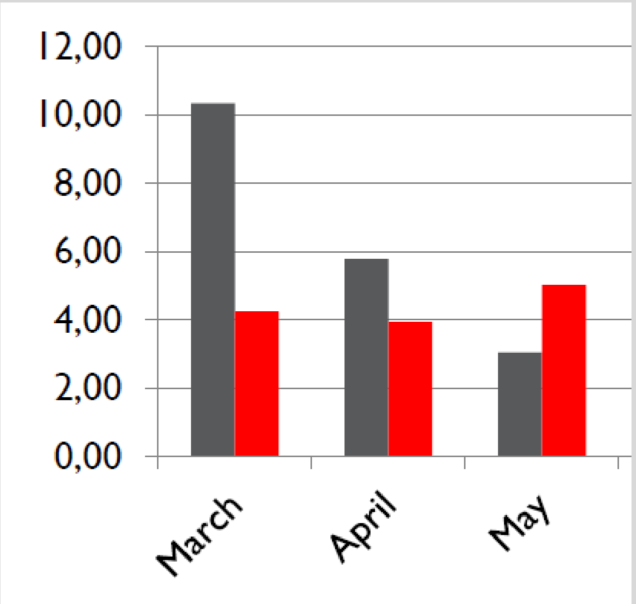


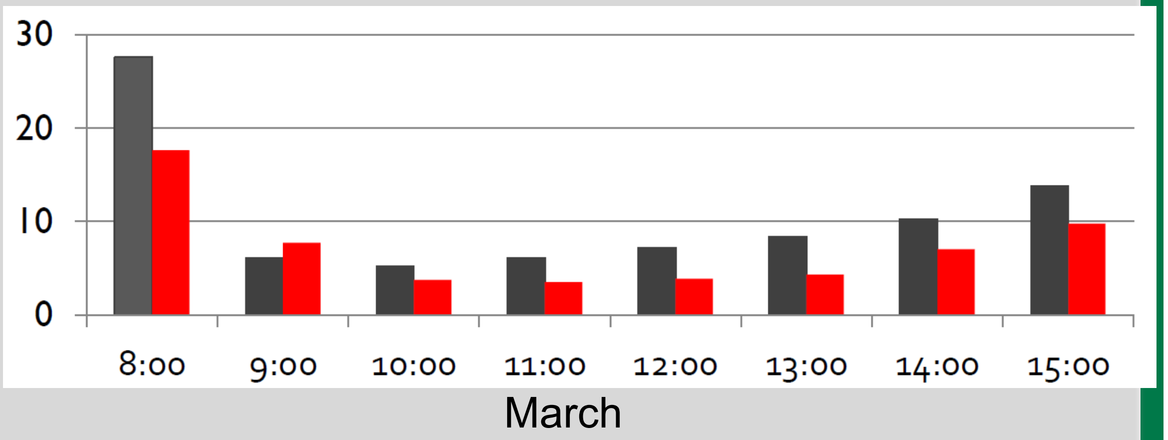
Enhancing the value of PV energy
Short-term energy forecasting

Short-term energy yield prediction of PV plants can have errors > 10 % => implications for producer, grid operator, …

Meteo forecast errors + Imperfect PV- plant energy yield models → PV-plant production forecast error

- PVSyst (15 min. resolution)
- Proposed model (1 sec. resolution)

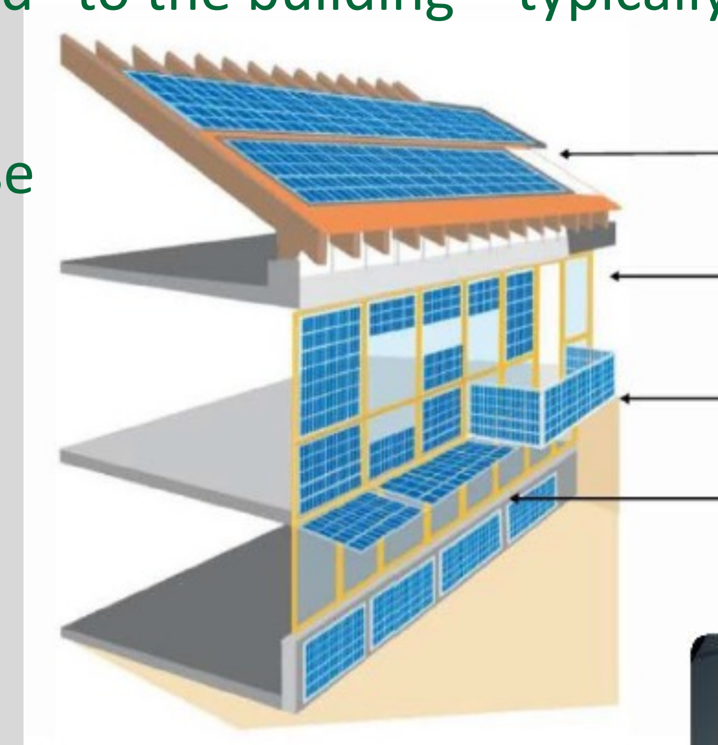




Ref: paper 8WeO115 - PWSEC 2014

Towards Building-Integrated-PV (BIPV)

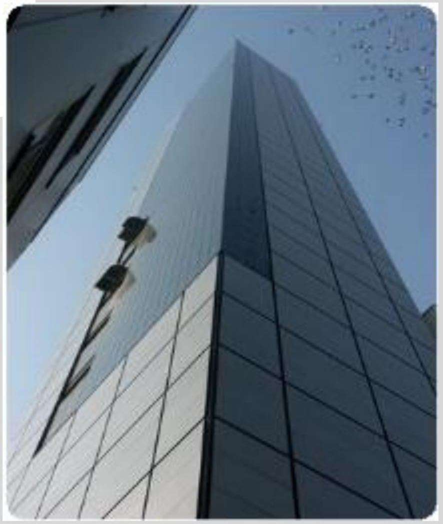
- ~~Today: PV modules "added" to the building – typically the roof~~



- BIPV = multi-functional use
  - As building component
  - To generate electricity

- What will drive BIPV ?
  - Façade-integration of PV for tall NZEB-compliant buildings

    potential market > 100 GW/yr
  - PV-roofs with improved esthetics
  - Lower overall cost (building + PV)



Building-Integrated-PV (BIPV)
Demonstrators and facilities

- ## Back-contact (“ MWT ”) Si-PV modules

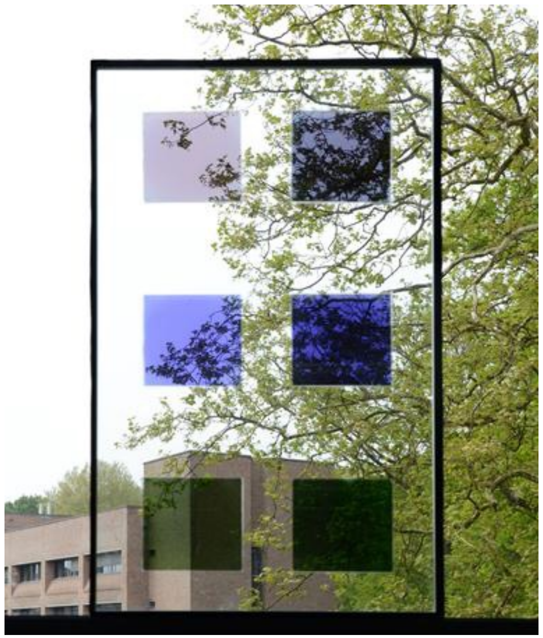
  rooftop & rooftile / improved esthetics / higher efficiency / cost-effective Si-PV

