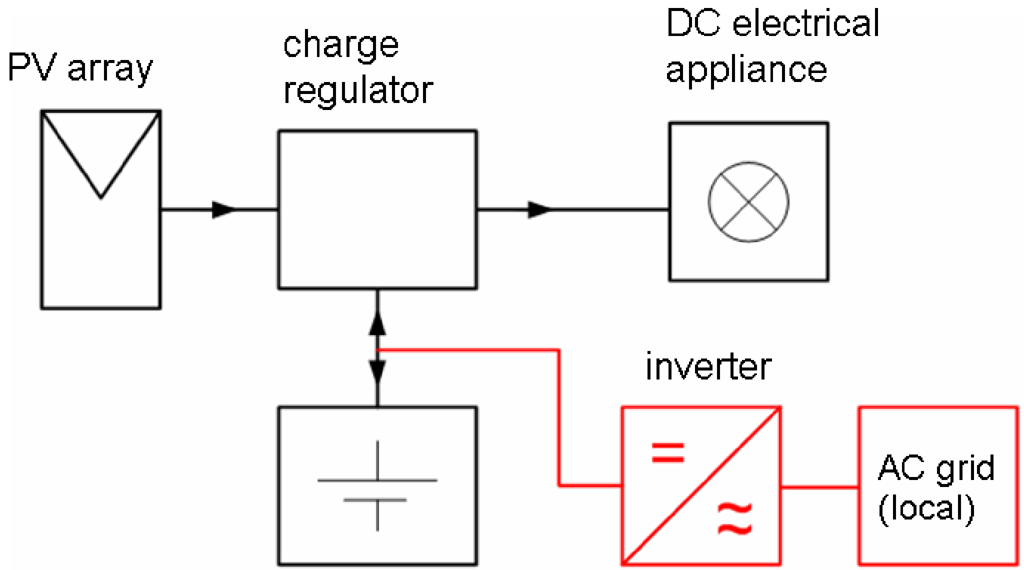
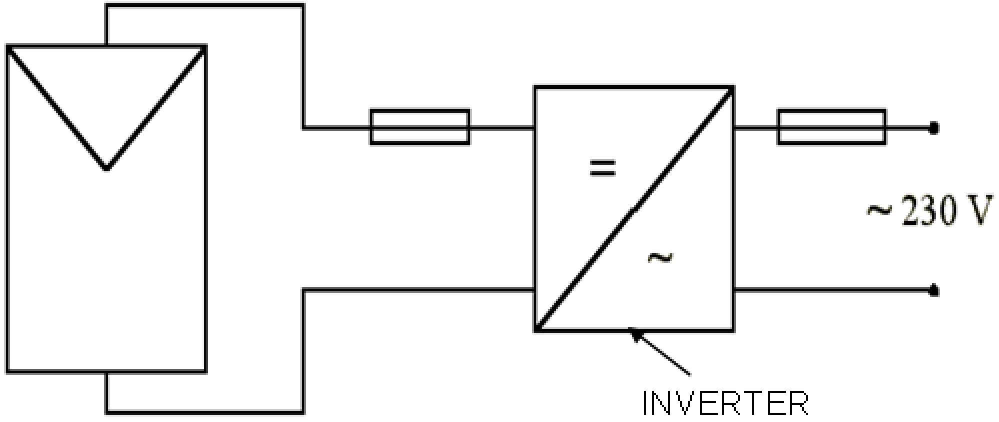
Grid-on PV systems

