

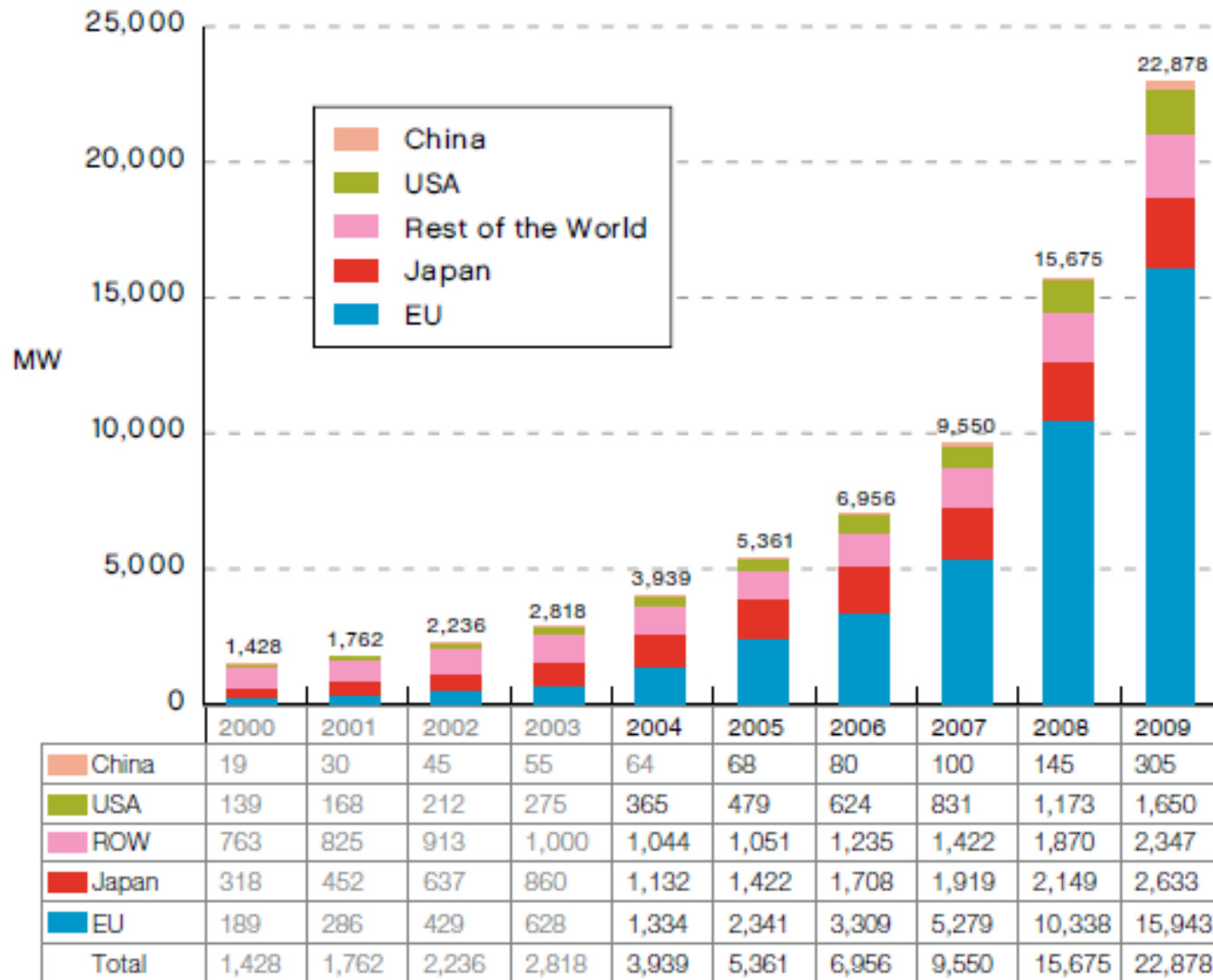
# Diagnostics of photovoltaic power plants operation