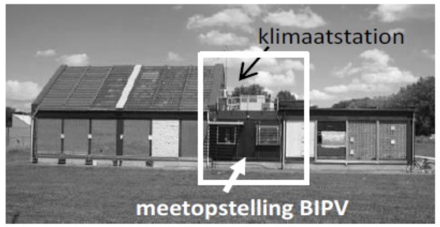
- ## Organic-PV

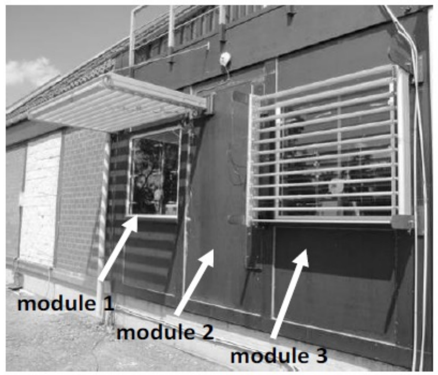
  facades / semi-transparent / color-on-demand

- ## Testing and modelling interaction PV <-> building

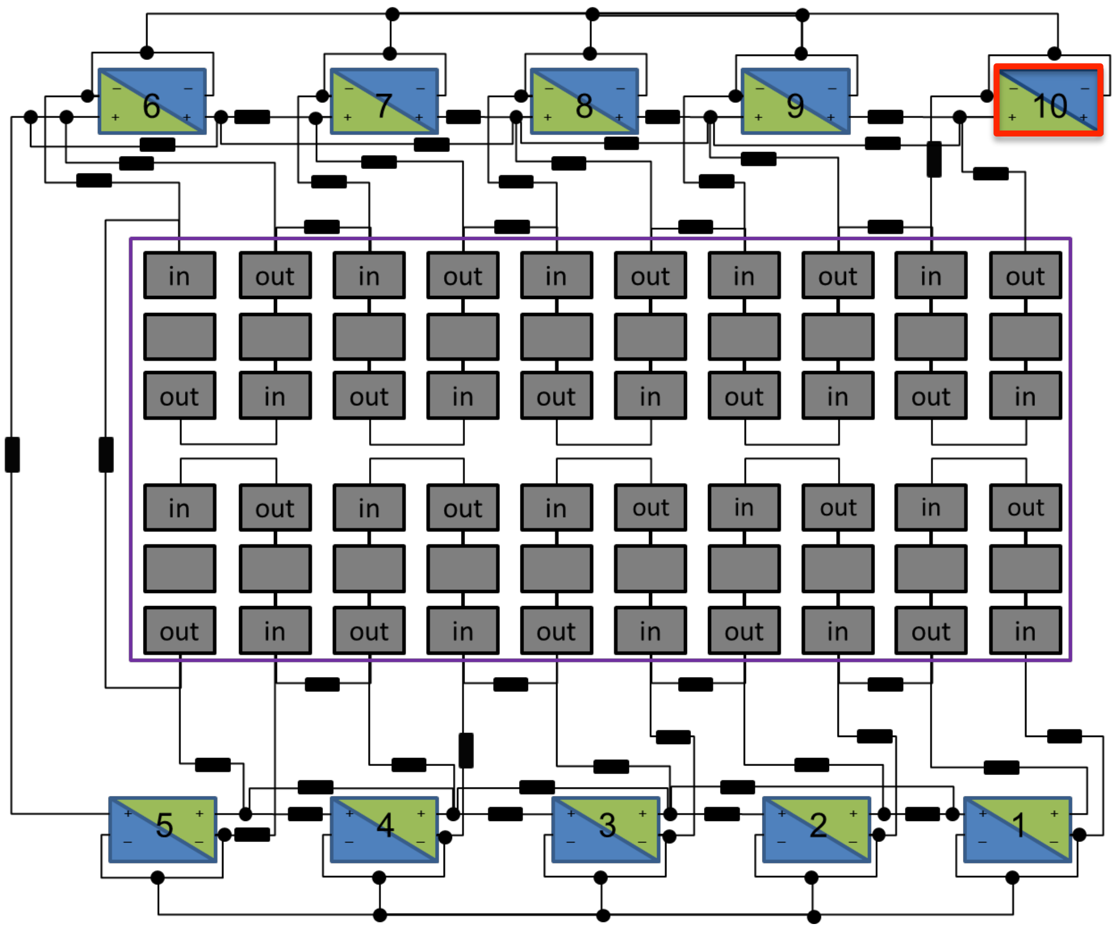
  Hygrothermal & mechanical / model & lab validation







Towards reconfigureable modules ?



- Concept: re-configure substrings of module to maximize power output also under non-uniform conditions
- This example:

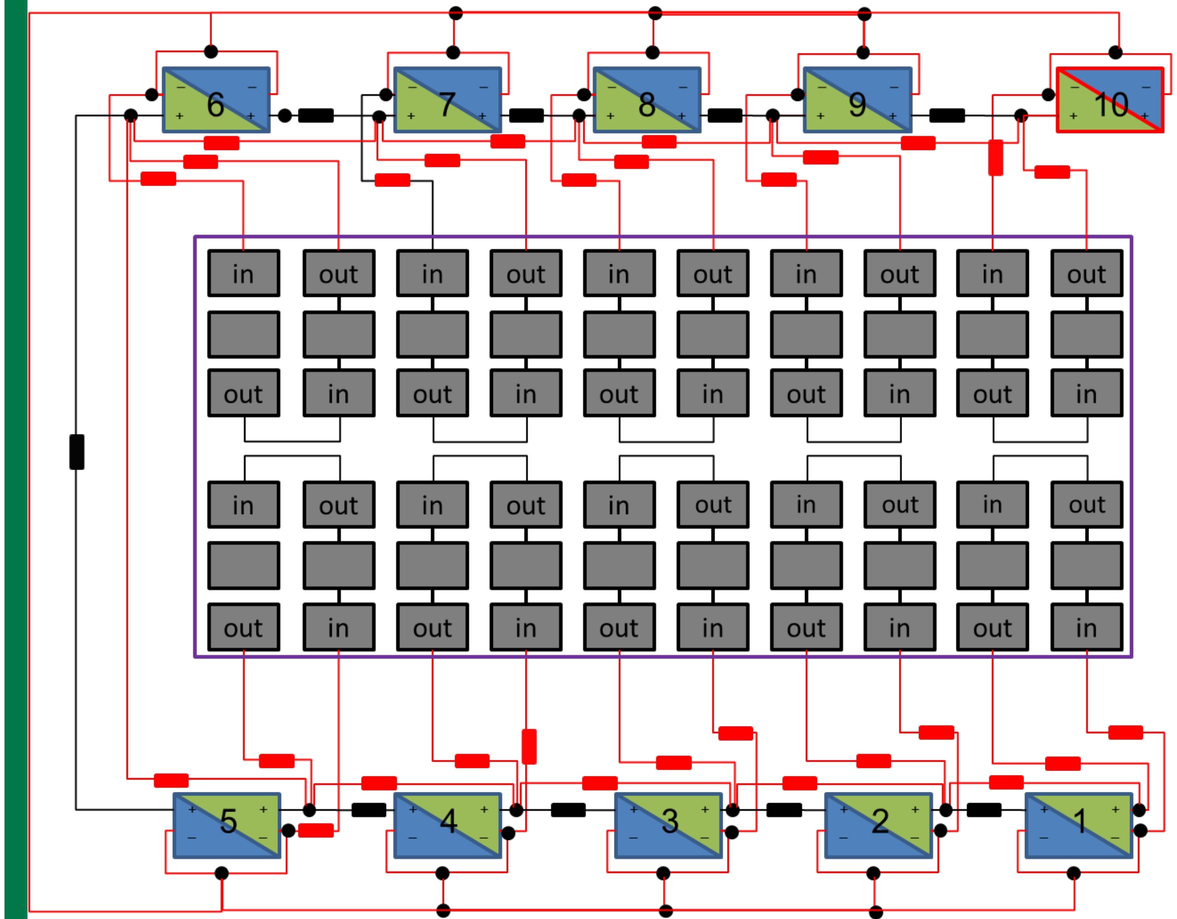
  Each substring 1 chip with
  - basic DC/DC converter*
  - 4 switches