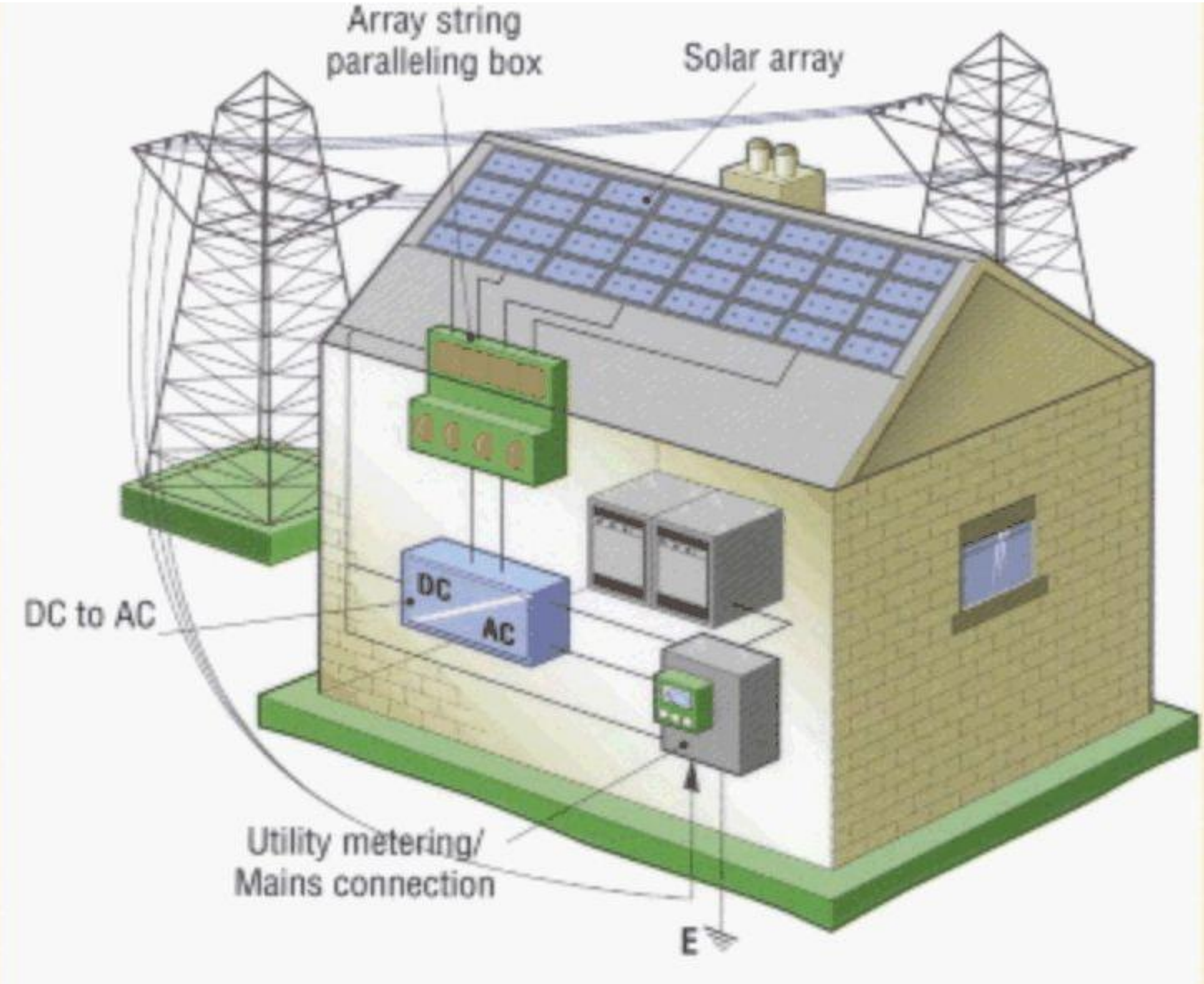
Autonomous systems



Grid-on photovoltaic systems



No energy storage

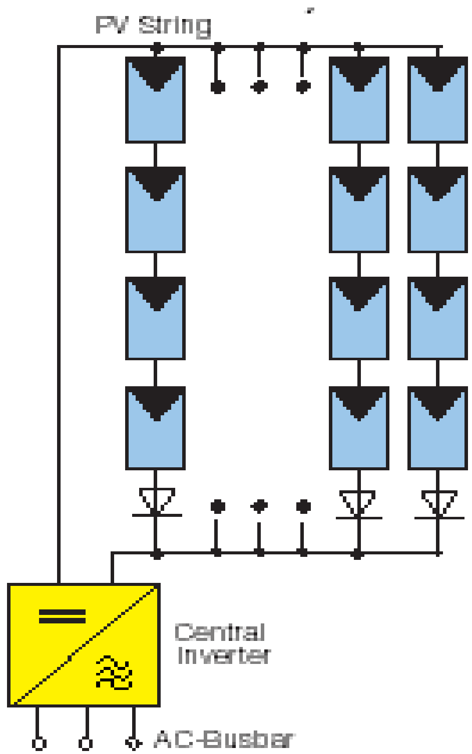


Array string
paralleling box
Solar array
DC
AC
DC to AC
Utility metering/
Mains connection
E

Solar City - Amersfoort

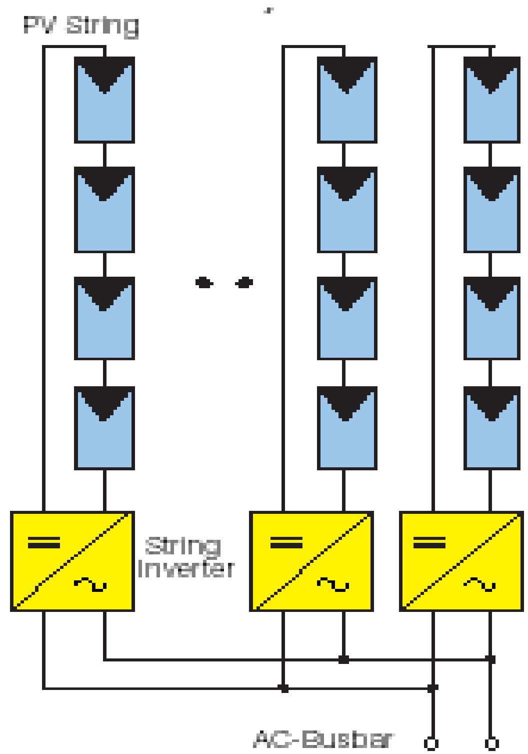
600 kW_p PV power station Bušanovice

35 MW_p power station in Veprek (20 km from Prague)



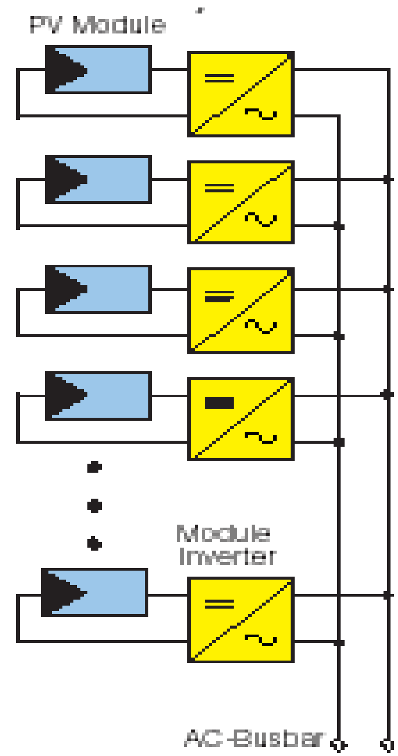
Central inverters

- 10 kW-250kW, three-phase, several strings in parallel
- high efficiency, low cost, low reliability, not optimal MPPT
- Used for power plants



