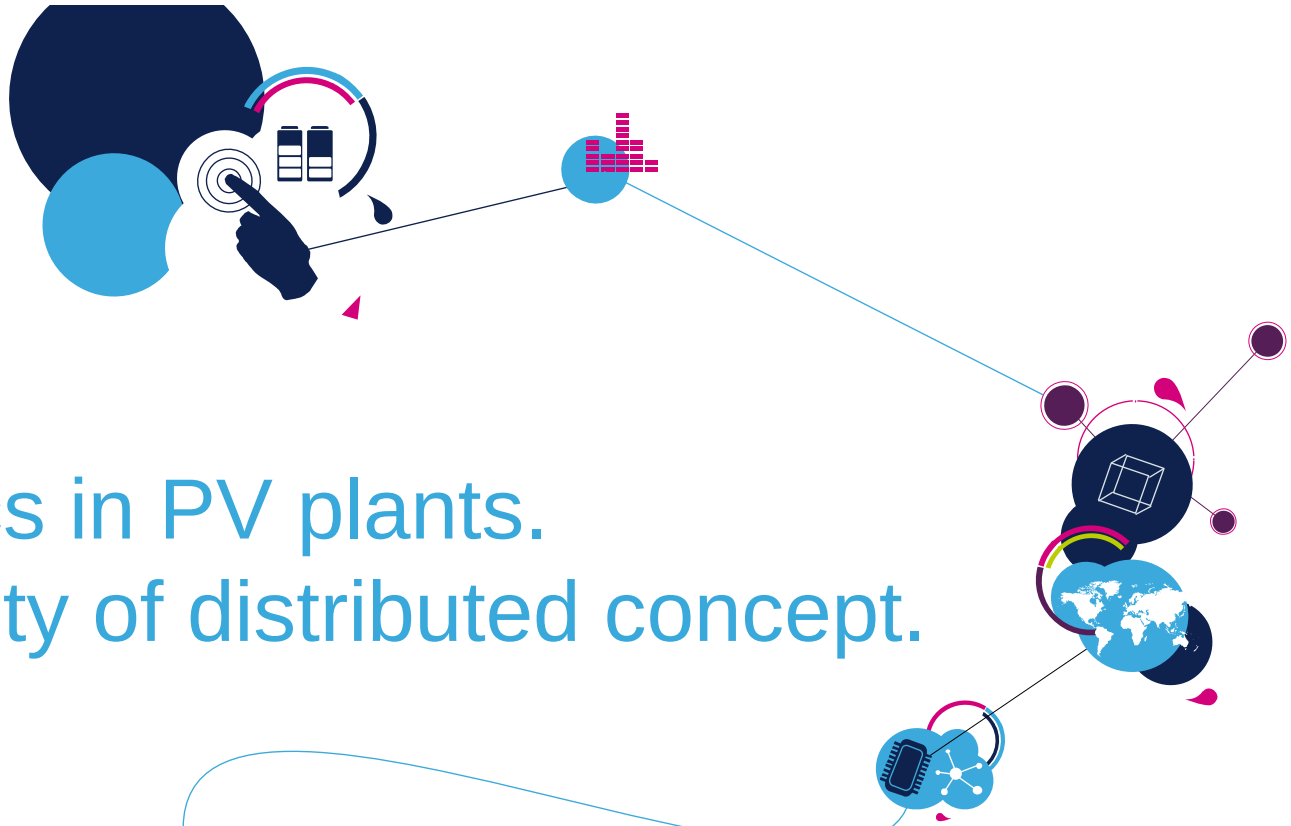


Electronics in PV plants.
Opportunity of distributed concept.

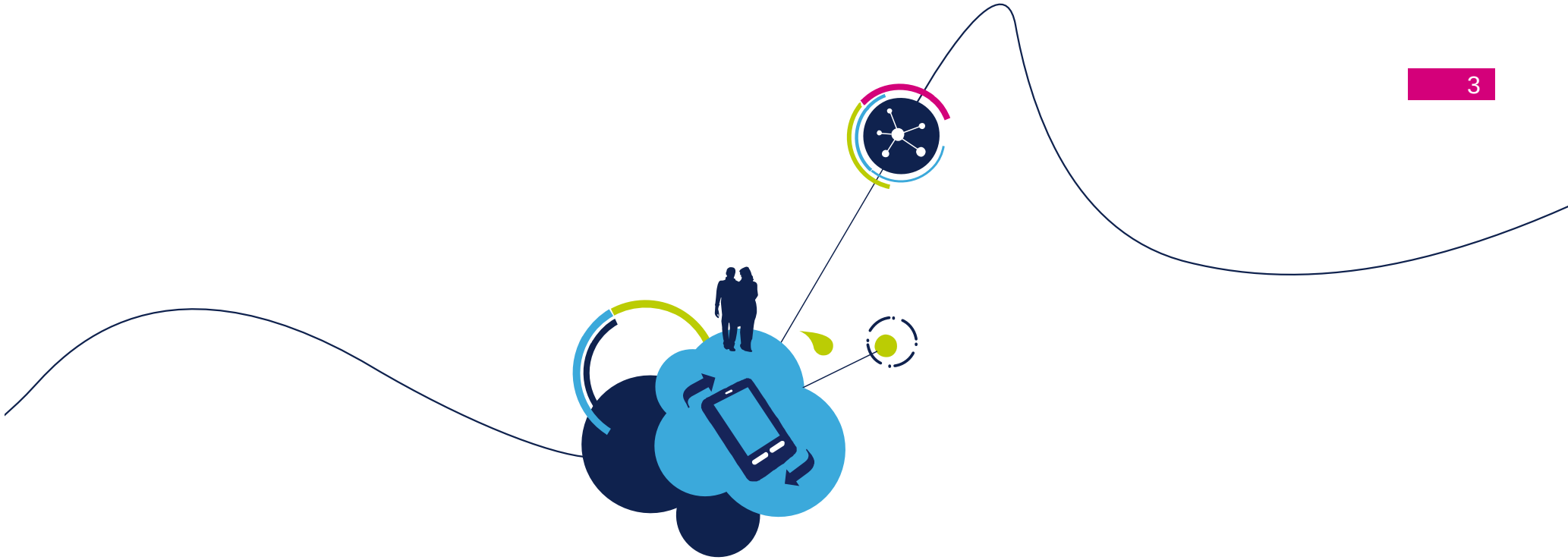
AEIT, Catania 15-05-2014

Natale Aiello
Power Conversion Applications Director

life.augmented

Summary

- General overview
- Distributed concept
- Parallel Approach
- Safety in PV installations
- Conclusion