  1 full-featured DC/DC converter per module (#10)

  * except # 10

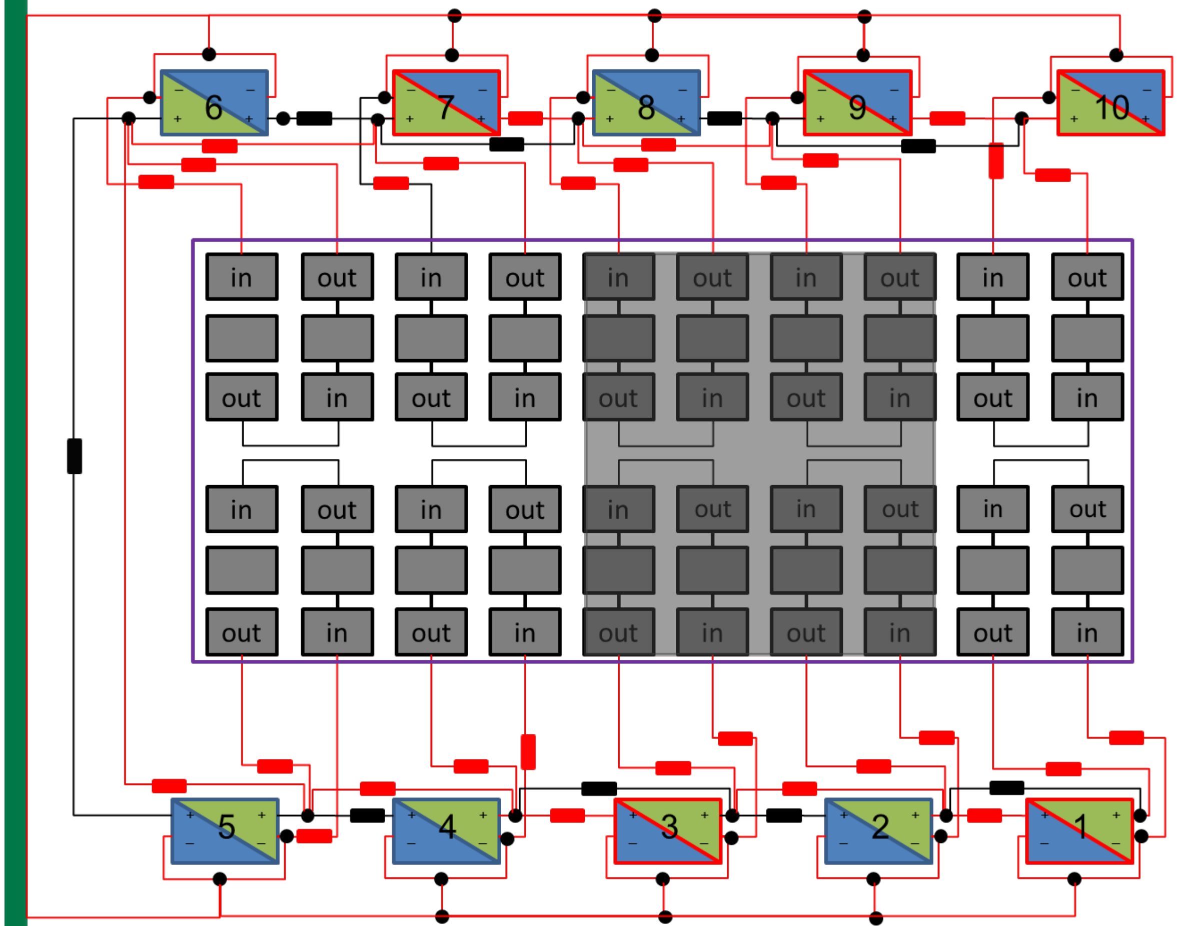
Patent application WO 2013/060564 A2: energy-yield under conditions of variable shading (F. Catthoor e.a .)

Configuration under uniform operation



- All substrings connected in parallel
- Module-level DC/DC converter (#10) converts power from all substrings