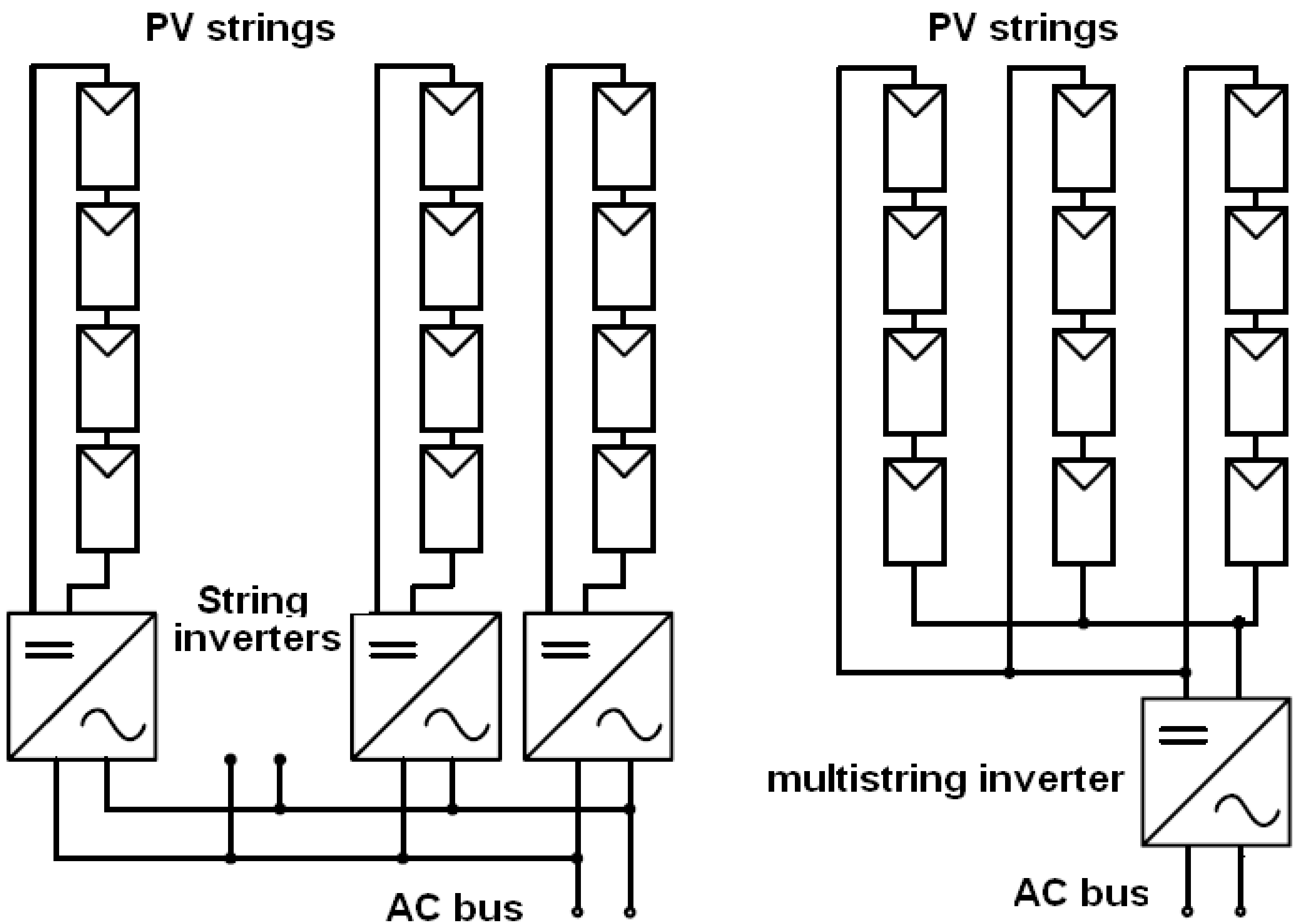
String inverters

- 1.5 - 5 kW, typical residential application
- each string has its own inverter enabling better MPPT
- the strings can have different orientations
- Three-phase inverters for power < 5kW



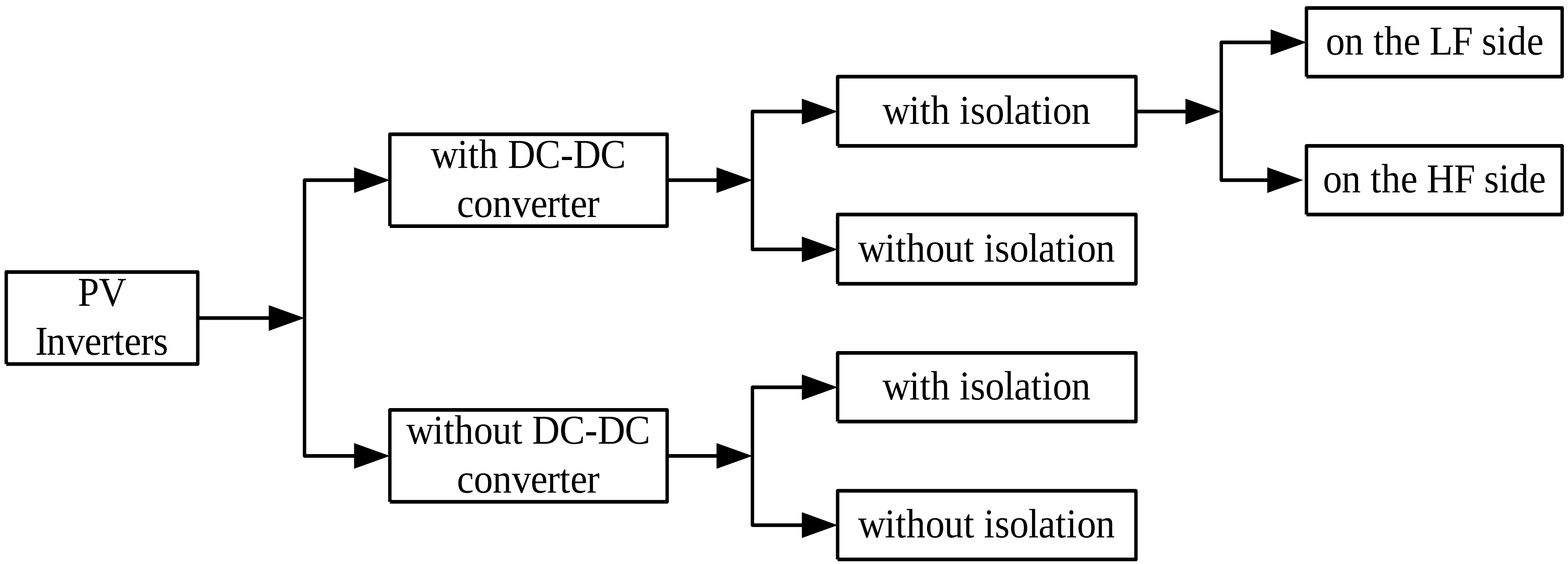
Module inverters

- 50-180W, each panel has its own inverter enabling optimal MPPT
- lower efficiency, difficult maintenance
- highercost/kWp