PV Installation Overview

life.augmented

PV Panels Technologies

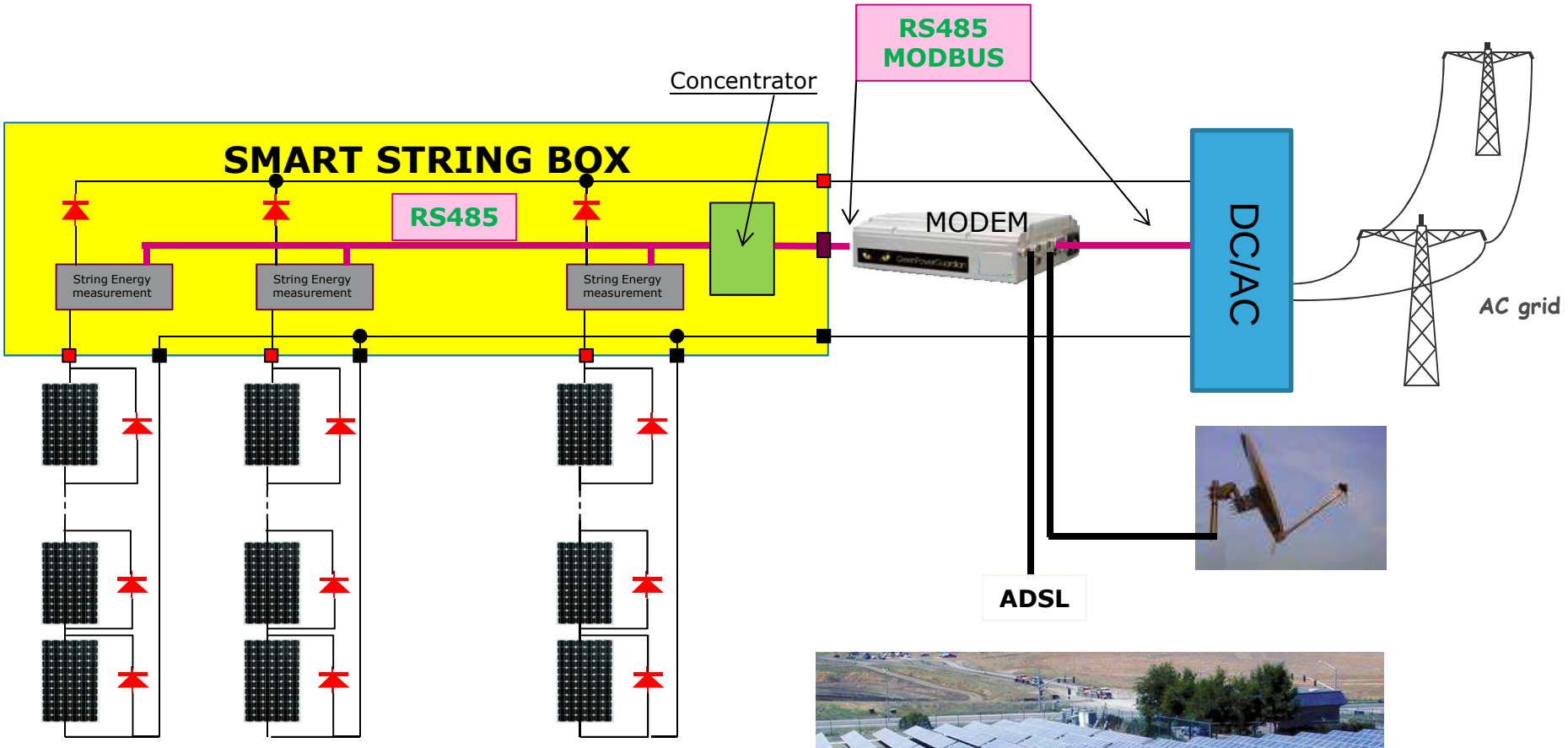
- The main technologies in for PV panel are:
  - **Single** and **Multi crystalline** silicon
  - **Thin-Film**
- The differences are in the output power and in the electrical parameters

Single/Multi crystalline:
- Typically 60 o 72 cells put in series with three by-pass diodes.
- Pout≈230W for 60 cells, 280W for 72
- Isc≈8A
- Voc≈40V for 60 cells, 45 for 72

Thin-Film:
- Typically one or two by-pass diodes.
- Pout≈130W
- Isc≈2-3A
- Voc_{MAX}≈100V