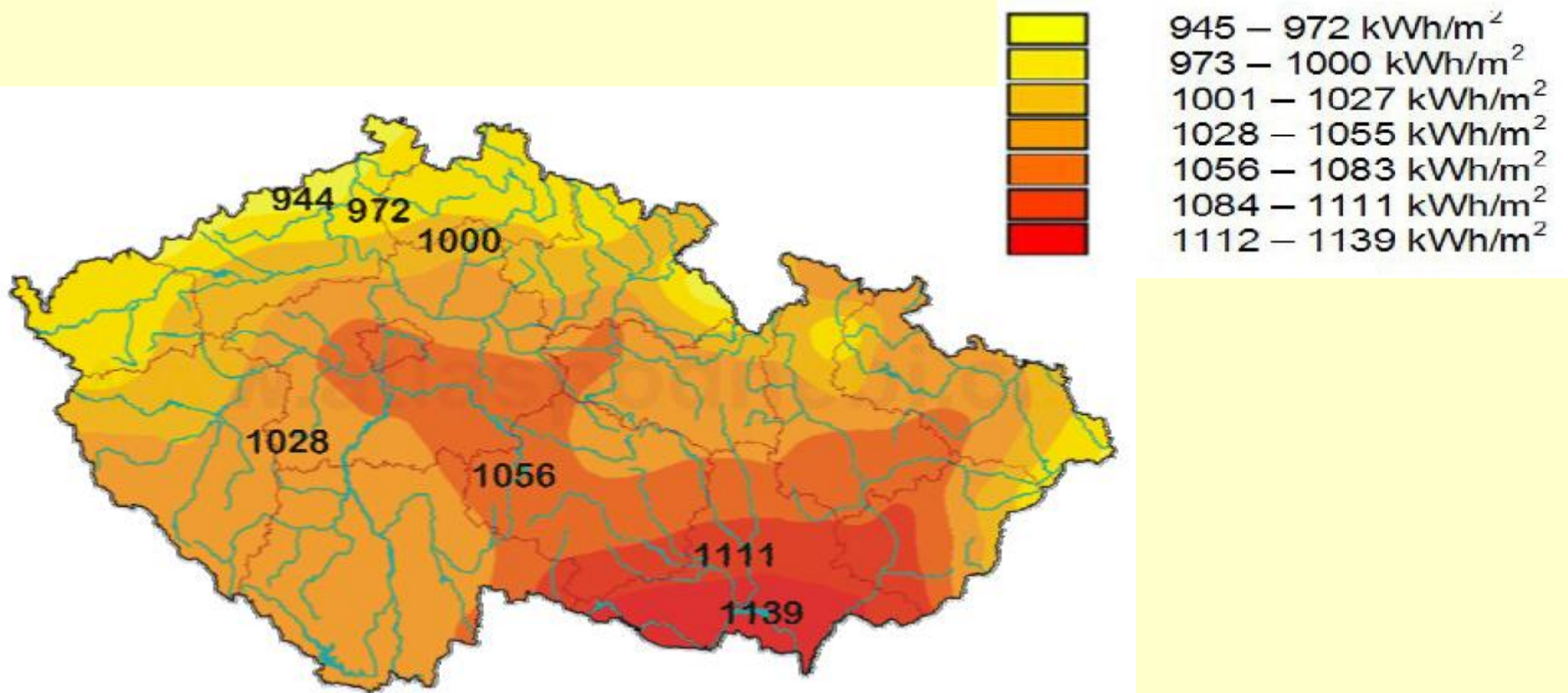
**Vitezslav Benda,**  
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