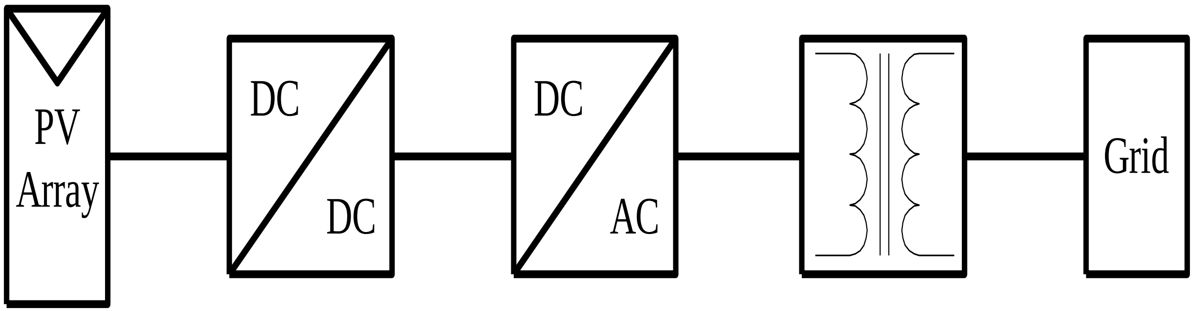
5 – 20 kW, high efficiency

Converter topologies for PV inverters

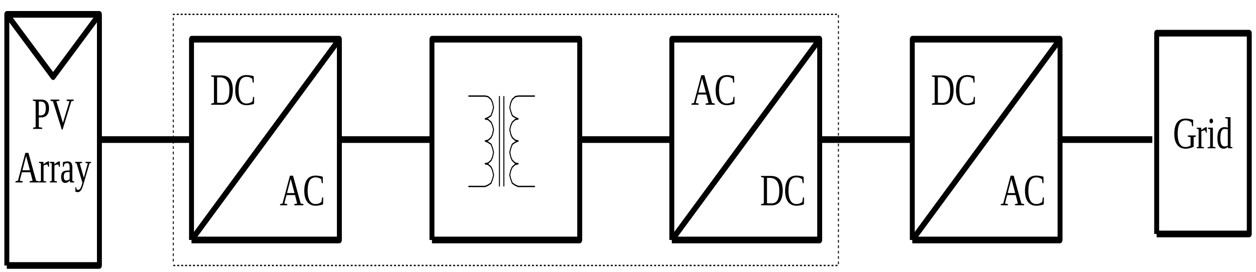


- Without boost / with boost of dc voltage
- Galvanic isolation necessary some places
- LF/HF transformer (cost-volume issue)
- A large variety of possibilities
- The optimal topology is not matured yet as for drives
- Transformerless topologies having higher efficiency are emerging

PV inverters with dc-dc converter and isolation



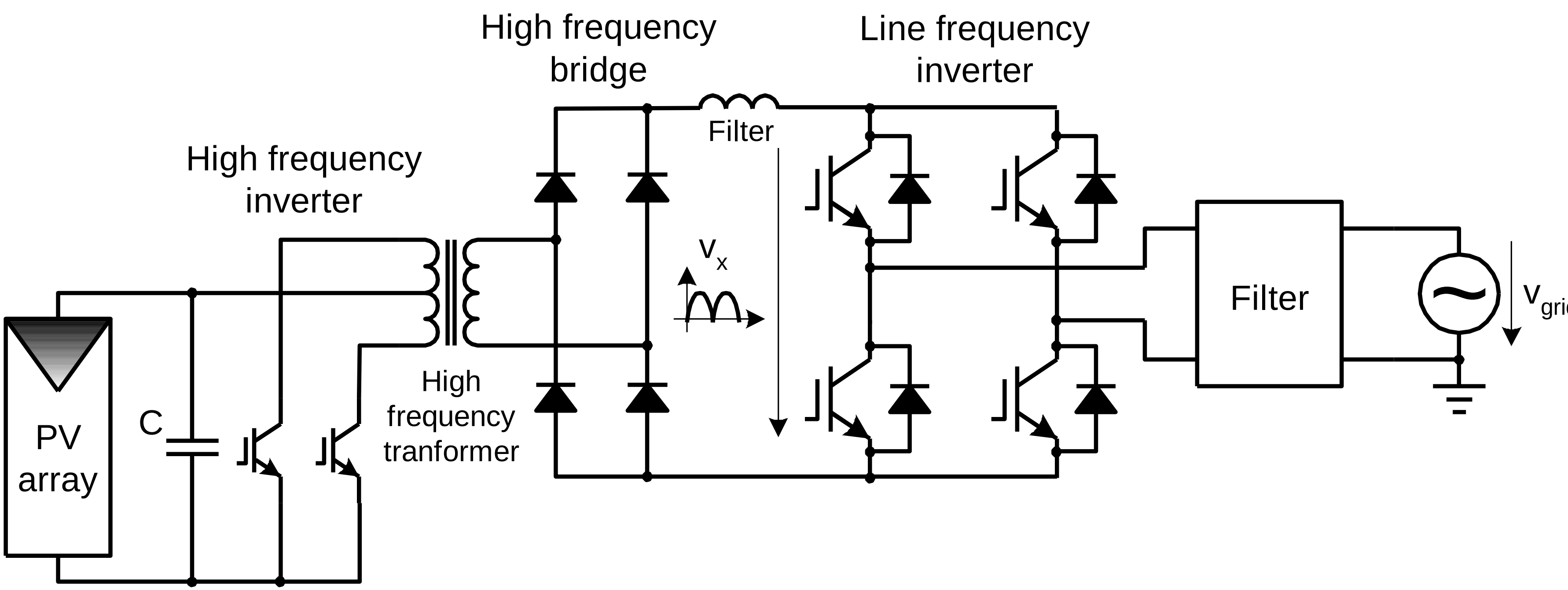
On low frequency (LF) side



On high frequency (HF) side

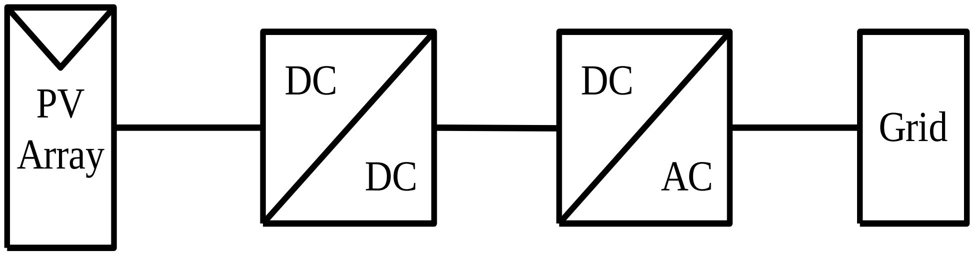
The HF transformer leads to more compact solution but complex design

