

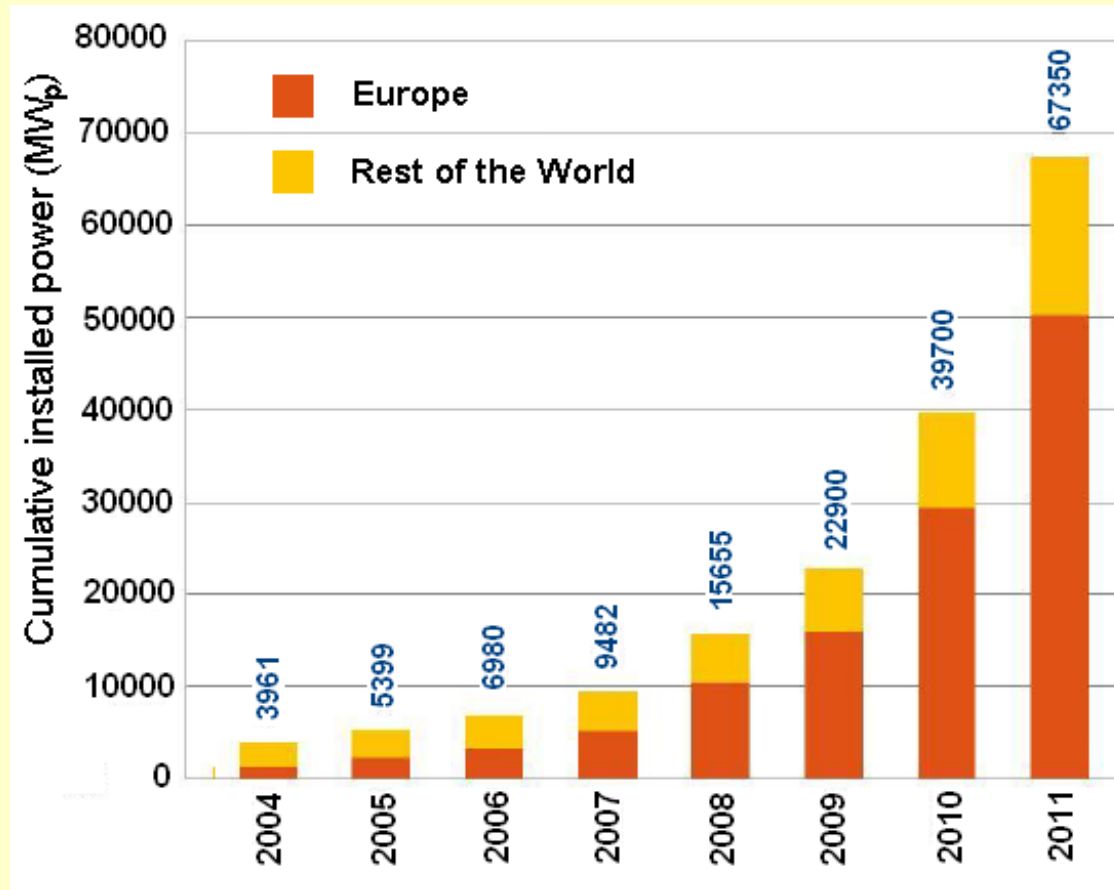
# Diagnostics of photovoltaic power plants operation