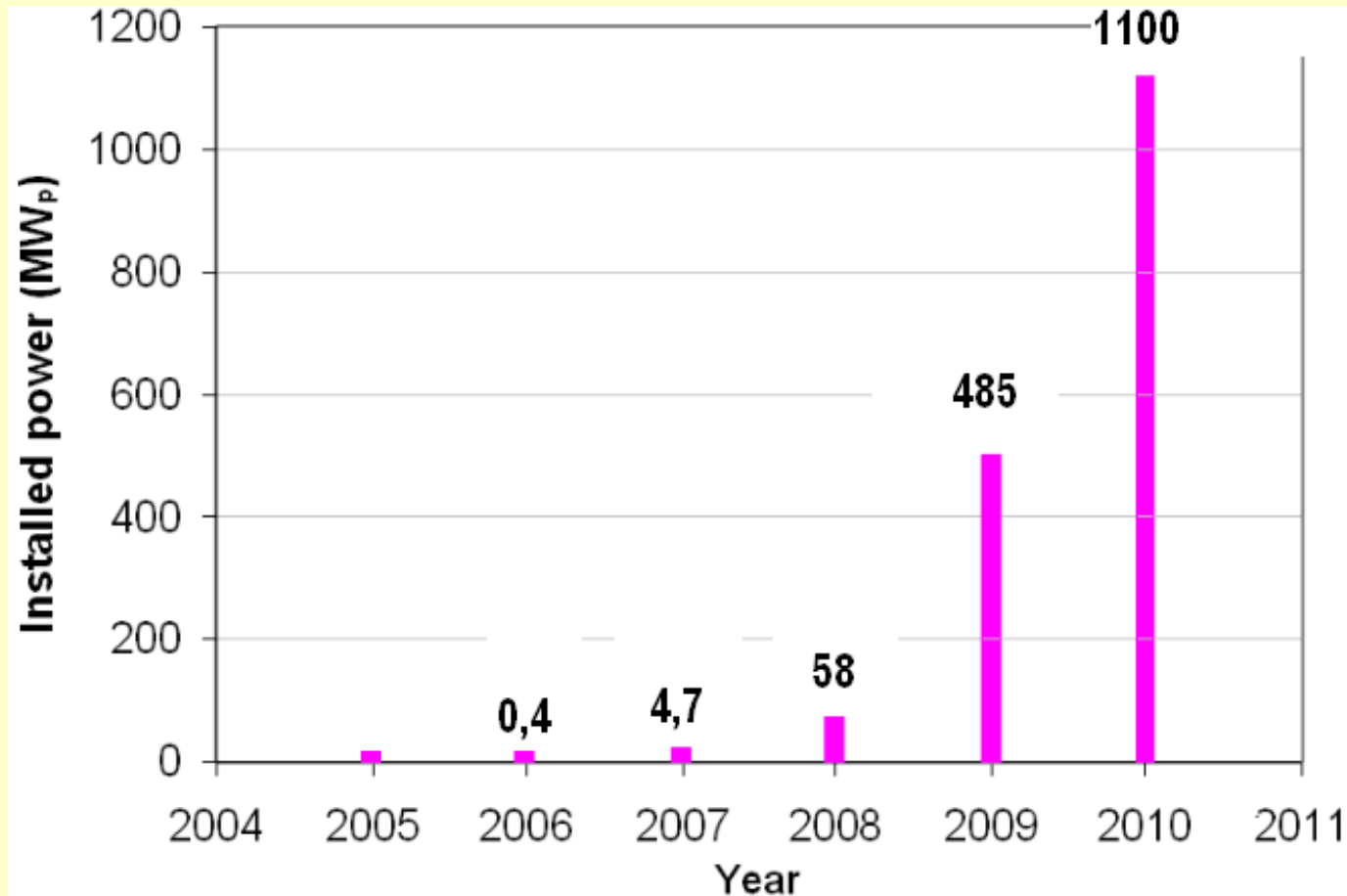
# Progress in photovoltaics