life.augmented

Typical PV Plant Configuration



life.augmented

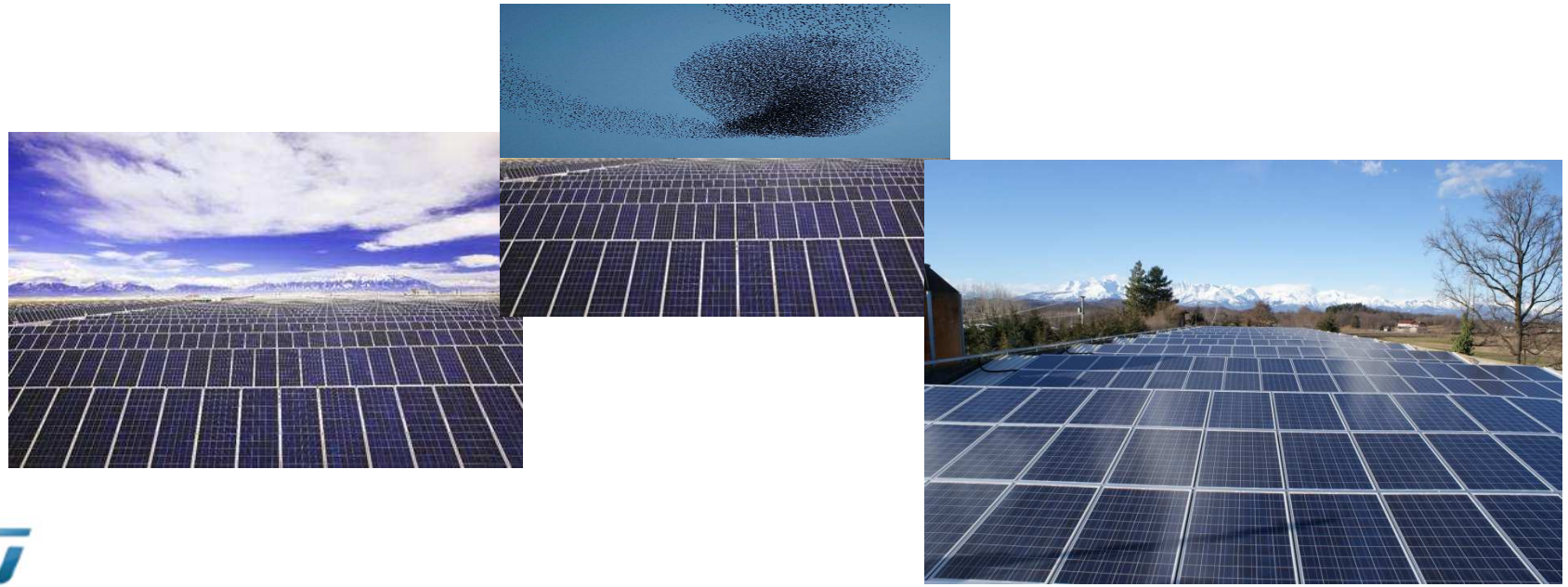
Limits of the present configuration

- The main improving areas for PV plants can be summarized in the following three items:

  - Definition of real amount of energy produced respect the “peak power” installed
  - Impact of the maintenance costs
  - Safety

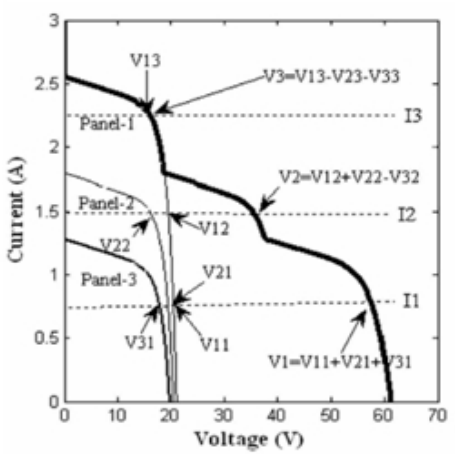
Energy production

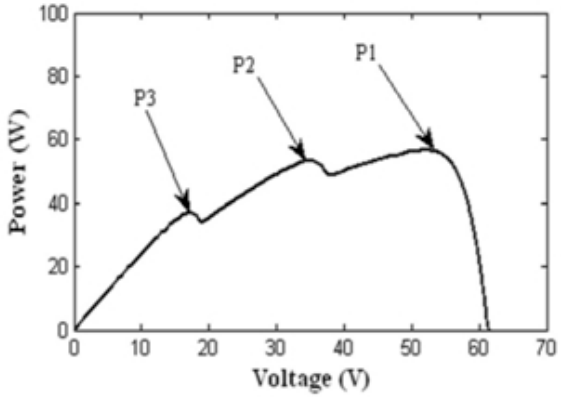
- The quantity of energy really produced by PV plant is strongly related to several, not controllable, events:
  - Environmental conditions. Situation like: cloudy, dust, leaf, flocks,….. are the main causes of partial or total panels shading.
  - Panels ageing.
- The impact is mainly on the panels/string mismatching.



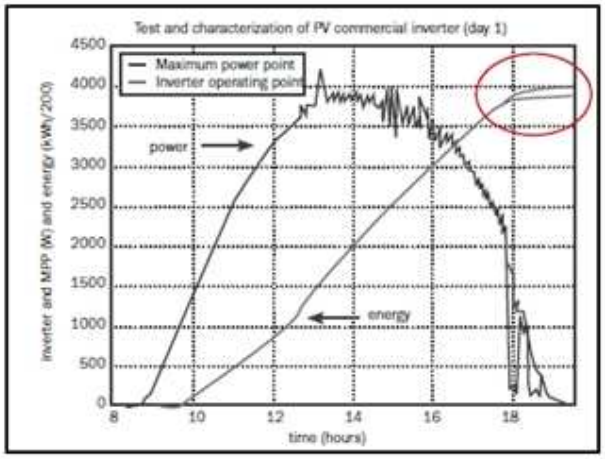
Impact on panel power curve

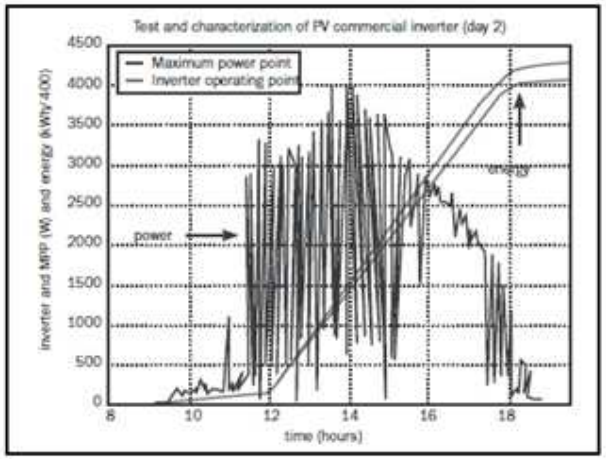
- The negative effect of the shades is not limited only to the panel with reduced sun irradiation but it impact also on the well radiated panels belonging to the same string or in strings connected to the same inverter input.