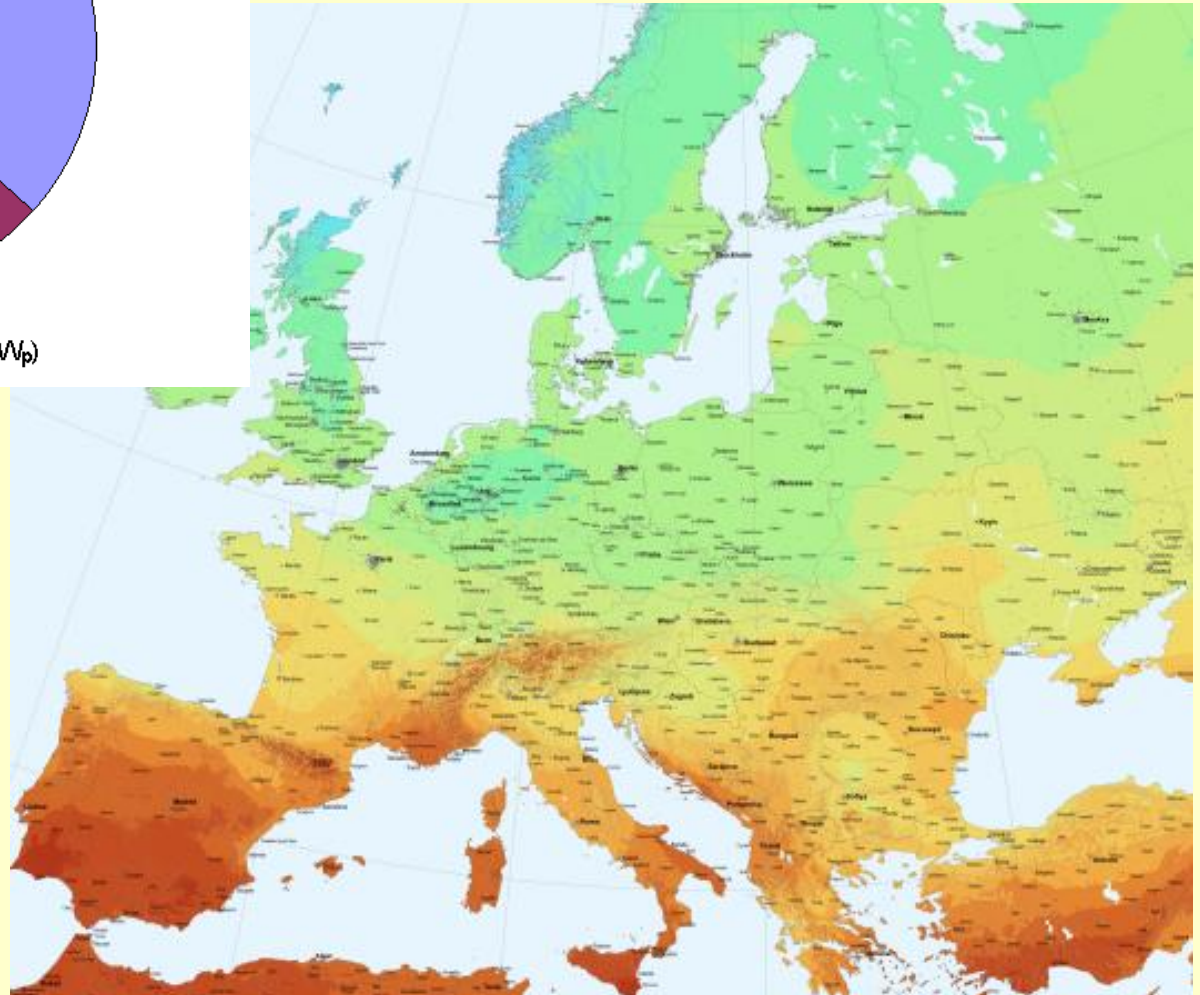
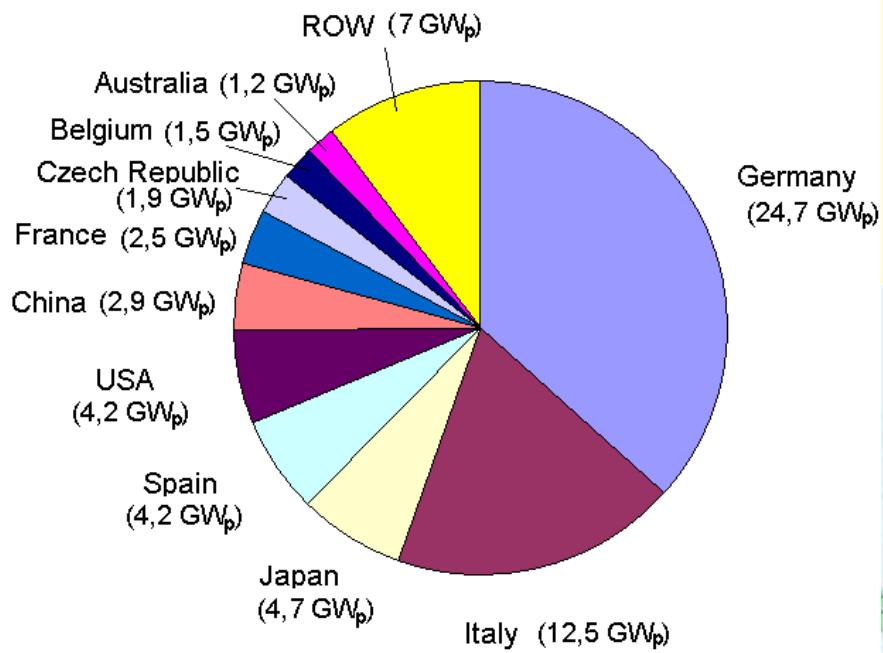