# Czech Republic



# The total output power of solar power plants in the Czech Republic



## 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 string configuration
- 26 transformers from 0.4kV to 22kV
- 1 transformer connects the total generated power to the 110 kV high voltage power line

# 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

# 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 'Confirmed' column for all entries contains a red 'X' icon. A tooltip is visible over one of the entries, 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 table, there is a 'Select all' checkbox, a 'Confirm' dropdown menu, and a 'Submit' button.

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

## 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

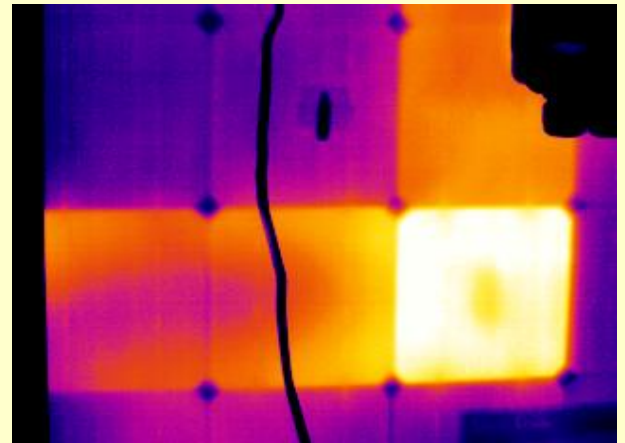
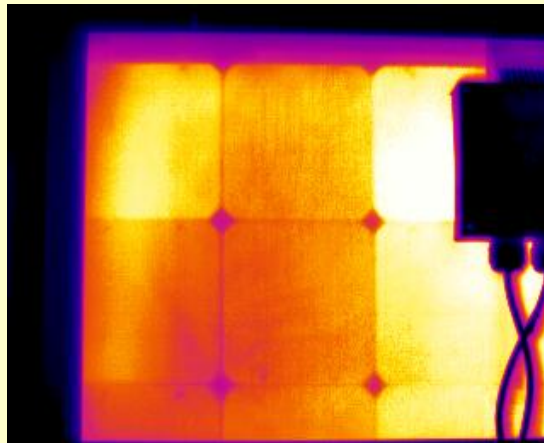
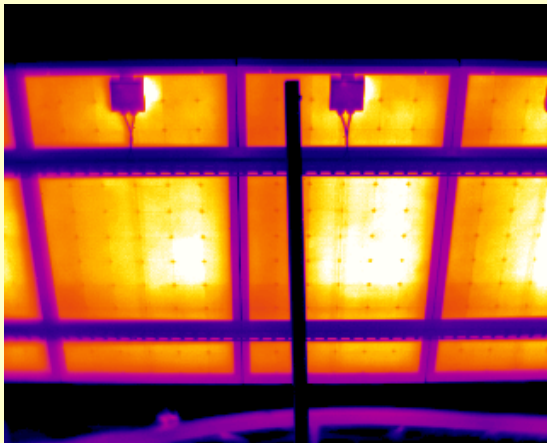
- follows (broken fuses or disconnected breakers, destroyed over voltage protections)