Three panels connected in series with different sunlight level





Energy obtained in:

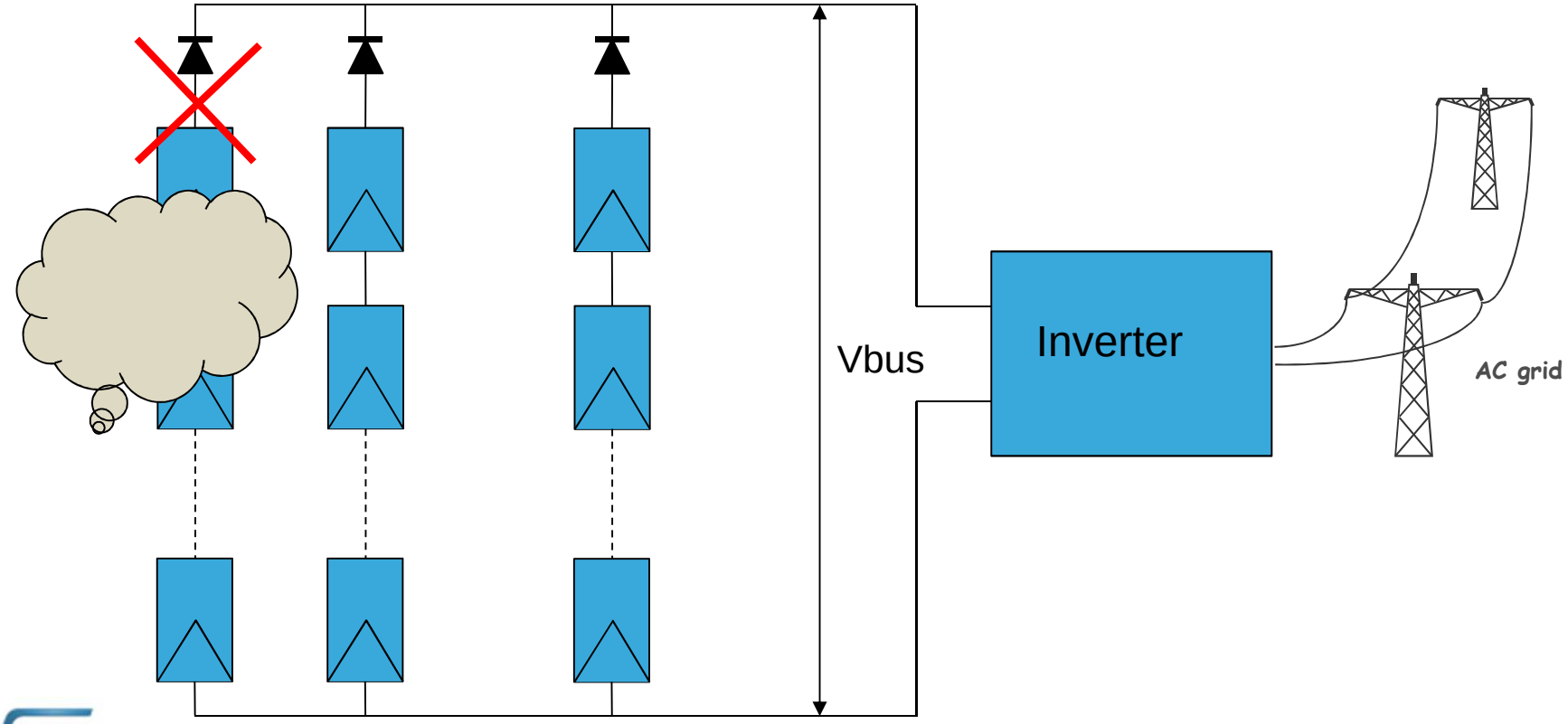
- first image, partial cloudy day,

- second image, high variable day

MPPT management

- Today these phenomenon are managed by the central inverter reducing the string bus voltage in order to maximize the total energy produced (central MPPT).

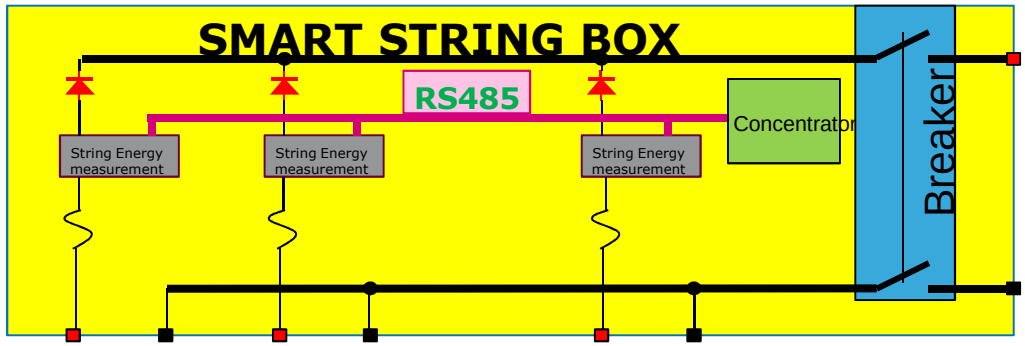
- This approach involve a lower energy harvesting because a modulation of bus voltage impact also on the strings properly working biasing them at not optimum power point.



Maintenance

- The main problems in PV plan maintenance is the panel fault individuation, in that cases infrared camera analysis is implemented in order to point out hot spots.

- Also the fuse substitution impact on systems maintenance costs.



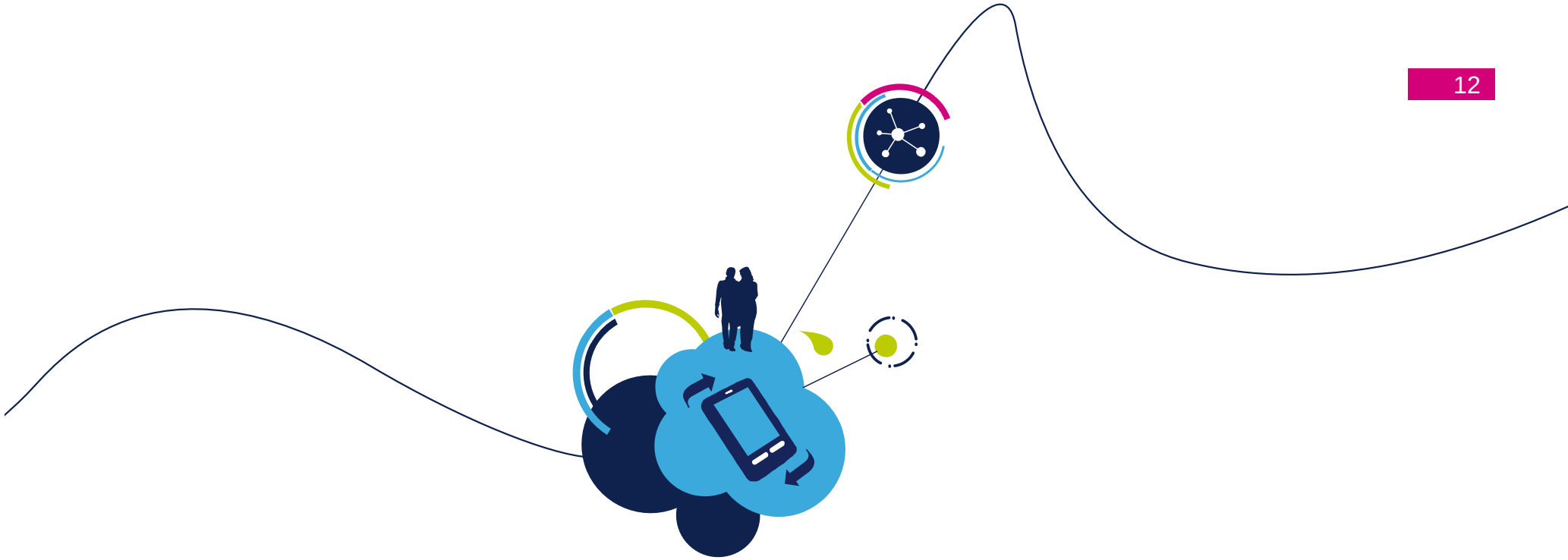
- The PV strings are connected in parallel inside the “String Connection Box”. The box can connect also 24 different strings.

