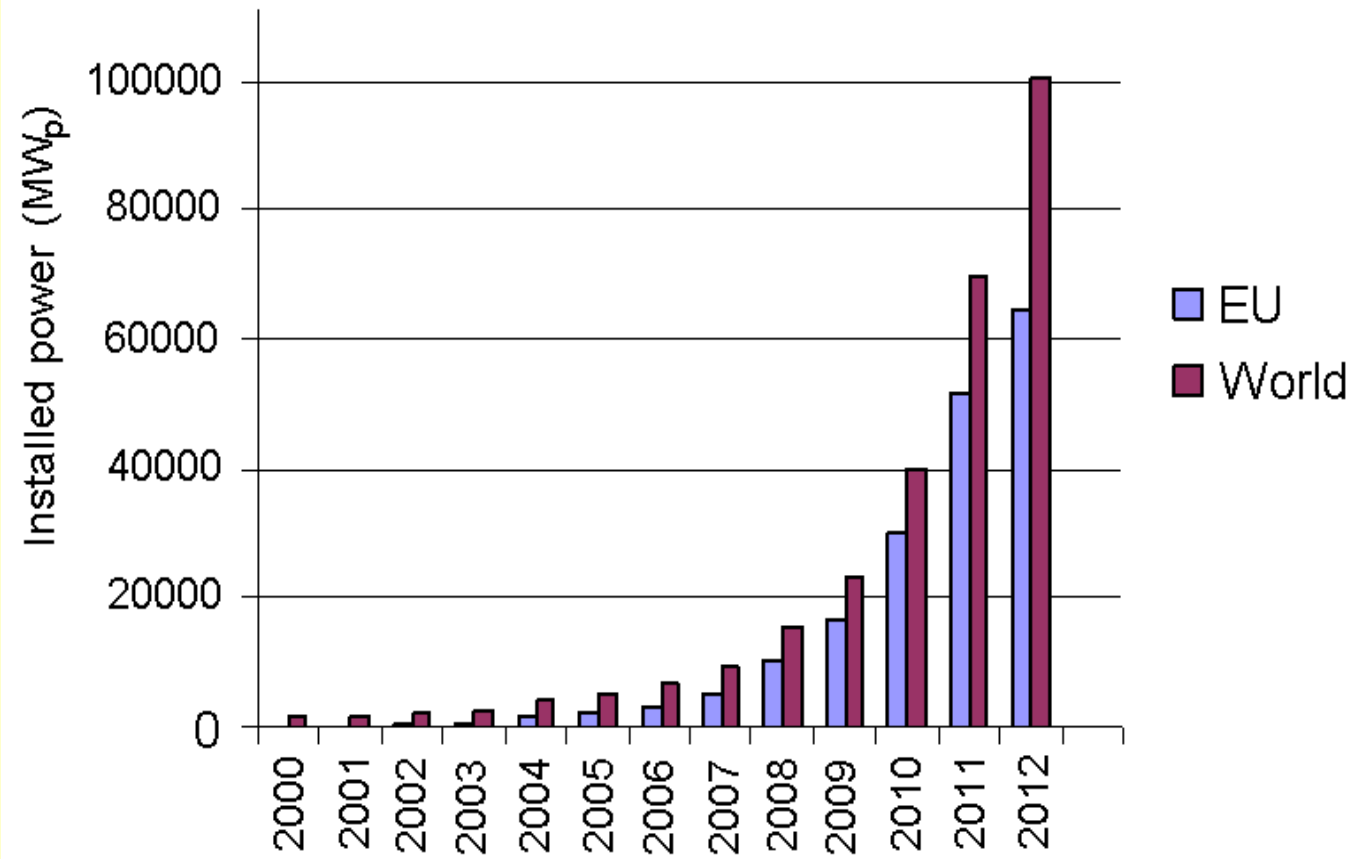
Diagnostics of photovoltaic power plants operation