PV inverters with dc-dc converter and isolation

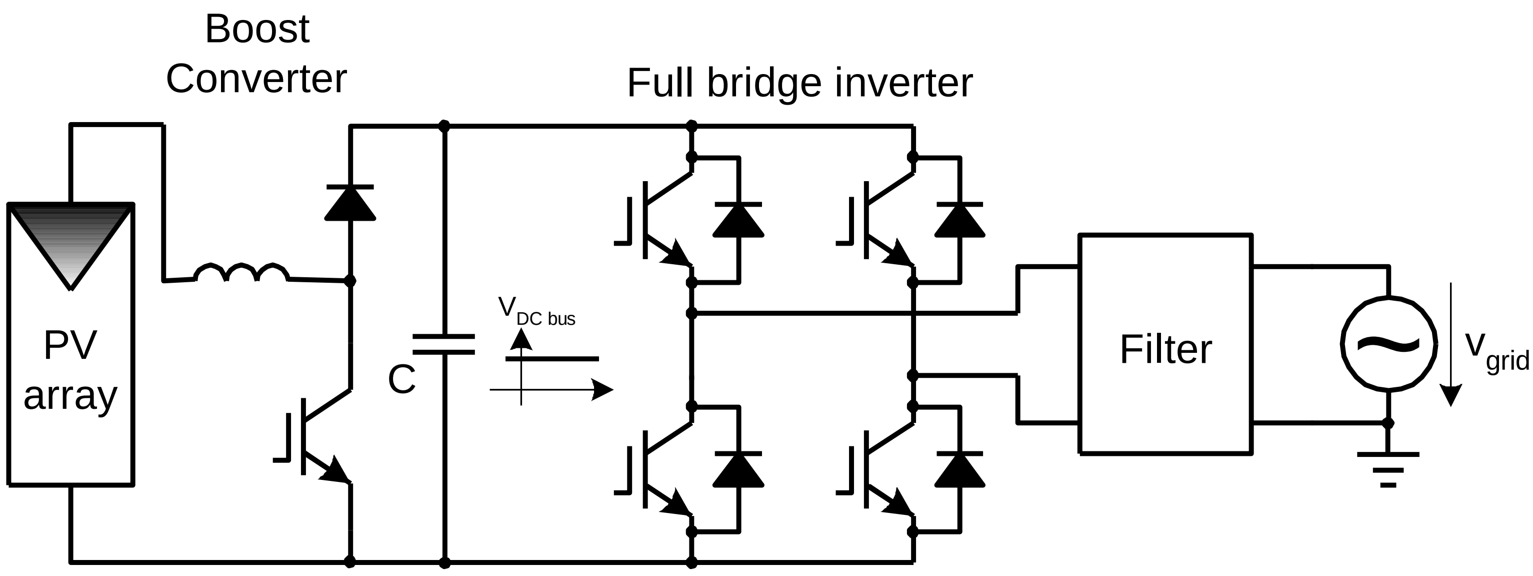


Typical solution with push-pull dc-dc converter with HF transformer and PWM full-bridge inverter with filter (LCL, LC,L)