- The main elements are:
  - **Block diodes**, they block the reverse current flux in case of string shaded presenting too low voltage respect the other ones, this to avoid reduction in not working panels life time. The trend is don’t put these low reliability devices accepting a reduction in energy production and managing extreme conditions by fuses.
  - **Fuses**, their task is to open the string in case of current exceeding 16-20A
  - **String energy measurement**, they are elements act to measure the string current and voltage transferring these data to a concentrator.

life.augmented

Safety

- In today installation it is not possible to disconnect the panel from the string in case of dangerous situations (fire, during maintenance or installation)
- In that case the string remain under voltage also in the inverter is switched off.
- This situation is particularly dangerous in case of fire with panels sunned.
- Panels theft is an other big issue, especially for grounded plants.



Distributed Concept

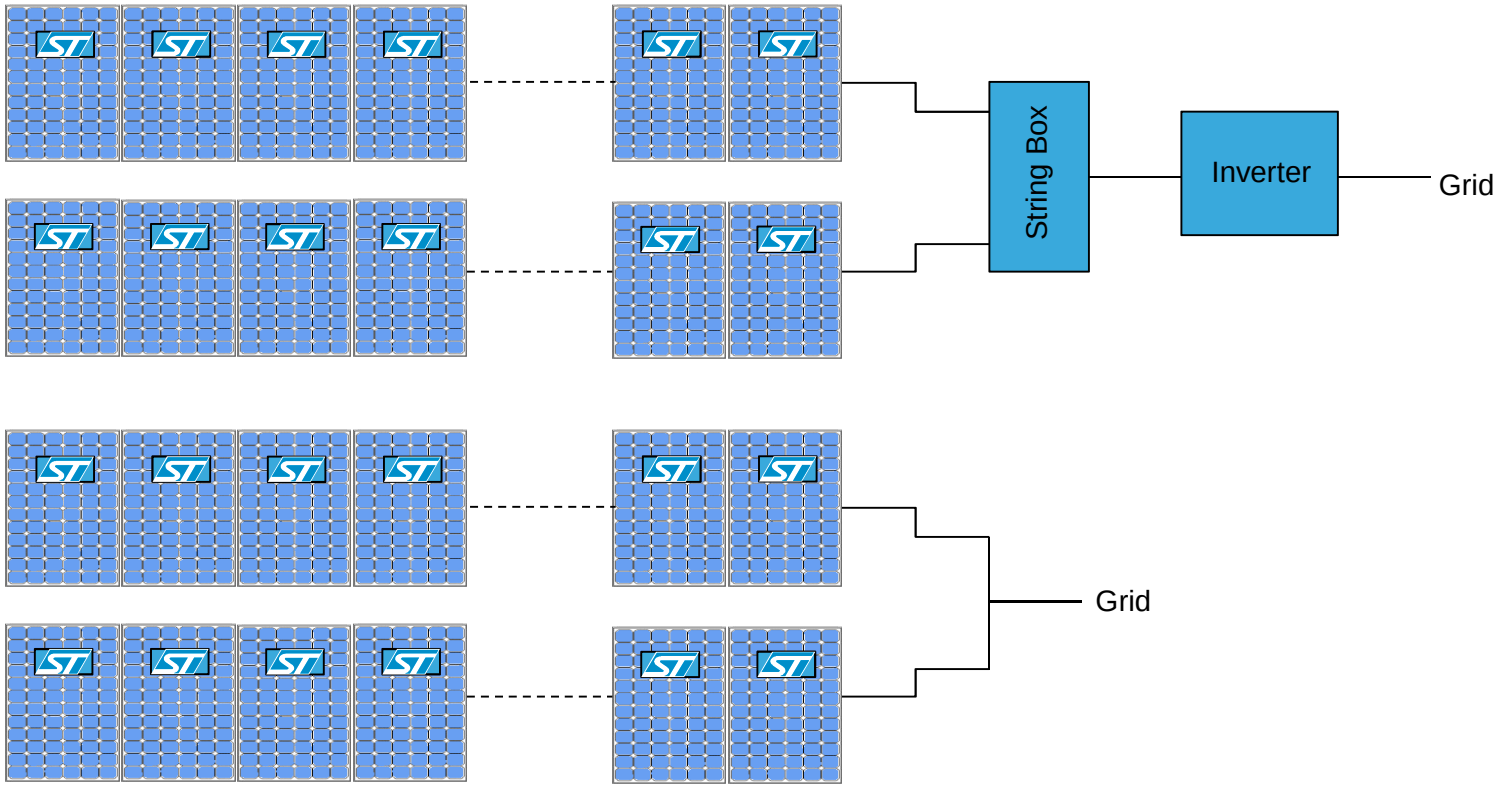
Definition

- **Distributed concept** consist of the introduction of electronics in each individual PV panel.