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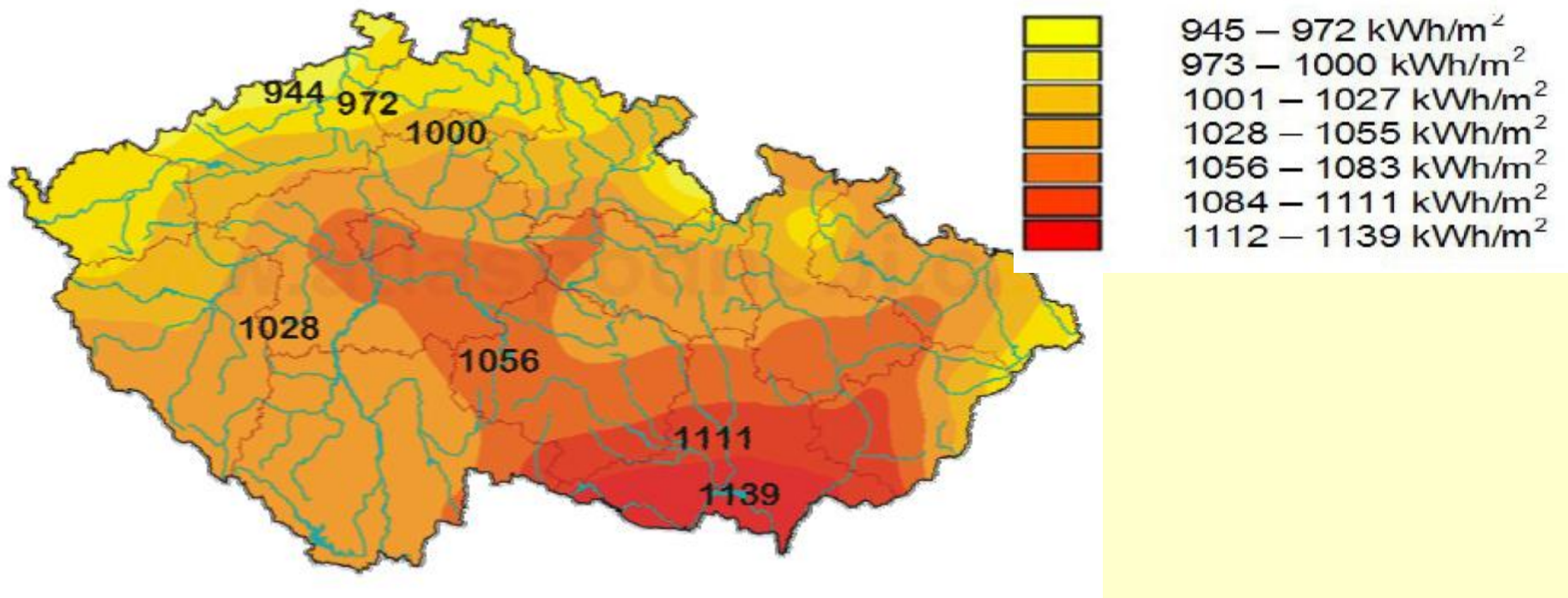