Configuration under non-uniform operation

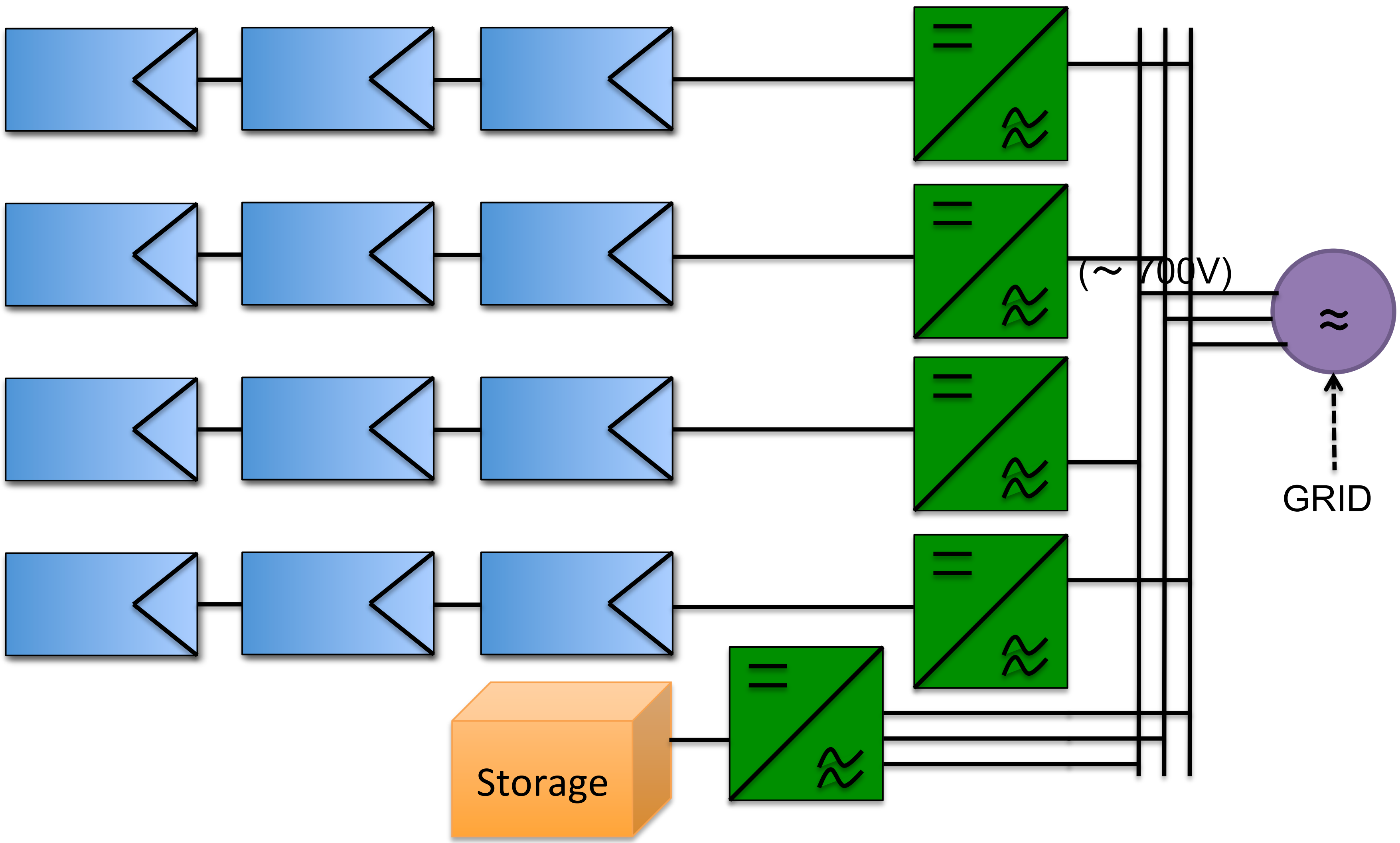


- Converters 1, 3, 7, 9 also activated
- Module-level DC/DC converter active (#10)

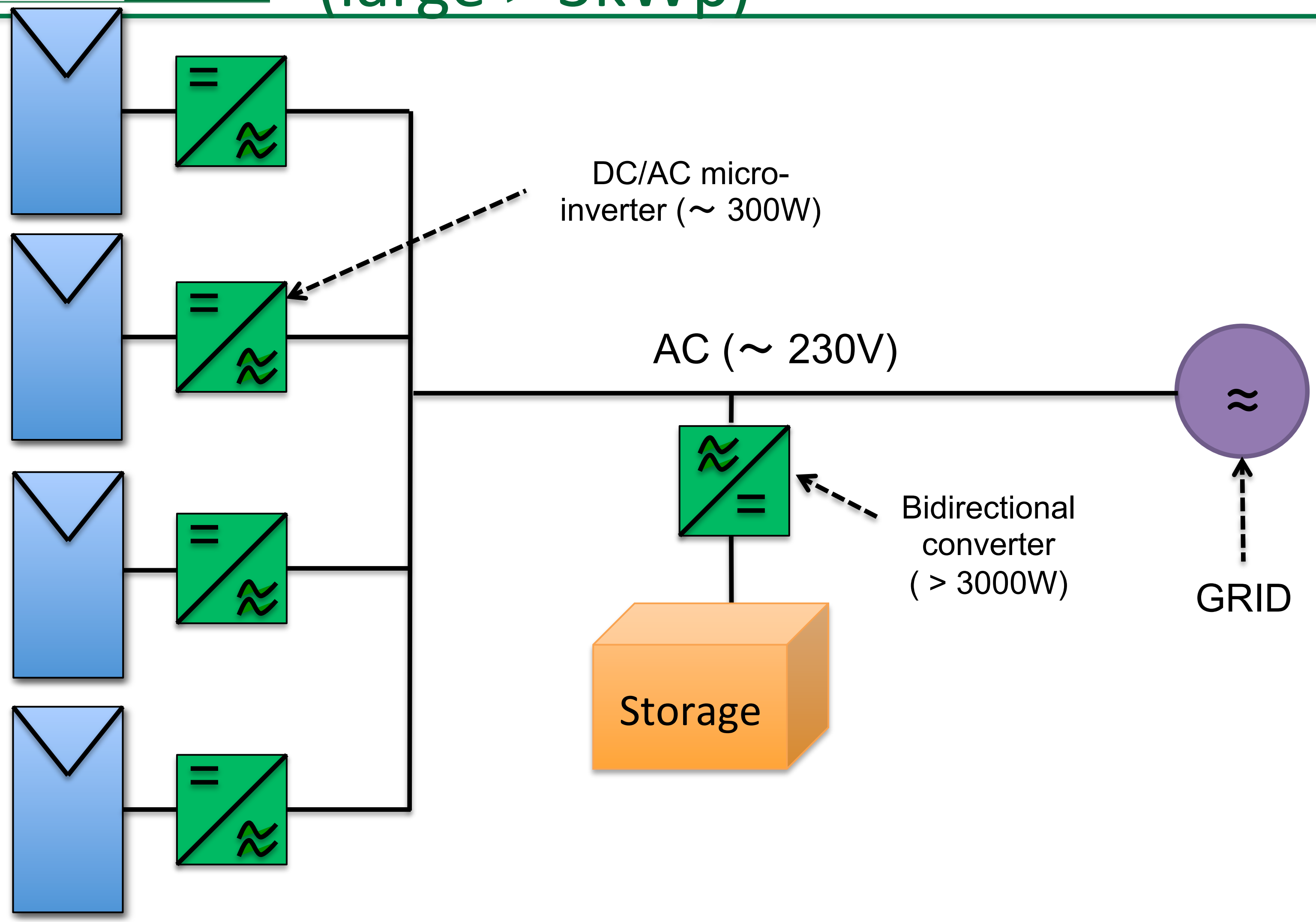
=> can recover up to 80 % of energy lost in substring