- **The main advantage of this concept are in:**
  - Significantly improved PV management and performances in not optimal operating conditions (shadow, cloudy sky, dusty, modules mismatching, etc.),
  - The safety can be guarantee switching off each panel (no output voltage),
  - The maintenance can be simplified thanks to the knowledge of main panel parameters,
  - Several “anti-theft” solutions can be implemented

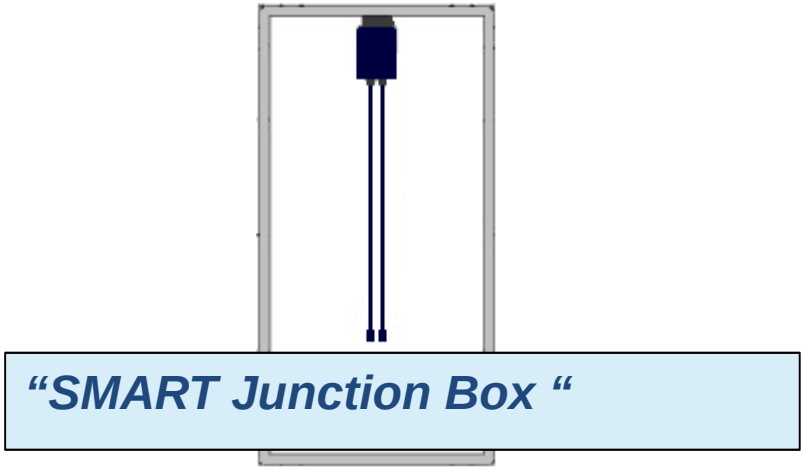
Possible solutions

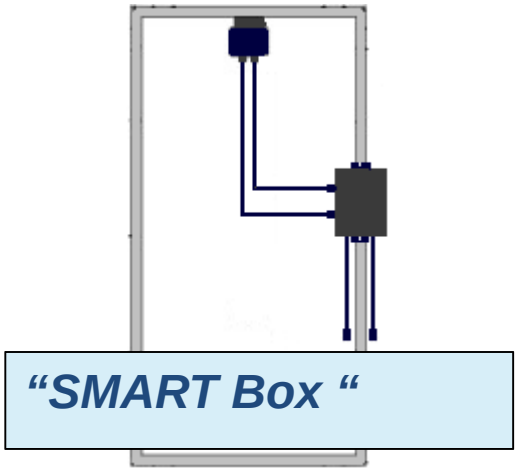
- **Two different distributed approaches can be considered:**
  - **Power Optimizer, in this case only the electronics dedicated to the panel management is moved onto it while the connection with the mains is released to the standard inverter**
  - **Microinverter, in this case is connected directly to the grid**



life.augmented

Smart Junction Box and Smart Box Concepts





- **Electronics can be introduced onto the panel in two different ways, or by “Smart Junction Box” or by “Smart Box”.**
- **The first solution consist in a box applied to the panel back and supplied together it, in that case the by-pass diodes are included.**
- **The second solution is an add-on to standard panel.**
- **The Boxes include a step forward DC/DC converter to improve PV efficiency, main parameters monitoring for maintenance simplification, protections. The data transmission can happen or by PLM or by RF (ZigBee) transceivers.**
- **Considering the different electric characteristics, versions for “Thin-film” and “Single/Multi-crystal” panels will be developed.**

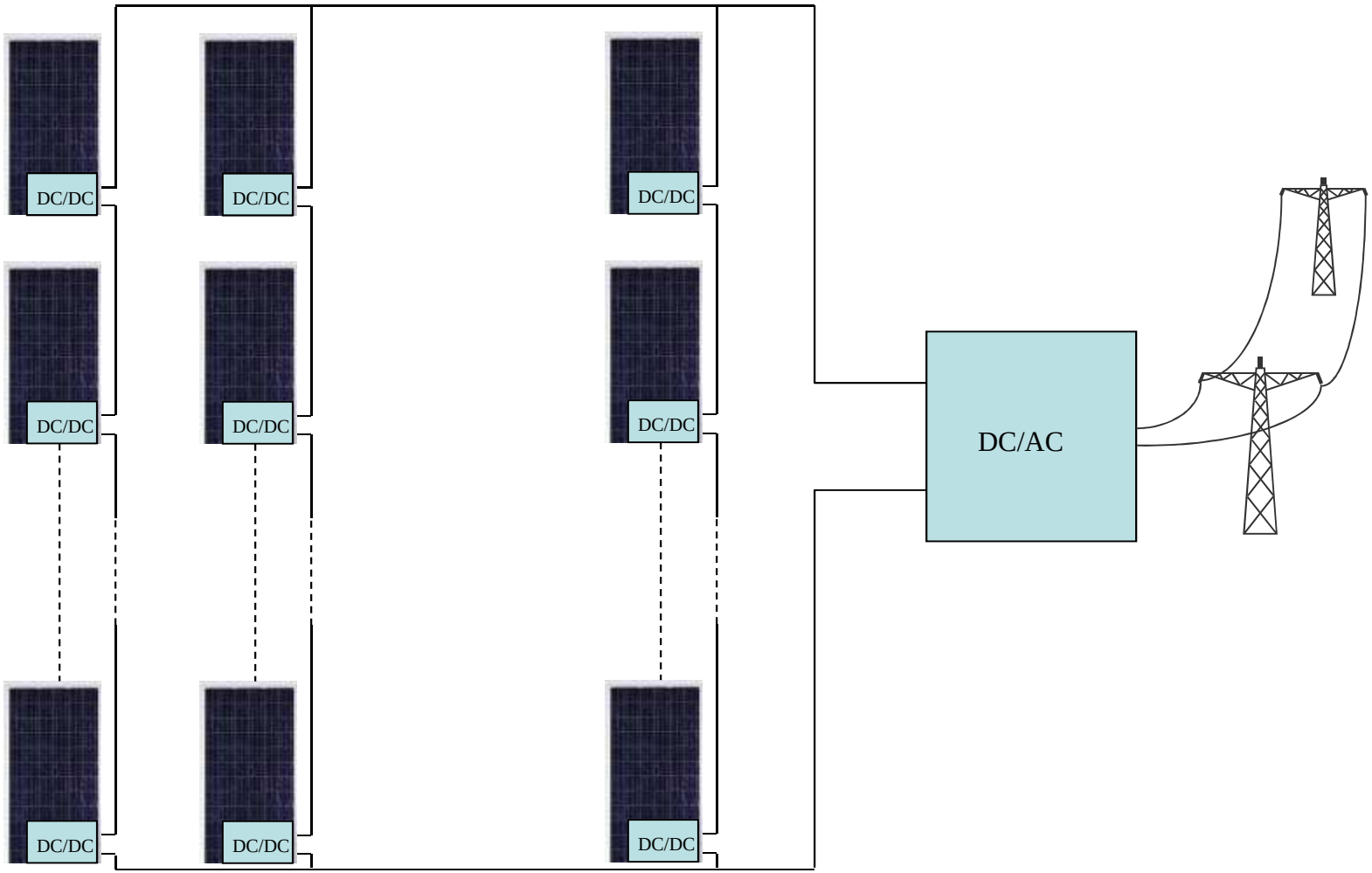
life.augmented

Power Optimizers

- The power optimizer have the scope to manage the single panel in the best way in order to track the Maximum Power Point. Furthermore it is able to send information on the panel working modalities and to disconnect it in case of dangerous situations.