# Progress in photovoltaics





# Czech Republic

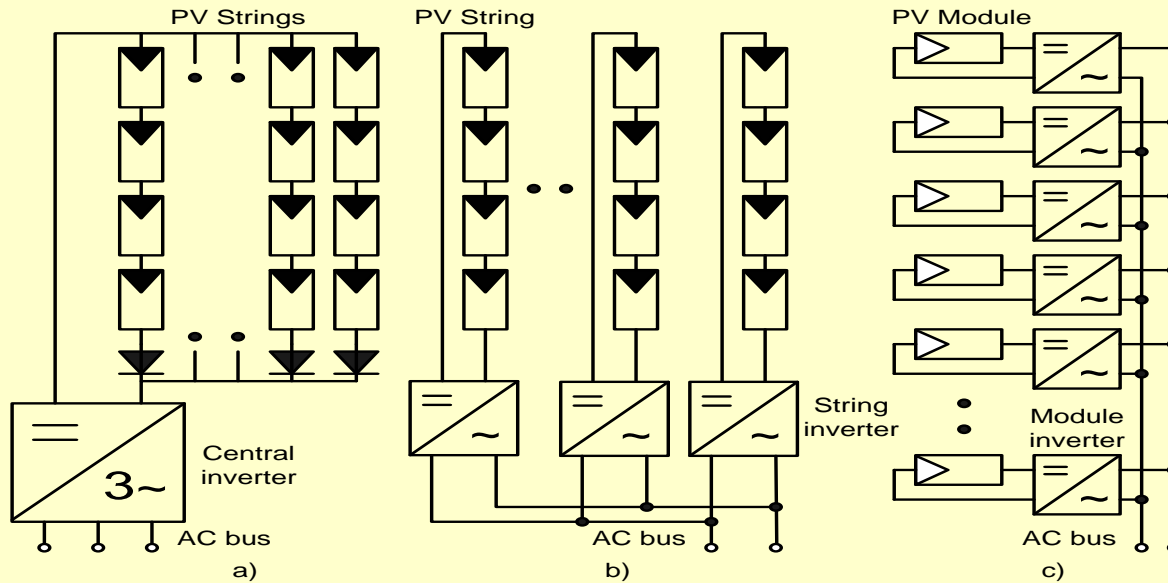


## Installed power of PV plants in Czech Republic

2006	0,4 MW <sub>p</sub>
2007	4,7 MW <sub>p</sub>
2008	58 MW <sub>p</sub>
2009	485 MW <sub>p</sub>
2010	1958 MW <sub>p</sub>

**A proper function of built PV power stations is very important**

# PV Systems Configurations



## 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 (Multi)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

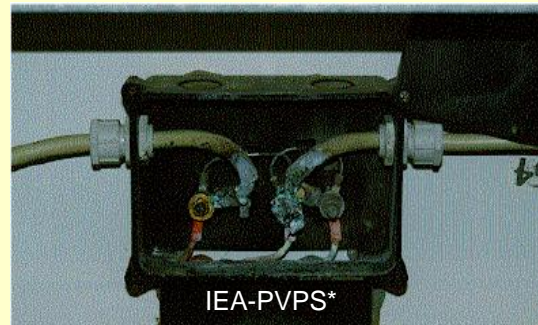
## Module inverters

- 50-180W, each panel has its own inverter enabling optimal MPPT
- Lower efficiency, difficult maintenance
- Higher cost/kWp

# Technical Description of a photovoltaic power plant

- PV modules
- supporting structure
- inverter(s)
  - central
  - decentral
- switchboards
- transformer for a conversion to a high voltage output

# Tens of millions of PV modules installed



## 35 MW<sub>p</sub> power station in Veprek (20 km from Prague)



- 186 960 panels rated at 185W<sub>p</sub> and 190W<sub>p</sub> each (Phonosolar)
- 3300 SMA 10 kW and 11 kW inverters using a (multi)string configuration
- 26 transformers from 0.4kV to 22kV
- 1 transformer connects the total generated power to the 110 kV high voltage power line



# The procedure for detection and removal of operational failures

- fault in a PV module
- fault in interconnection (connectors / cables / switchboard)
- fault in inverter (monitoring system)

## A) Data collection system

- shows the performance of all inverters
- the problem is localized if a power loss appears on one inverter (relative to an average performance of all of the inverters)
- Comparison of normalized inverter yields for 23.11.2009 brings following detailed data:
  - Inverter '2000760653'  
SN: 2000760653  
Generator: 11,9 kWp  
Total yield: 20,97 kWh  
Specific yield: 1,76 kWh/kWp  
deviation >8% (8,7%)