Critical: balance between
- additional complexity & cost
- enhanced energy yield

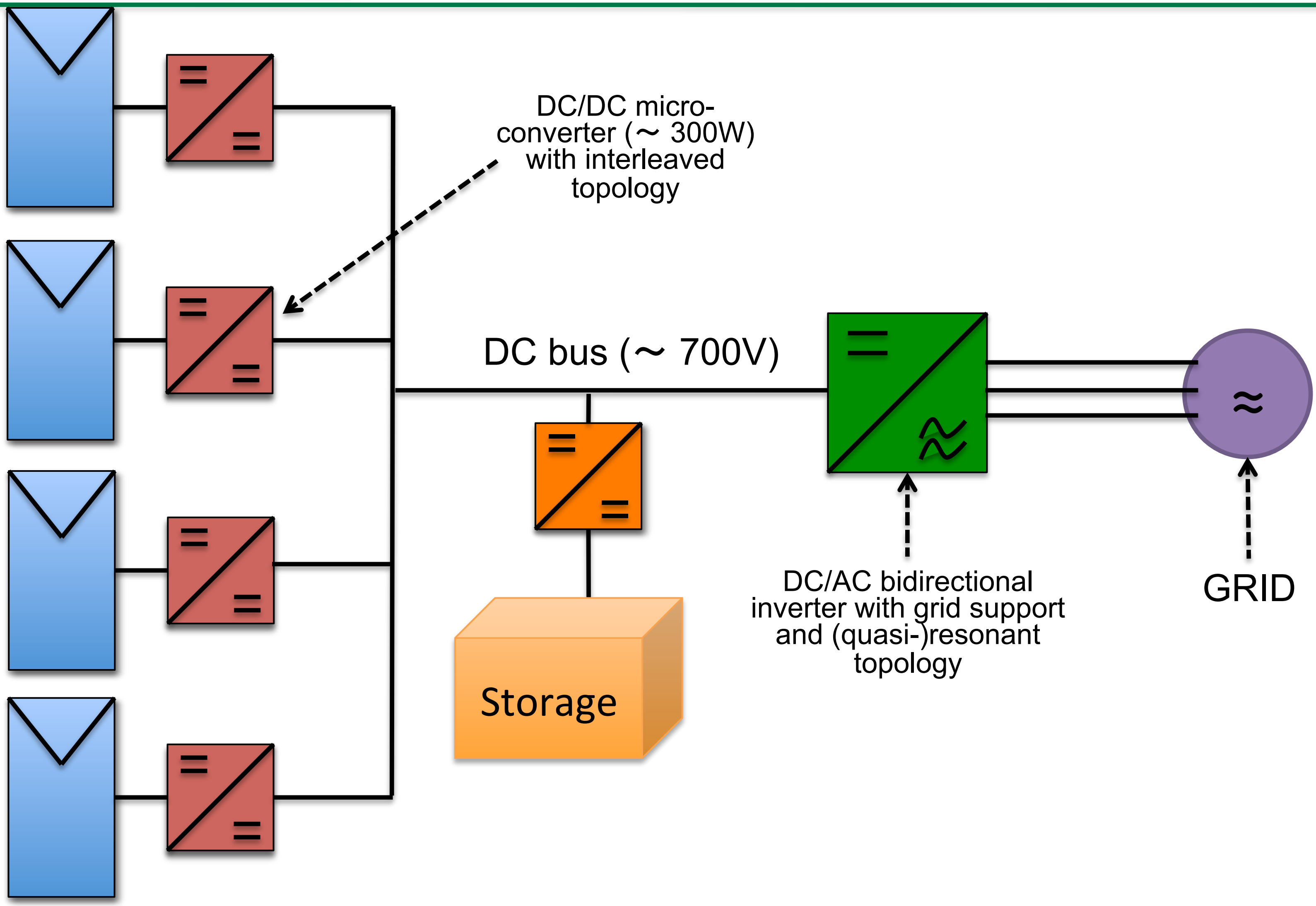
standard string inverter architecture (large > 3kWp)



AC micro-inverter based architecture (large > 3kWp)



DC micro-converter based architecture (large > 3kWp)



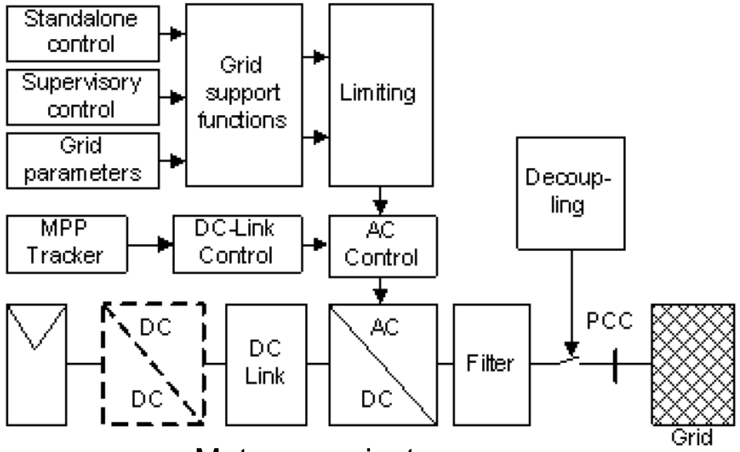
architectures comparison

(Full option : including storage, grid inverter with services)

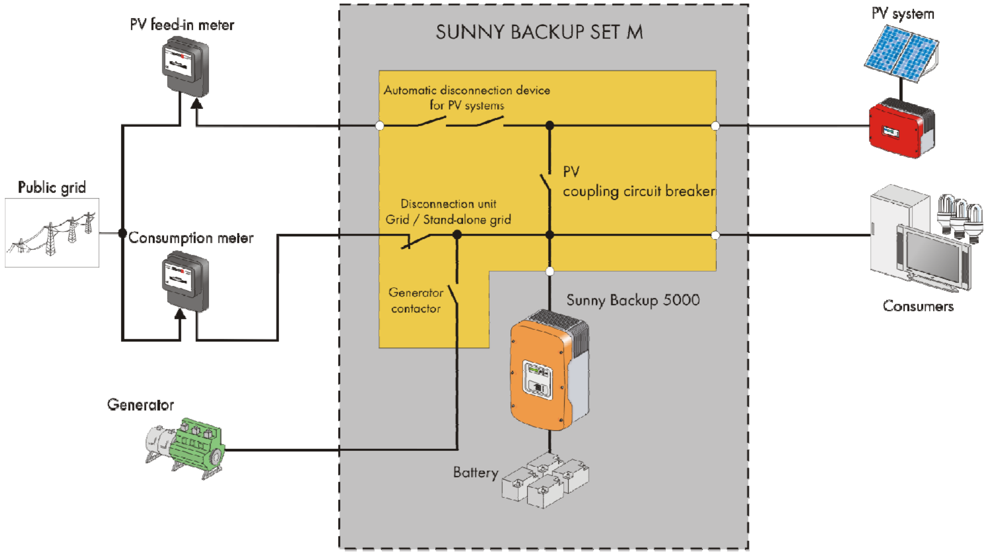
	Standard string inverter architecture	AC micro-inverter architecture	DC micro-converter architecture
Roof/facade ease of installation	--	++	++
Upgradeability	--	+	++
MPPT performance	-/--	+	++
Up-time	-	-/+	++
Monitoring and maintenance	-	++	++
Day->Night shift effectivity	-	+	++
Grid Voltage Services	-	--	++
Grid Reserve Services	-	--	++
Purchase cost	+	++	+

Grid & storage Inverters

- ## Grid Services
  - Reactive power control, Active power control
  - SMA; Danfoss; Power-One
- ## Storage
  - SMA Sunny Island
  - Nedap