Transformerless PV inverters with boost

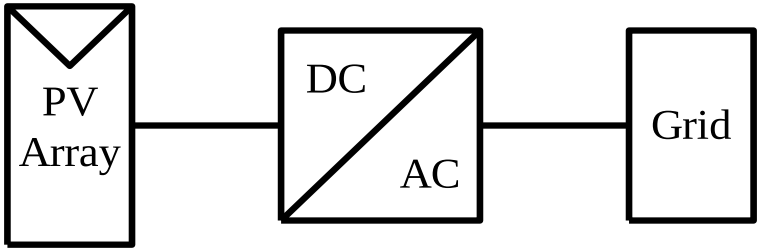


- Compact design
- Leakage current problem
- Safety issue

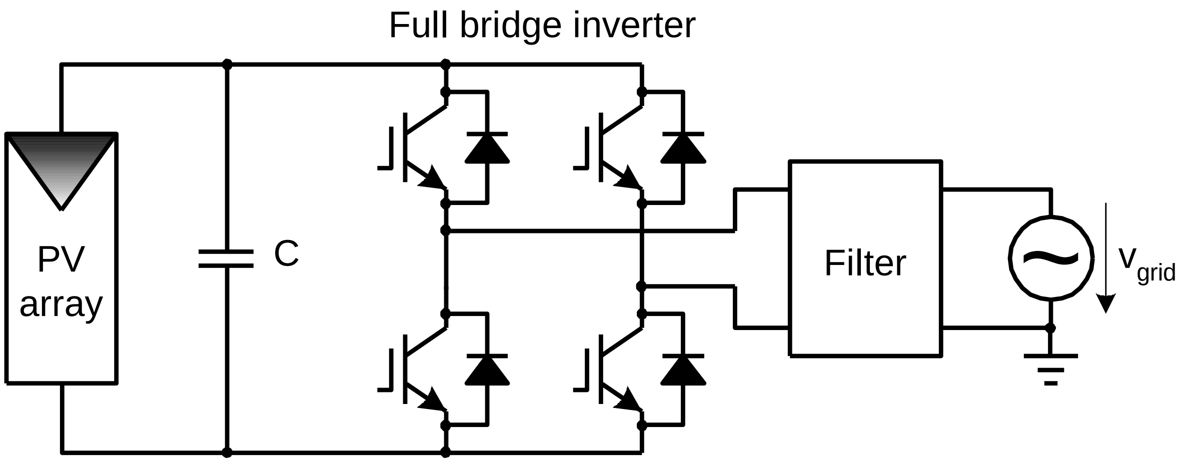


- Boost converter, full-bridge PWM inverter, grid filter

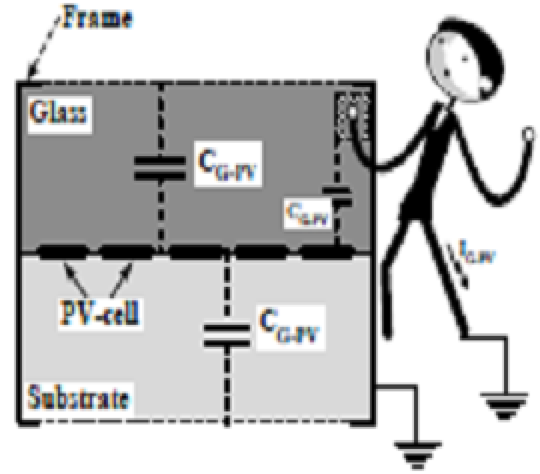
Transformerless PV inverters without boost



Typical solution with full-bridge inverter



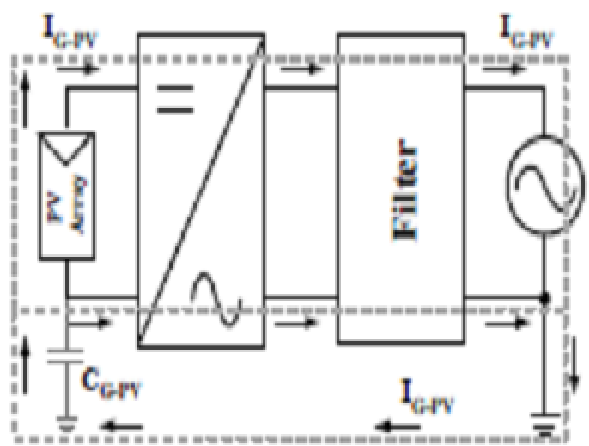
Parasitic capacitance of the PV array



- PV array has large surface
- Parasitic capacitance formed between grounded frame and PV cells
- Its value depends on the:
  - Surface of the PV array and grounded frame
  - Distance of PV cell to the module
  - Atmospheric conditions and dust which can increase the electrical conductivity of the panel's surface

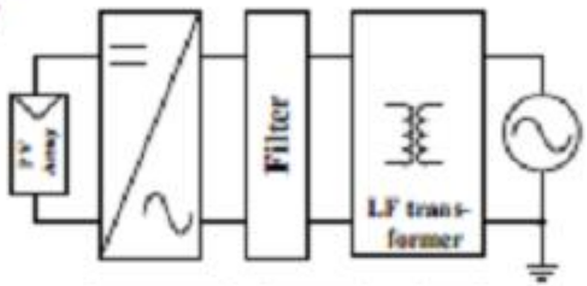
Leakage current

- Charging and discharging this capacitance leads to ground leakage currents (unsafe for human interaction; damage PV panels)
- Amplitude of leakage current depends on
  - Value of parasitic capacitance
  - Amplitude and frequency of imposed voltage
- RCM (Residual Current Monitoring) unit for monitoring leakage ground currents



With transformer

▼



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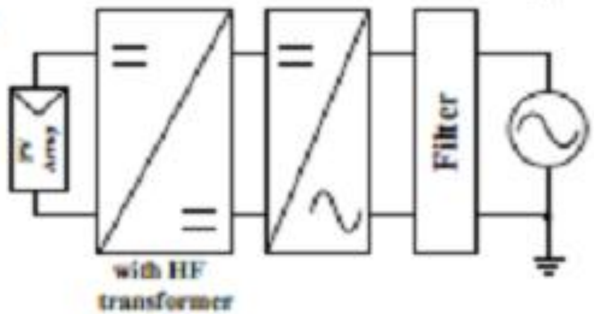
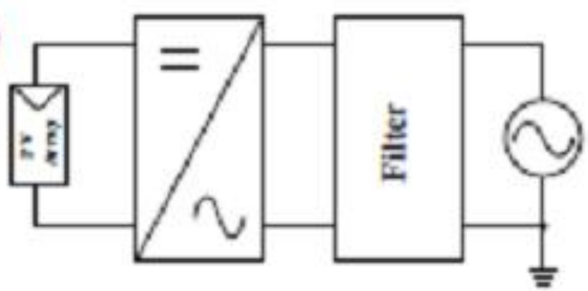
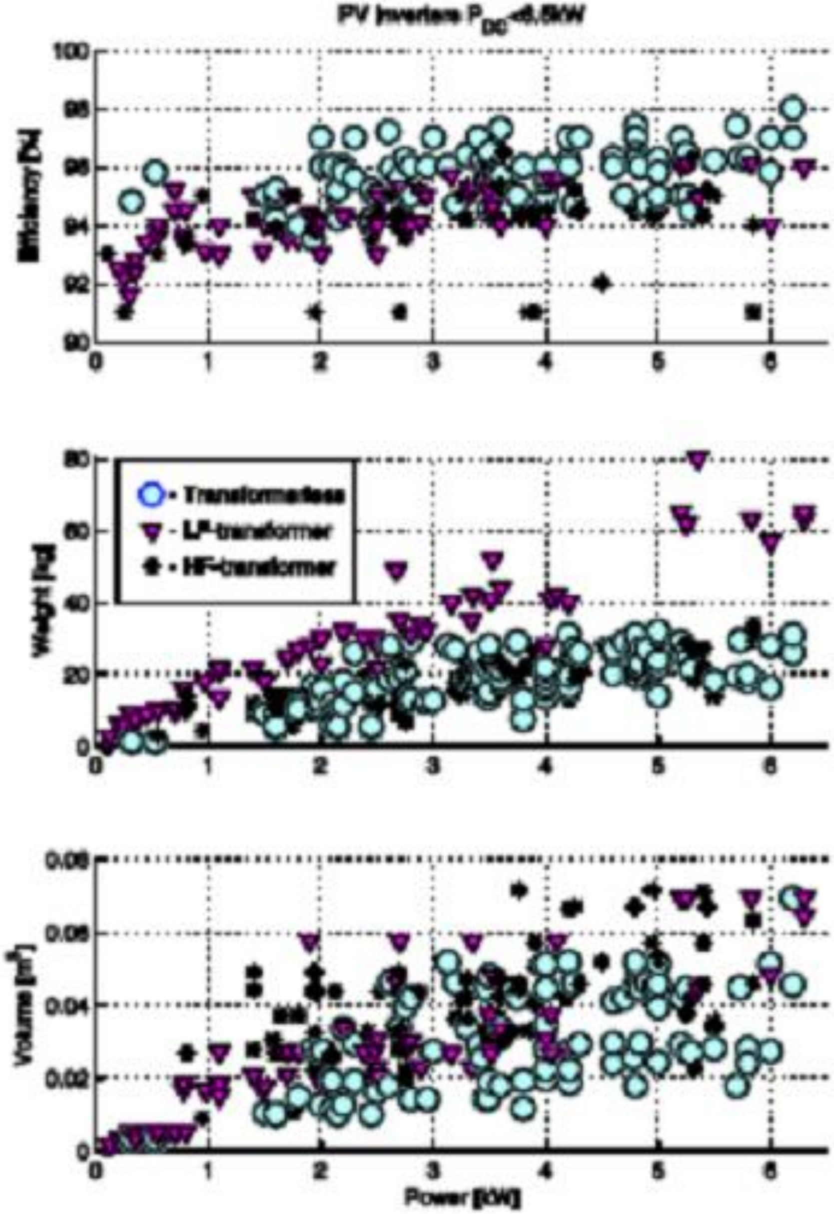