## D) checking the faulty string

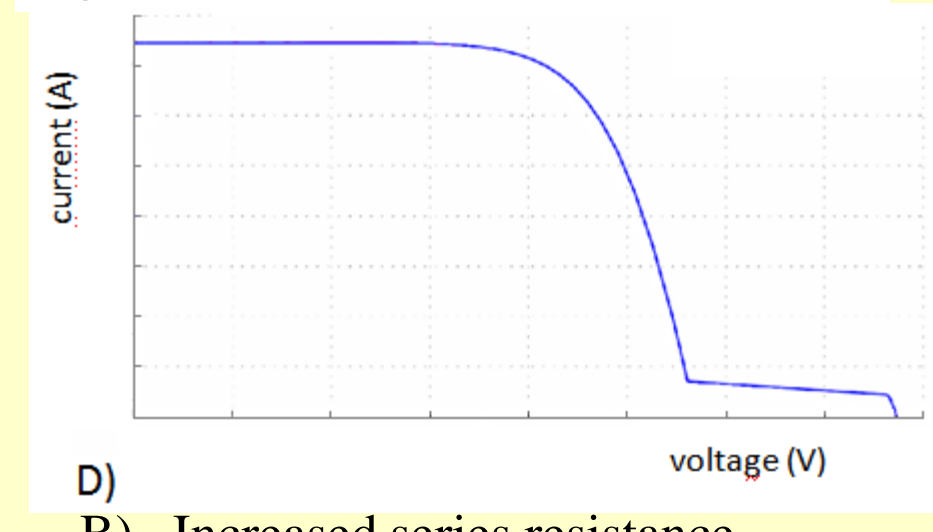
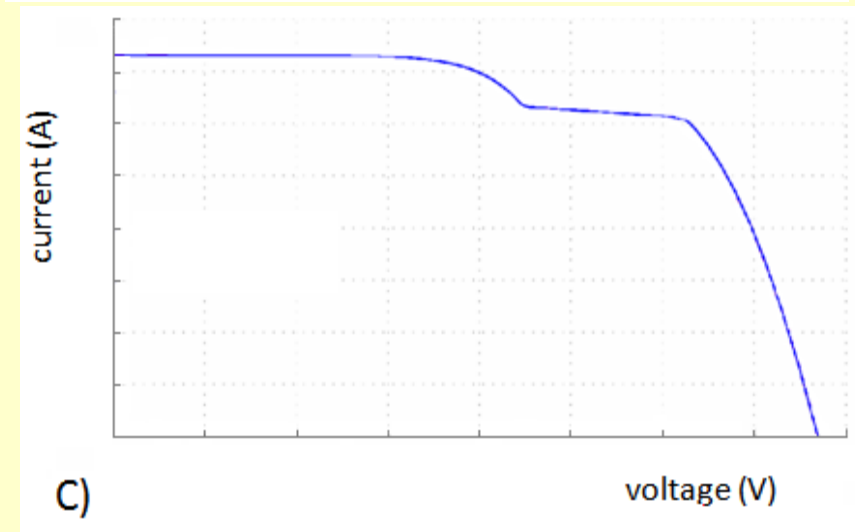
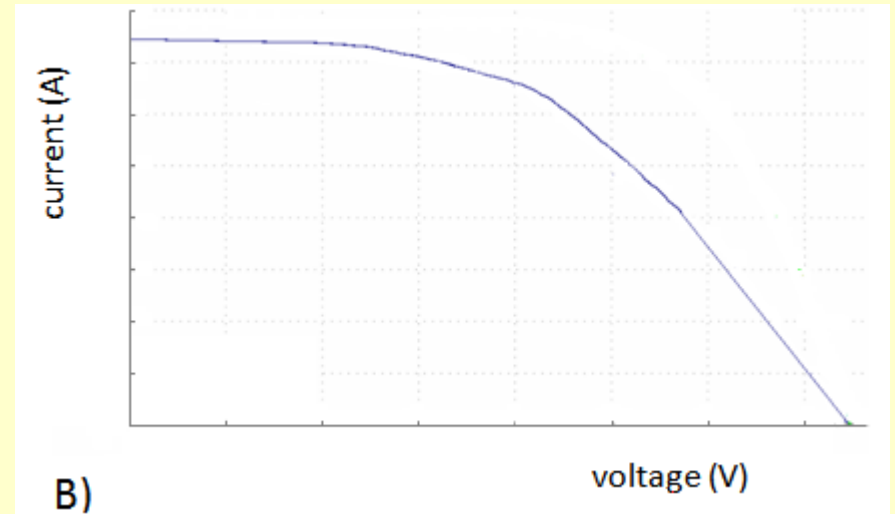
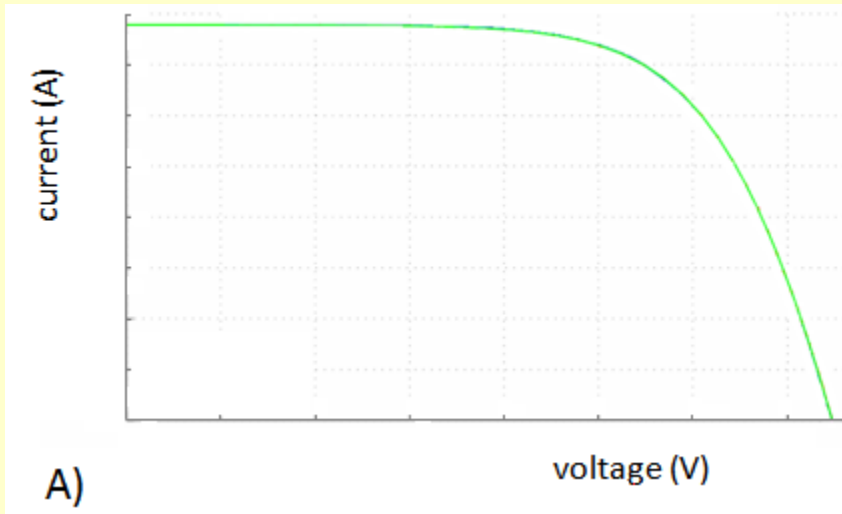
- should be done and voltage measurement conducted
- to localize a faulty connector, it is necessary to measure the modules as pairs

## 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



## 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

# 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**