# The exact localization of a problem could be found under „Plant Logbook“ on „Sunny Portal“ (www.sunnyportal.com)

The screenshot displays the 'Plant Logbook' interface for the plant 'FVE CZECH - Smirice I'. The left sidebar contains navigation options such as 'Plant selection', 'Plant Profile', 'Energy and Power', 'Yearly Comparison', 'Plant Monitoring', 'Plant Logbook: 152', 'Visualization', 'Prehled solárního systému', 'Energie a výkon', 'Normovaný výkon systému', 'Energie a výkon\_1', 'Energie a výkon\_2', 'Report (3)', 'Sensors (4)', 'Devices (547)', 'Configuration', and 'User Information/Logout'.

The main content area includes search filters: 'Go to:' (30/05/2010), 'Status:' (not confirmed), 'Plant/Devices:' (all), and 'Number per Page:' (20). Below these are checkboxes for 'Type:' (Info, Warning, Failure, Error), with 'Warning', 'Failure', and 'Error' selected.

The logbook table lists 20 entries, all of which are 'Warning' type. The entries are as follows:

Plant/Devices	Time	Type	Description	Confirmed
2000760007	30/05/2010 11:30:42	Warning	Warten /Iso-resistance	✗
2000760007	30/05/2010 06:30:17	Warning	Warten /Iso-resistance	✗
FVE CZECH - Smirice I	29/05/2010 15:04:26	Warning	Yield deviation from inverter comparison Inverter ...	✗
FVE CZECH - Smirice I	29/05/2010 15:04:18	Warning	Yield deviation from inverter comparison Inverter ...	✗
FVE CZECH - Smirice I	29/05/2010 15:04:17	Warning	Yield deviation from inverter comparison Inverter ...	✗
FVE CZECH - Smirice I	29/05/2010 15:04:13	Warning	Yield de	✗
FVE CZECH - Smirice I	29/05/2010 15:04:11	Warning	Yield de	✗
FVE CZECH - Smirice I	29/05/2010 15:04:02	Warning	Yield de	✗
FVE CZECH - Smirice I	29/05/2010 15:04:01	Warning	Yield deviation from inverter comparison Inverter ...	✗
FVE CZECH - Smirice I	29/05/2010 15:03:53	Warning	Yield deviation from inverter comparison Inverter ...	✗
FVE CZECH - Smirice I	29/05/2010 15:03:51	Warning	Yield deviation from inverter comparison Inverter ...	✗
FVE CZECH - Smirice I	29/05/2010 15:03:37	Warning	Yield deviation from inverter comparison Inverter ...	✗
FVE CZECH - Smirice I	29/05/2010 15:03:35	Warning	Yield deviation from inverter comparison Inverter ...	✗
FVE CZECH - Smirice I	29/05/2010 15:03:33	Warning	Yield deviation from inverter comparison Inverter ...	✗
FVE CZECH - Smirice I	29/05/2010 15:03:32	Warning	Yield deviation from inverter comparison Inverter ...	✗
FVE CZECH - Smirice I	29/05/2010 15:03:31	Warning	Yield deviation from inverter comparison Inverter ...	✗
2000760082	29/05/2010 14:30:46	Warning	Netzueb. /Grid voltage L1	✗
2000760678	29/05/2010 14:30:35	Warning	MPP /Grid voltage L1	✗
2000760090	29/05/2010 14:30:26	Warning	Warten /Grid voltage L1	✗
2000759900	29/05/2010 14:30:10	Warning	Netzueb. /Grid voltage L1	✗

A tooltip is visible over the 'Yield de' entry at 15:04:11, providing detailed information: 'Yield deviation from inverter comparison Inverter '2000760568', SN: '2000760568', total yield 45.9 kWh, specific yield 3.9 kWh/kWp, deviation 25.9% (>8%) compared to the average of monitored inverters (5.2 kWh/kWp on 28.5.2010)'. At the bottom of the interface, there are controls for 'Select all', a 'Confirm' dropdown menu, and a 'Submit' button.