- There are two possible architectures:
  - Low Voltage (the power optimizer output voltage is in the same range of the panel Voc => series connection in order to reach a voltage compatible with the inverter stage)
  - High Voltage (the panel voltage is stepped up to a value enough to be the inverter working, Vout>350V. In this case the connection is in parallel.

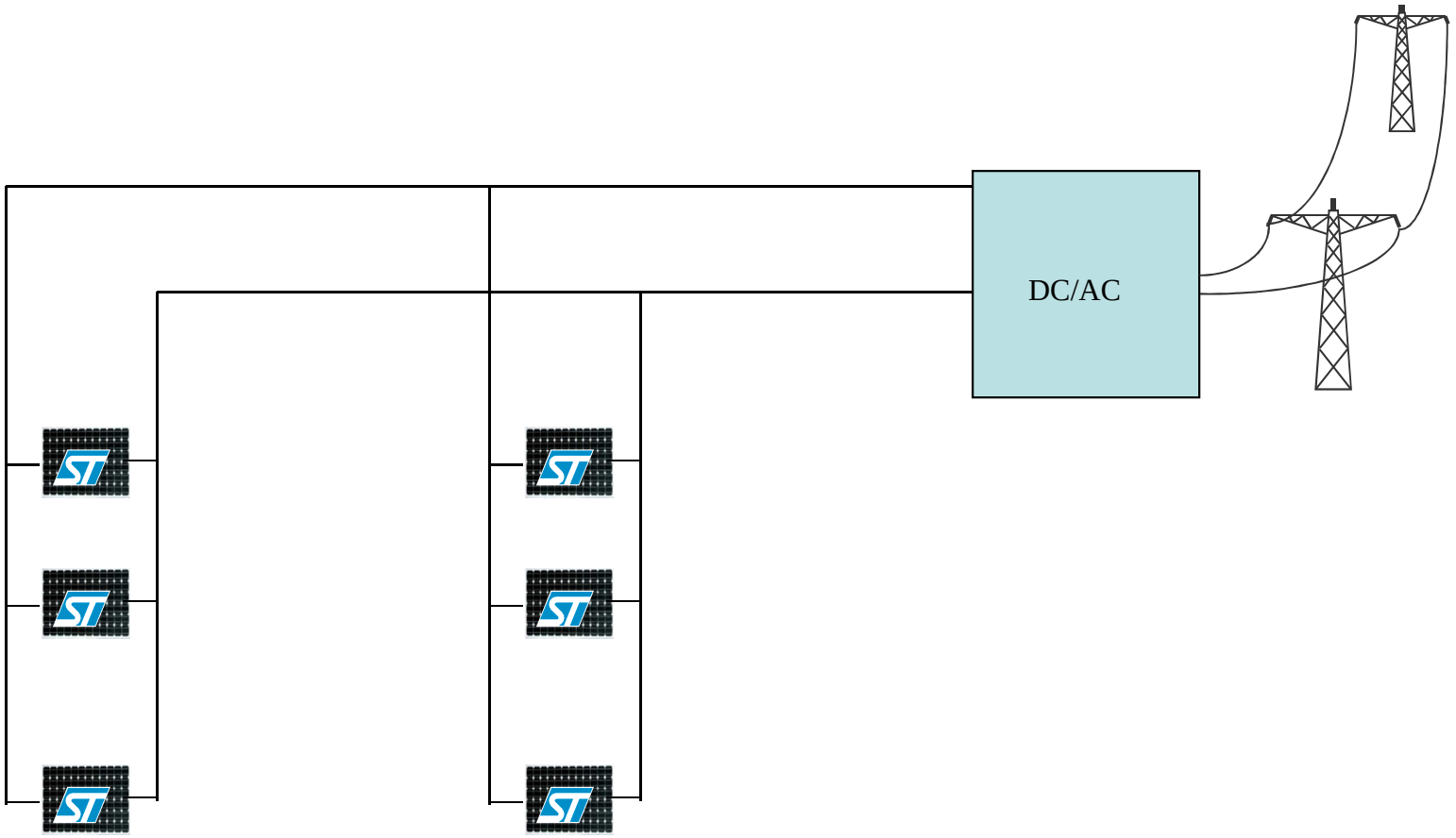
Low Voltage Architecture



Considering power optimizer V_{outmax}=50V and inverter V_{inmax}= 550V the maximum number of panels in series is 11.

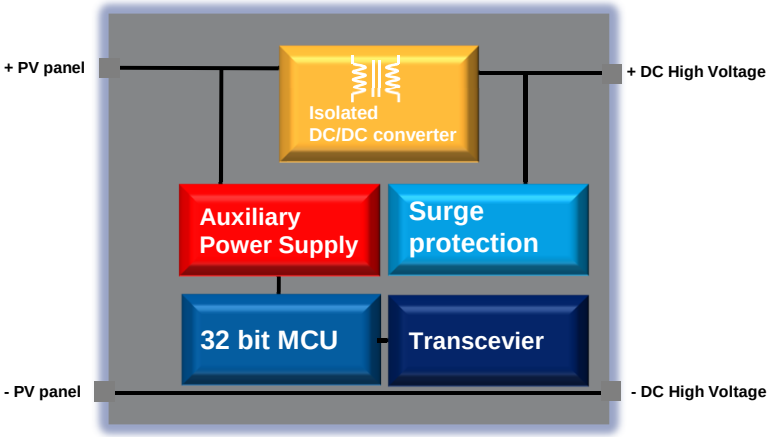
life.augmented

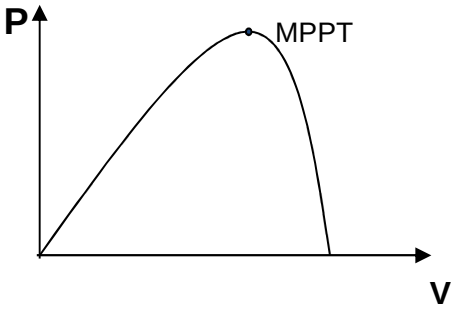
High Voltage architecture



The limit at the maximum number of panels to be connected in parallel is fixed by the wire section