Meta-pv project

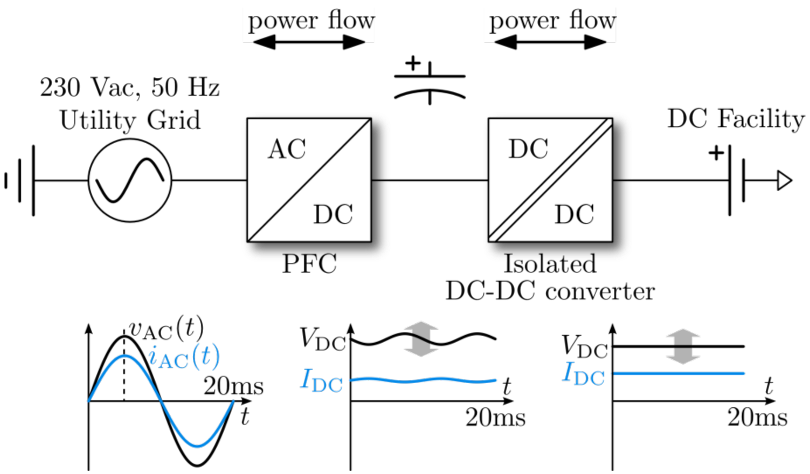


Grid-side converter

- needs to be "smart grid" compatible
  - ancillary services
    - voltage support
    - capable of offering reserves
  - blocking net feed-in
    - new grid codes (e.g. Germany)?
  - with communication interface for aggregator/DSO communication
- high-efficiency
- Increased compactness
- hard to implement in small 1-phase unit

Bidirectional Dual Active Bridge Inverter

Traditional: dual-stage



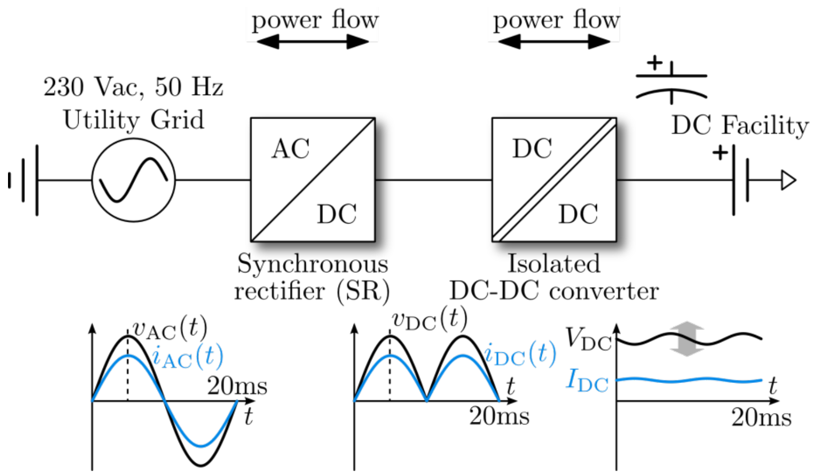
PFC

- Rectification + voltage boost
- Power factor correction (PFC)

Isolated DC-DC converter

- Galvanic isolation
- Output voltage regulation

This work: single-stage



SR

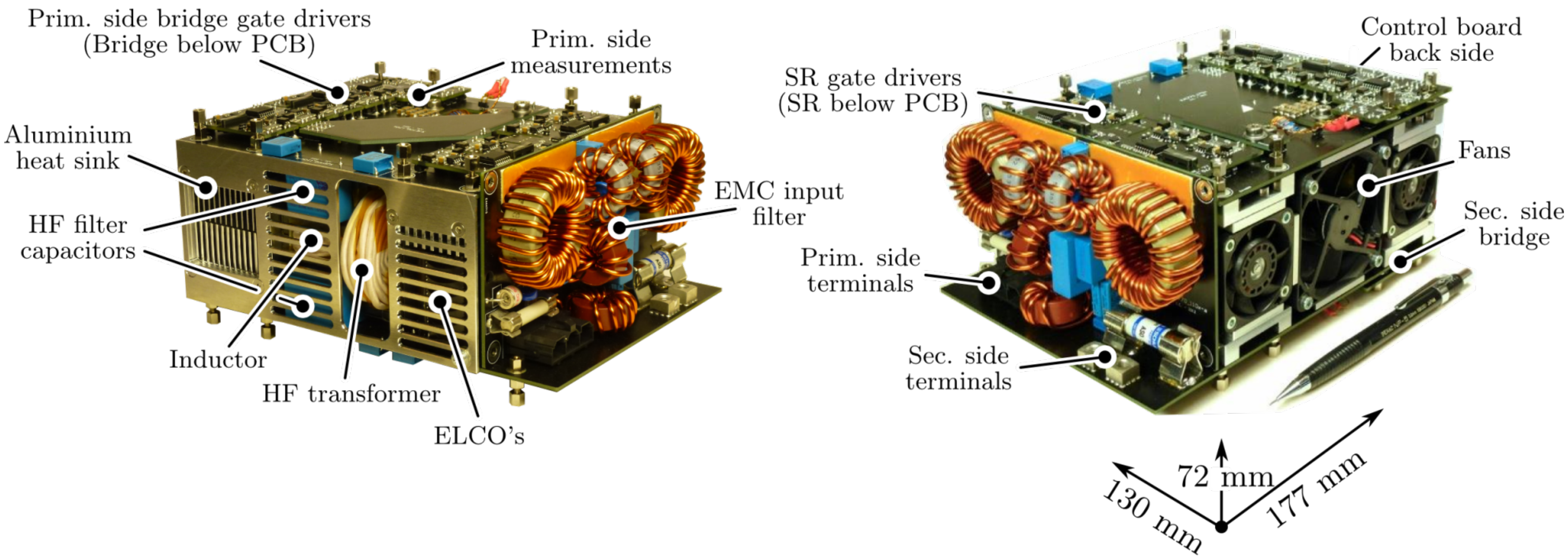
- Quasi lossless rectification
- Can be integrated

Isolated DC-DC converter

- Power factor correction (PFC)
- Galvanic isolation
- Output voltage regulation

Prototype

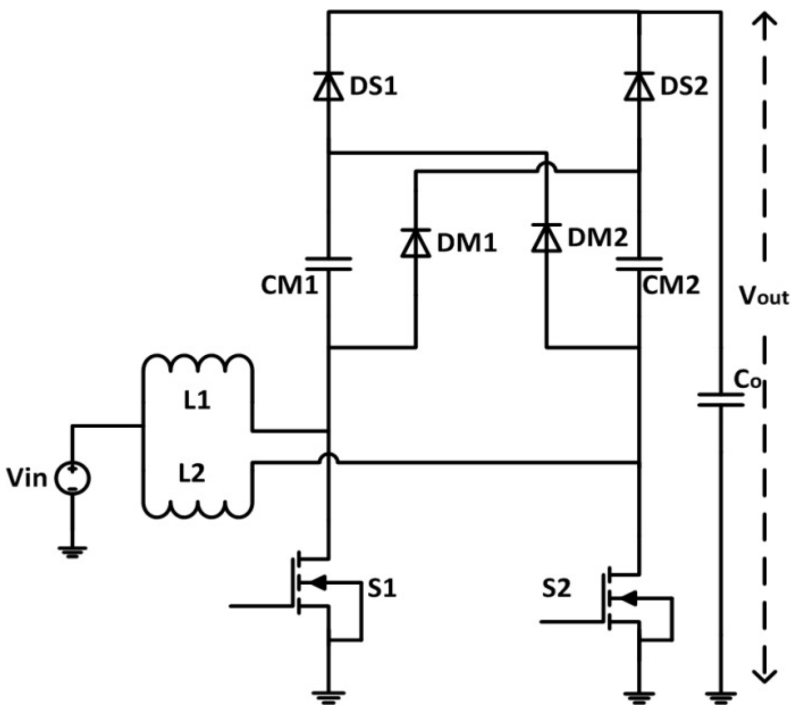
- DAB AC-DC converter prototype
- According to predefined specifications
- Recursive design procedure and MOO optimization