Without transformer

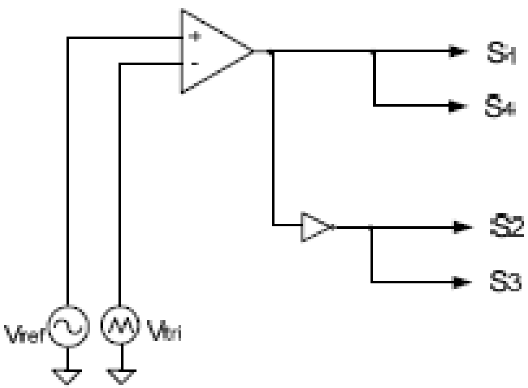
●





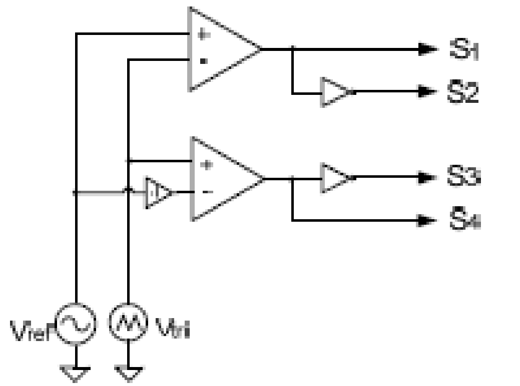
Bipolar PWM

S1 + S4 and S2 + S3 are switched complementary at high frequency



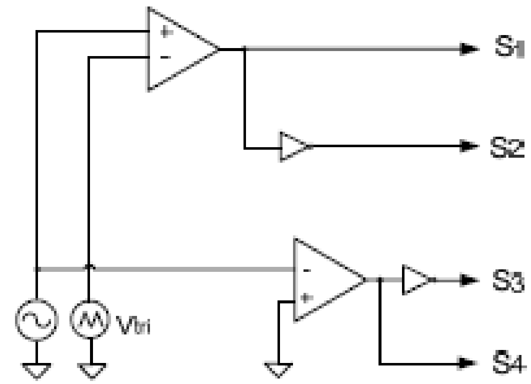
Unipolar PWM

Leg A and B are switched with high frequency with mirrored sinusoidal ref.

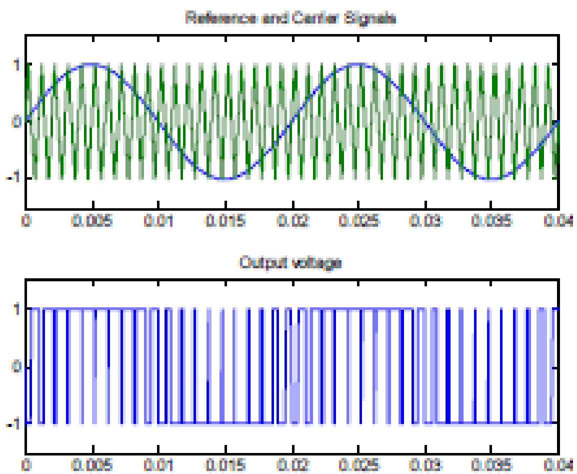


Hybrid PWM

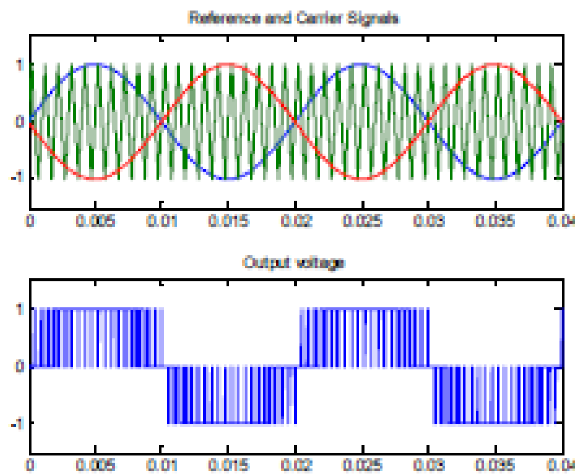
Leg A is switched with high frequency and Leg B is switched with grid frequency