ST Proposal for HV Optimizers



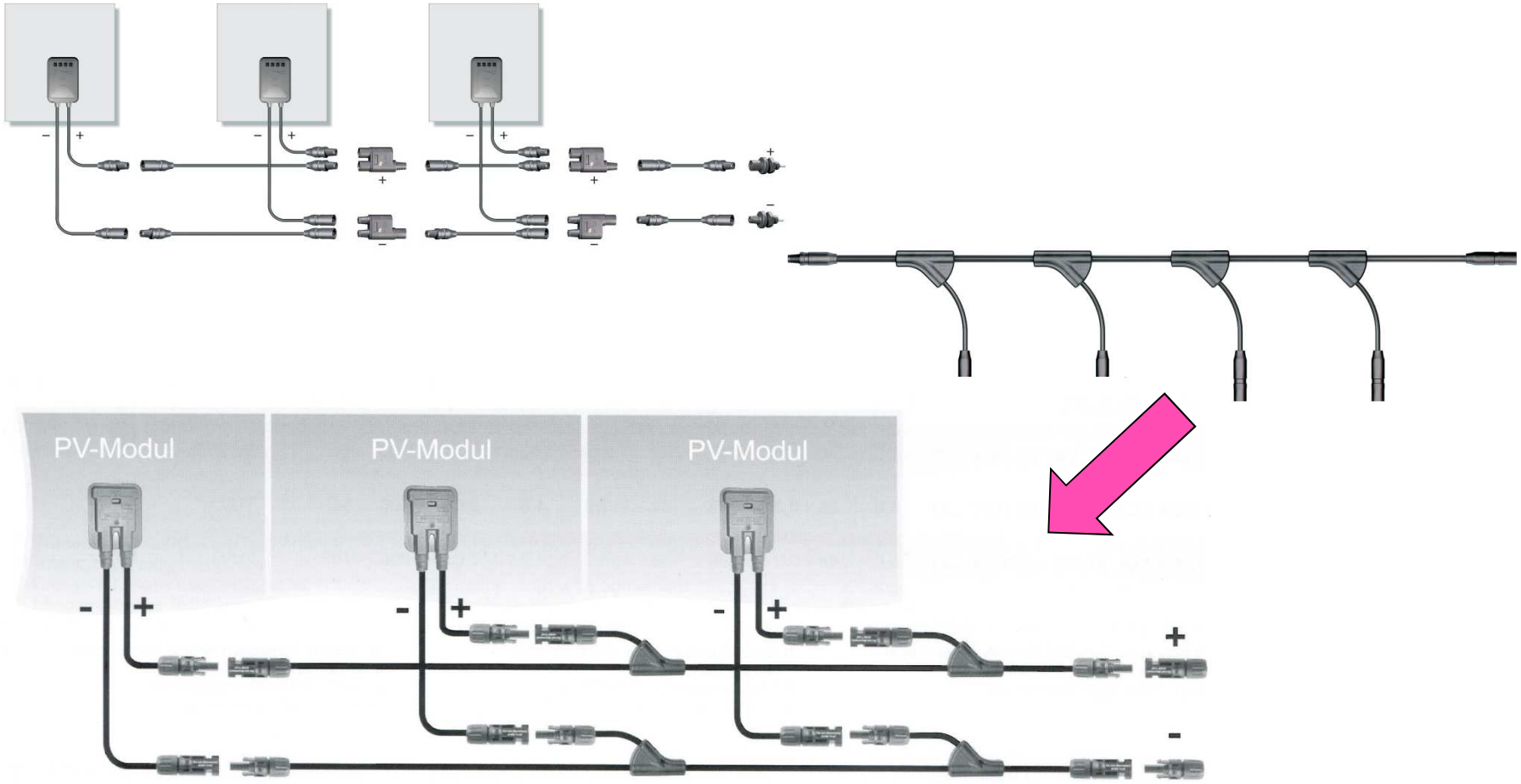


- DC/DC current generator with embedded MPPT calculation
- Panel diagnostic
- Limited output voltage
- Panel/inverter synchronization (ST Patent)

  (Inverter ON => Panel ON, Inverter OFF=> Panel OFF)
- Fire protection
- Surge protection
- Thermal shut-down
- Anti-Theft protection
- Data transmission by PLC or RF technology

life.augmented

Connection Techniques



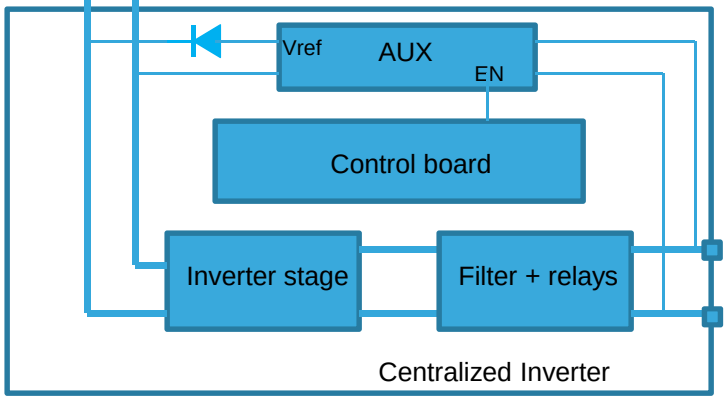
How to Switch ON/OFF the Panel?

It can be done or by communication techniques or by the ST solution:

Modules always OFF

Module ON only if centralized inverter is connected to the grid and working

Optimizer Inverter Synchronization



AC output

life.augmented

ST Demo Boards

Conclusions

- In standards PV plants the limitations due to environmental effect and for the safety has been analyzed.
- The main solution for distributed approach have been shown.
- The architectures for power optimizers have been discussed
- The technology developed by St have been presented, in particular the low and high voltage and microinverter solutions showing also possible connection techniques for parallel configuration.

Thank YOU