Design Requirement for Intra-module DC-DC Converter

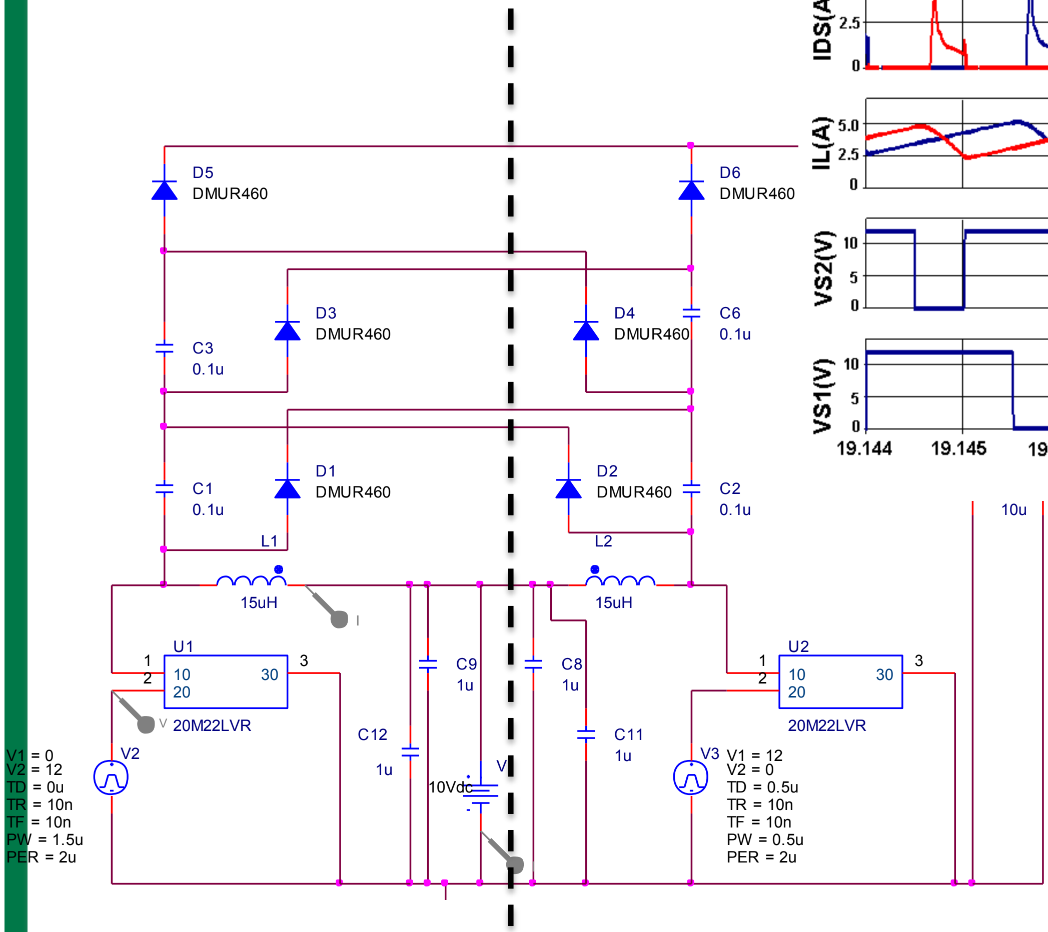
- Wide input voltage range to operate the converters dynamically, depending on the mismatches present.
- High voltage gain (>10) to boost till high output voltage to avoid several stages of power conversion before connecting to DC/AC inverter.
- High switching frequency to build compact (magnetics!) & cost effective converter to interface at string level
- Lower power rating to interface at string level
- Low output ripple to avoid MPPT fluctuation
- Higher efficiency
- Transformer less non-isolated converter to make compact and cost effective converter