## B) visual checking the corresponding PV string

- disconnection of the module, missing or broken module, by obstruction that shades a module, melted or burned junction box, etc.

## C) checking the switchboard

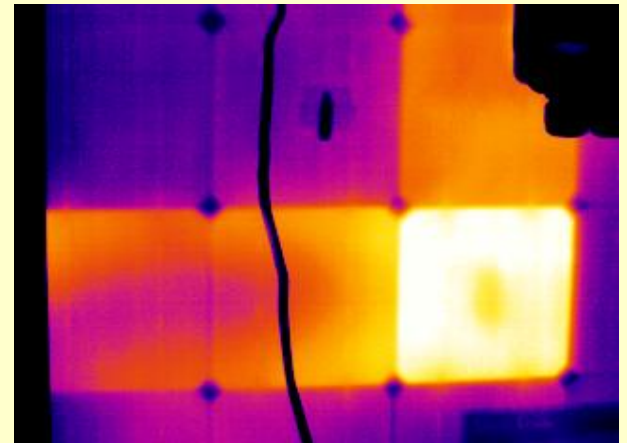
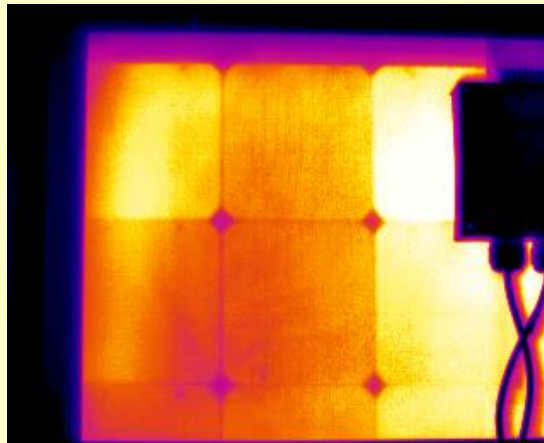
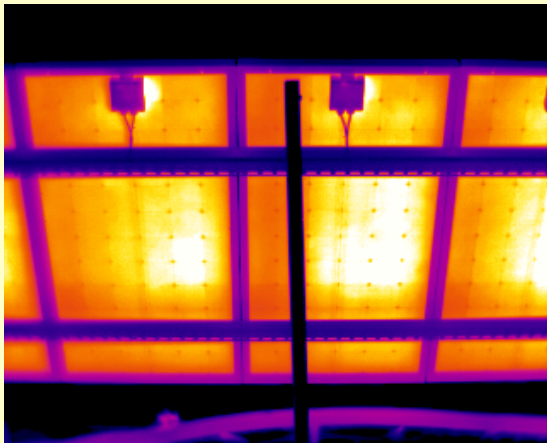
- follows (broken fuses or disconnected breakers, destroyed over voltage protections)

## D) checking the faulty string

- should be done and voltage measurement conducted
- to localize a faulty connector, it is necessary to measure the modules as pairs