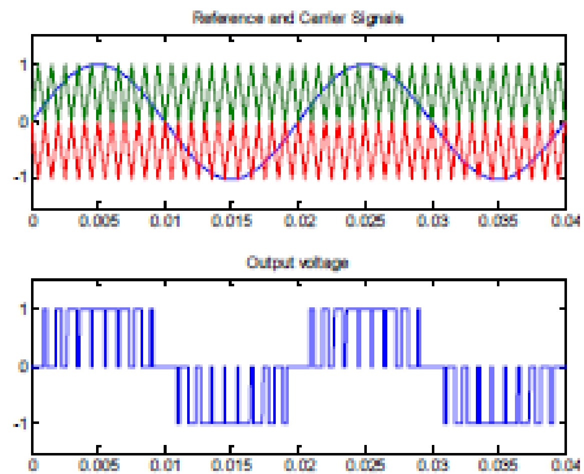
Bipolar PWM



Unipolar PWM

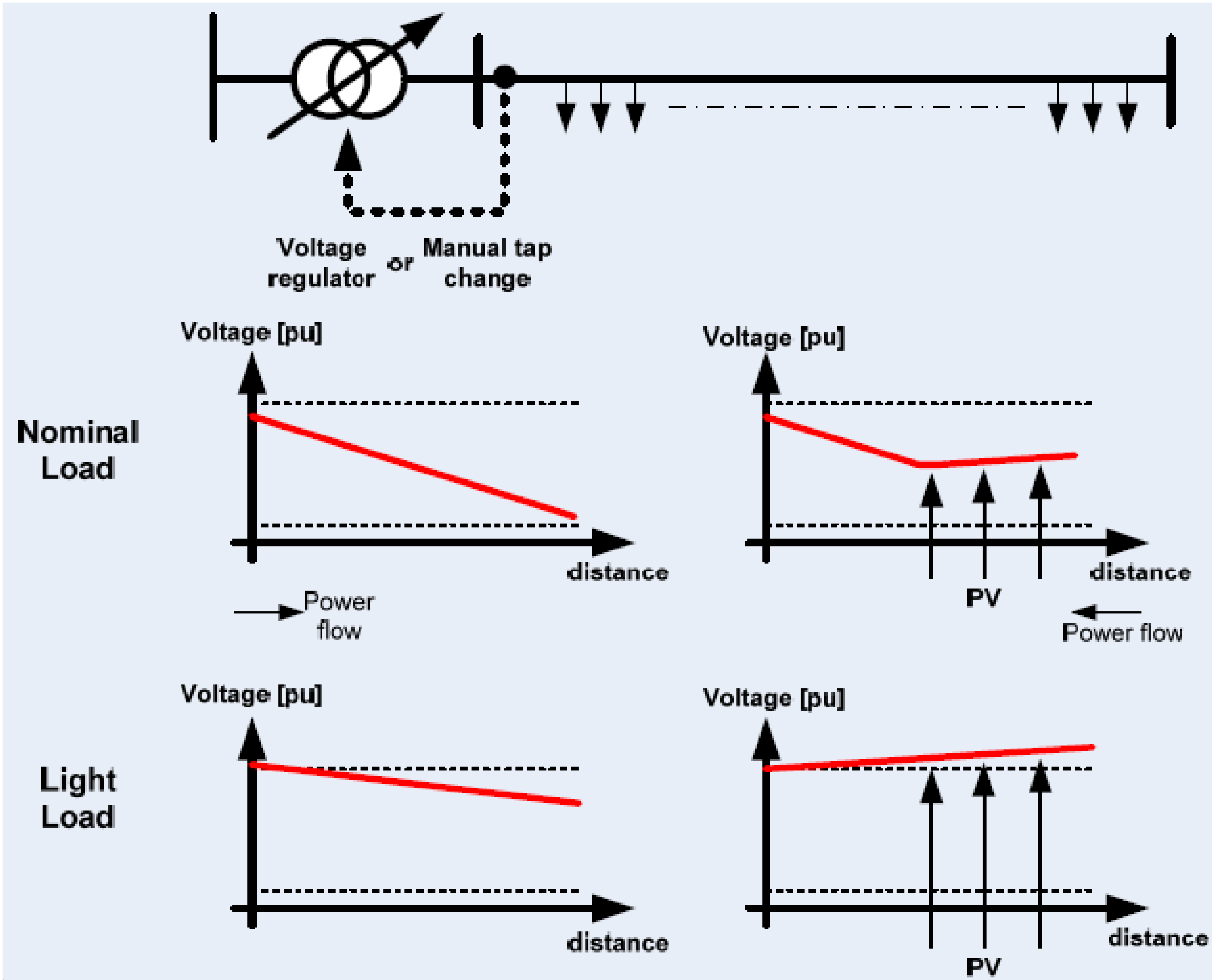


Hybrid PWM

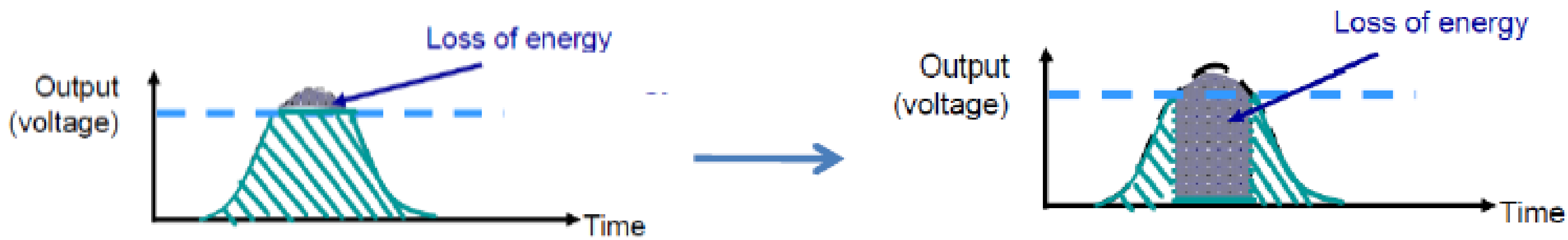


1kHz triangular wave and 50Hz sinusoidal reference

The increasing use of PV systems modifies the voltage profile along the power lines.



Power curtailment → **Inverter trip**



Charging excessive power into battery during overvoltage