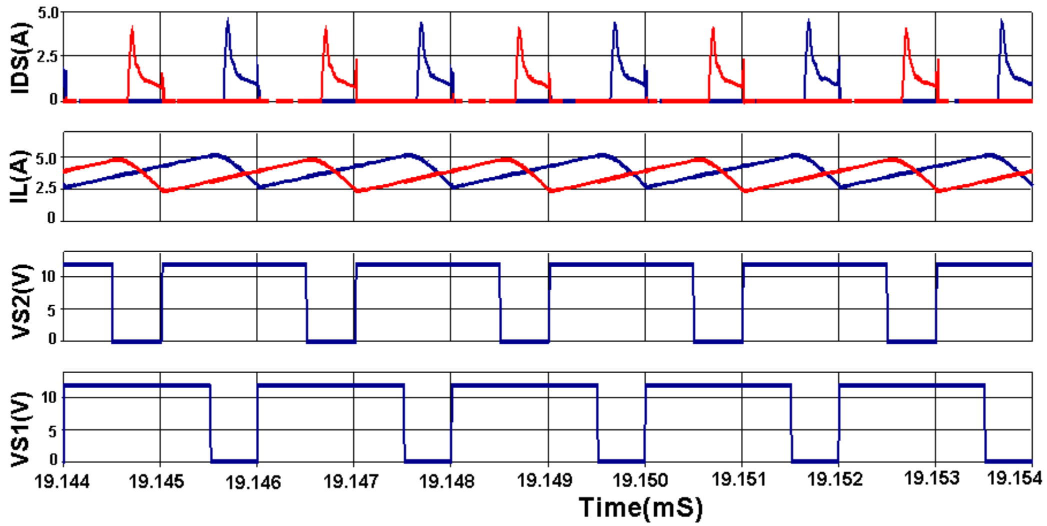
DC/DC Topology Selection

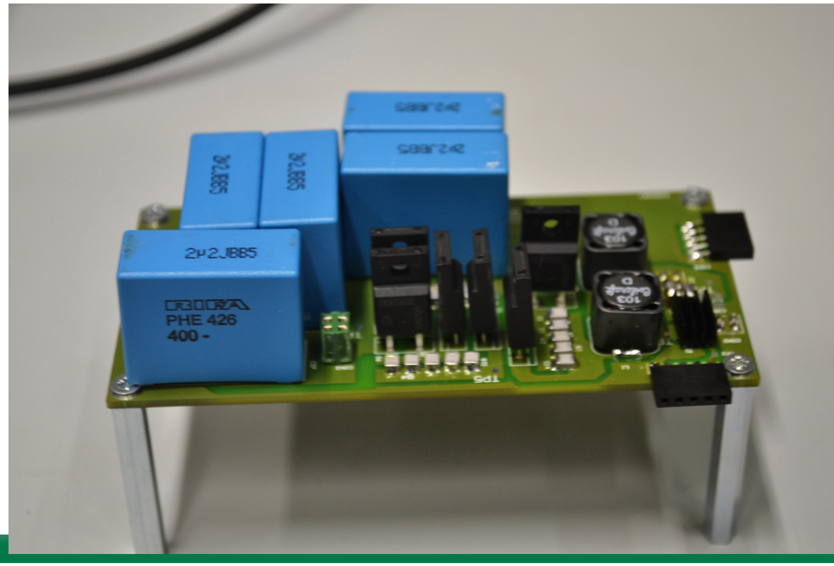


- Integrated multiplier capacitors in a classical boost converter for high gain. Simple topology
- Av = (M+1) / (1-D) ; M is no. of multiplier stage. Possible to achieve high gain without having high voltage stress
- Half of voltage stress across switches due to parallel connection of two switches, leads Lower conduction loss
- Reduce conduction loss due to parallel connection of multiplier diode
- Possible to achieve high efficiency
- Interleaved operation helps to achieve low input current ripple and lower current stress
- Lower ripple current for higher switching frequency operation
- Transformer less converter
- [currently in assessment]

DC/DC operation

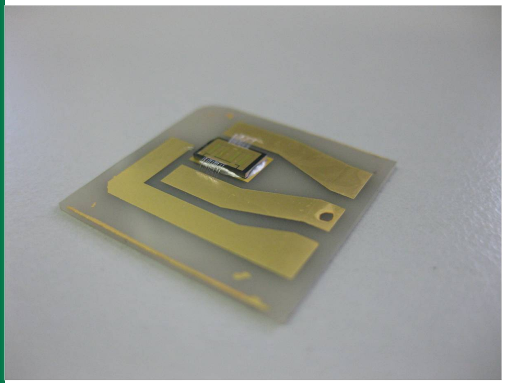






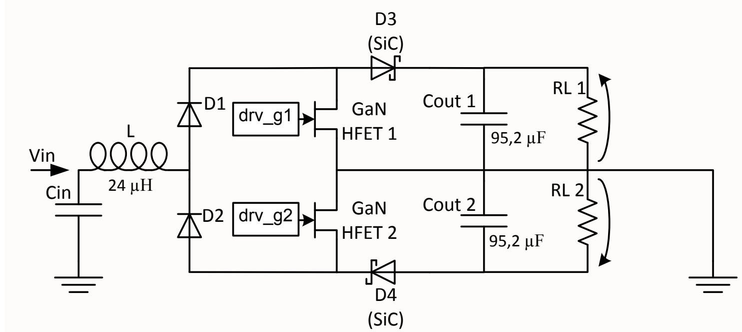
What components?

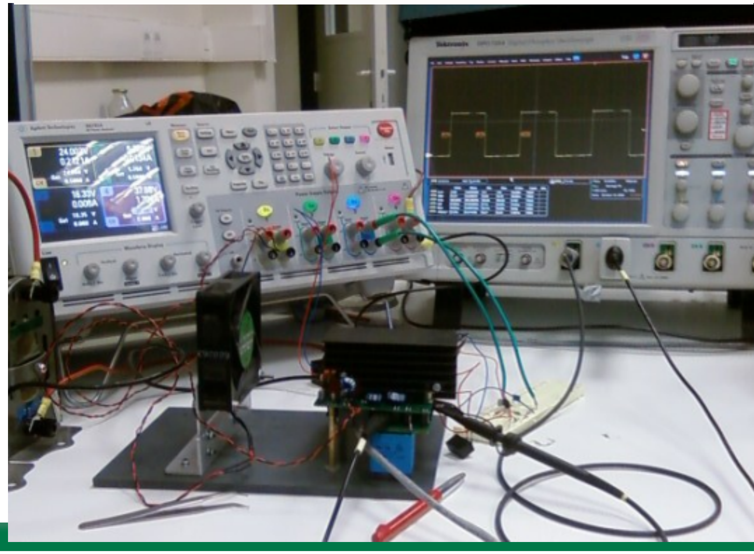
- Choice of
  - CoolMos
  - MultiJunction MOS (e.g. OnSemi)
  - GaN (Imec, EPC, OnSemi)
  - SiC (diodes only)



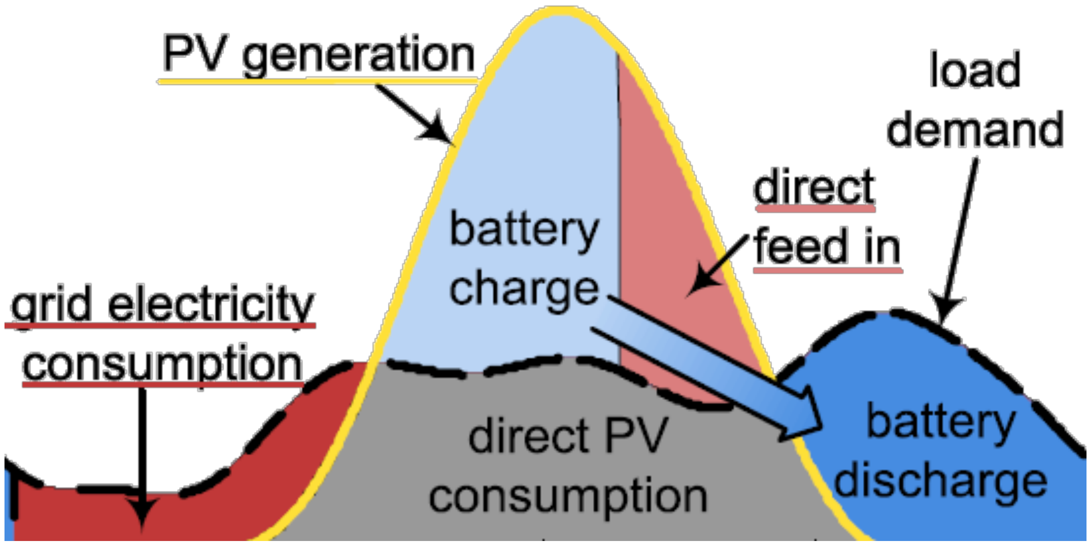
Patent: Voltage clamping circuit and use thereof US 20130049783 A1

- Component Characterisation
- VIENNA converter: two BOOST stages, driven separately





The main reason for storage in PV systems



- Peak shaving (grid support)
- Balancing
- Feed-in tariff
- Electricity cost
- Stand-alone operation

Current status

Residential energy storage

In Germany there are >35 suppliers of residential energy storage systems, offering about 100 different products





	IBC Solar	Conergy	Prosol Invest	Solarworld	Energy3000
Type	Li (LFP-LTO)	Li (NCA)	Li (LFP)	PbAc (gel)	PbAc
Efficiency	83%	92%	86%	94%	92%
Cost (€/kWh)	2900	3200	2100	1400	900
Lifetime (y)	20	20	25	13	7-10

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