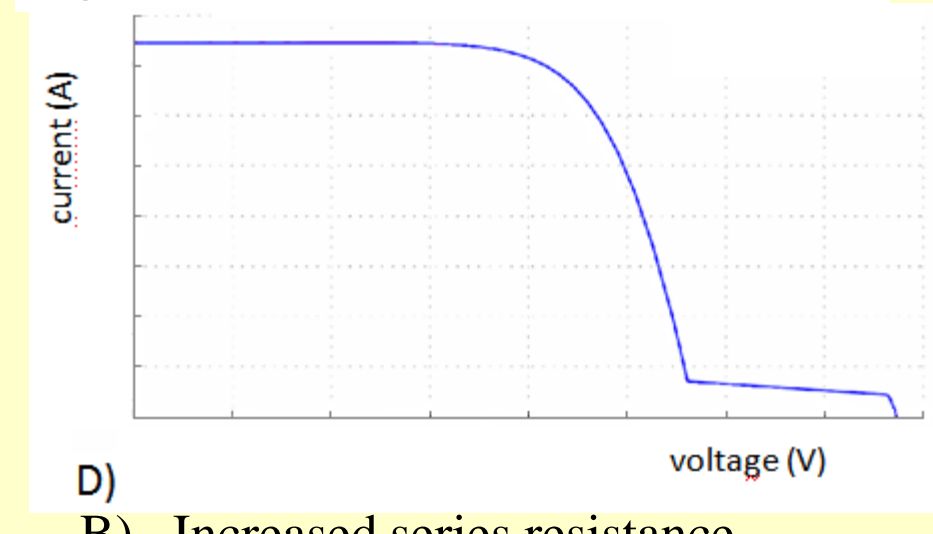
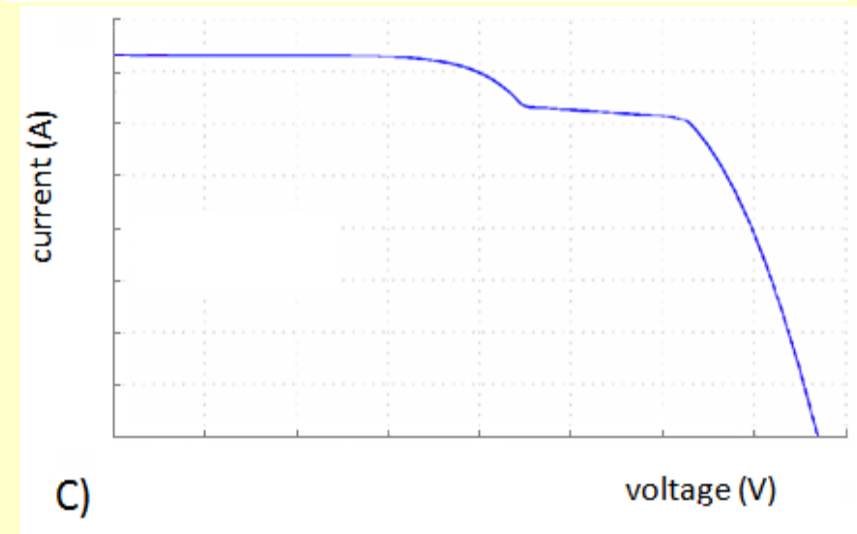
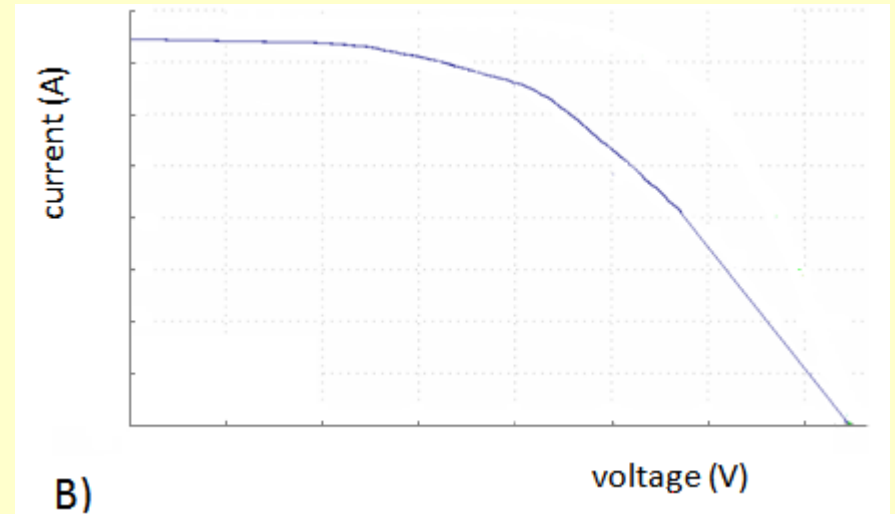
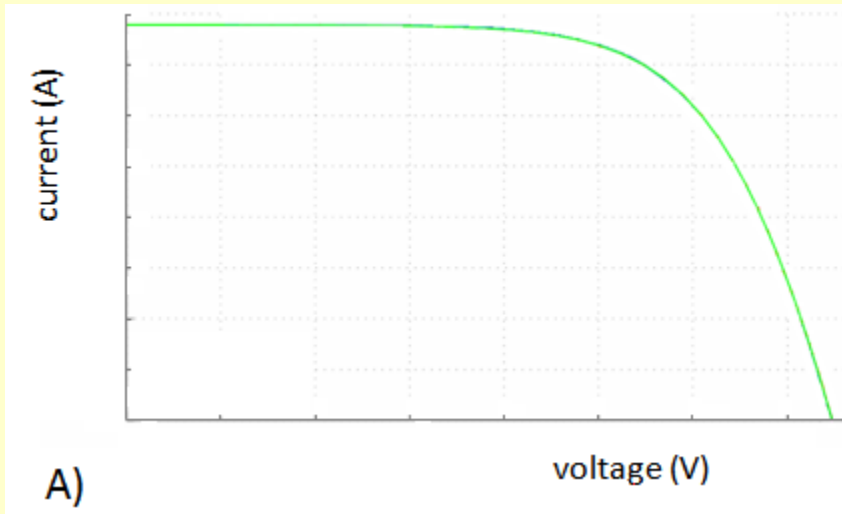
## E) check the temperature distribution

- under load over the modules can be evaluated using IR camera
- "Hot spot" appears together with the presence of local shading or when a single cell is cracked/damaged



Problematic parts of the PV system can be detected

## F) checking the I-V characteristic



- A) Common I-V curve characteristics
- C) Cracked or partially shaded cell

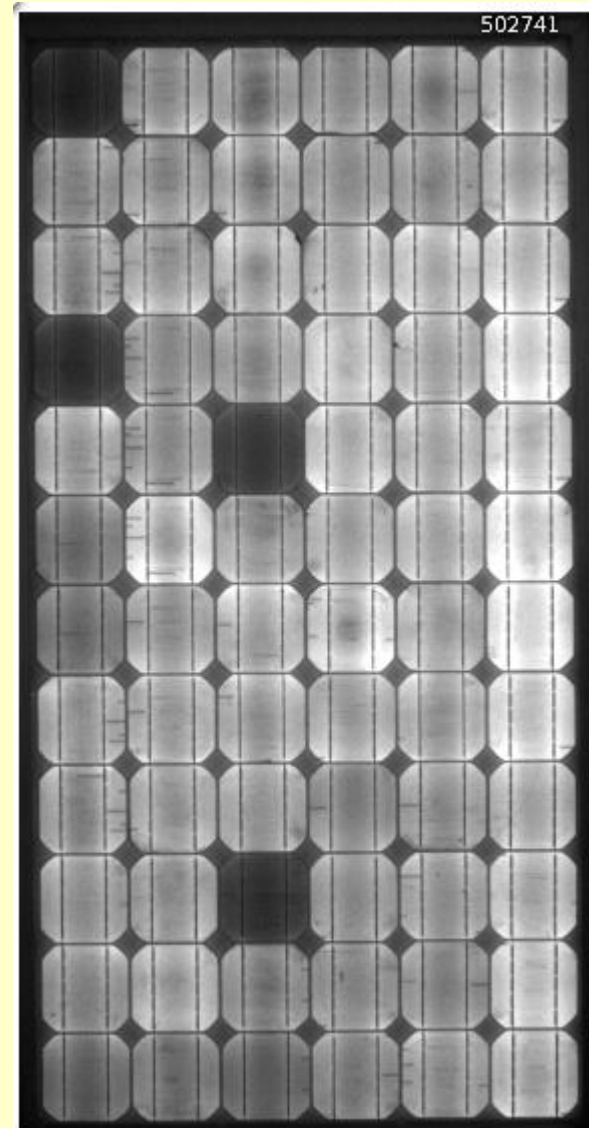
- B) Increased series resistance
- D) Interrupted chain of cells or completely shaded cell

## Changing defect parts

In the case of modules may  
be done more detail analyses

Precise I-V characteristic  
measurements

Electroluminisce



# Conclusions

- During PV power plant operation, faults decreasing the total power output of the power plant may arise.
- It can either be a fault in a PV module, failure in a connection (connectors/cables/switchboard) or a failure in an inverter.
- The inverters are equipped with a monitoring system that observes the operating parameters, inputs and output and is able to identify most of the error states.
- The identification and removal of the fault should be carried out in a shortest possible time in order to minimize losses in energy production.



**Thank you for your attention**