Vitezslav Benda,
CTU Prague, Faculty of Electrical Engineering

KATEDRA ELEKTROTECHNOLOGIE FEL PRAHA

Very fast development of Photovoltaics in the past decade



2004 - 1GW$_p$ installed in EU

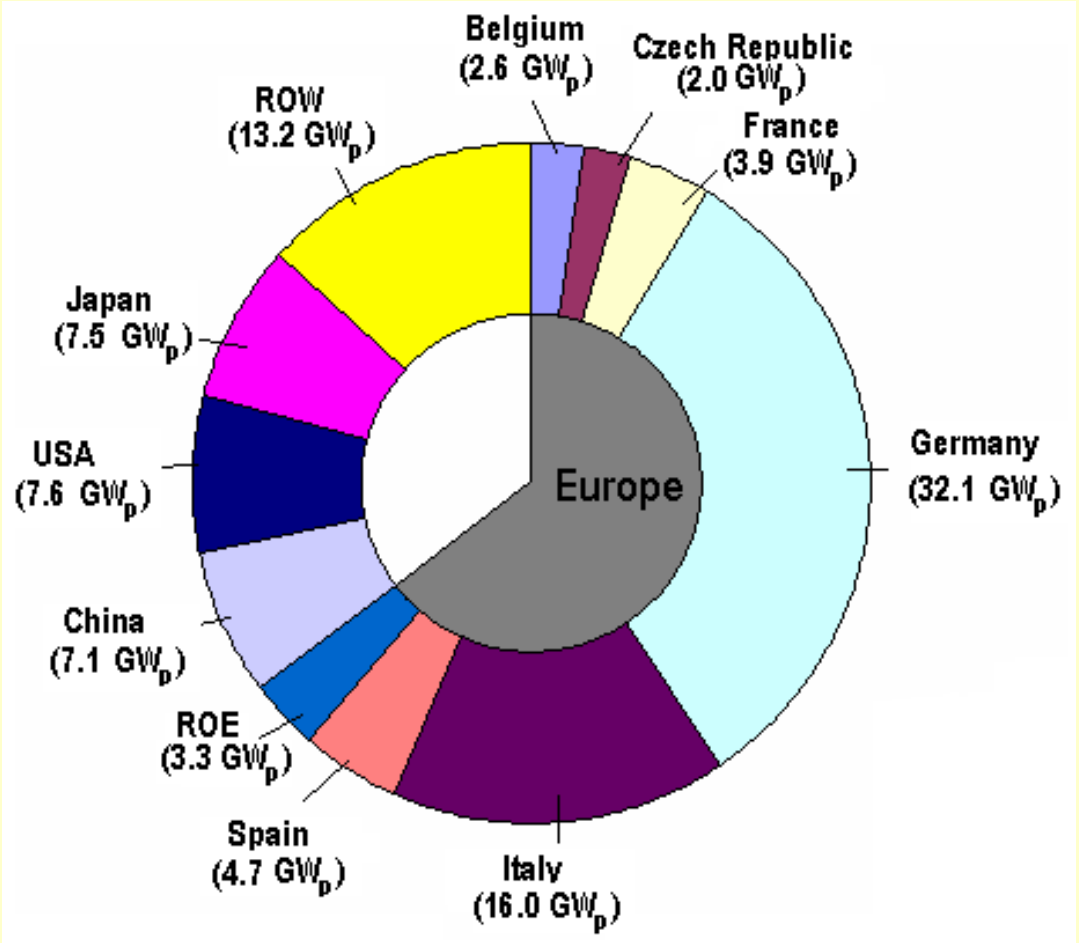
2006 - 3 GW$_p$ installed in EU

2010 - 29 GW$_p$ installed in EU

2011 - 50 GW$_p$ installed in EU

2012 – 63 GW$_p$ installed in EU

In the end of 2012 was installed in the World 102 GW_p



2010

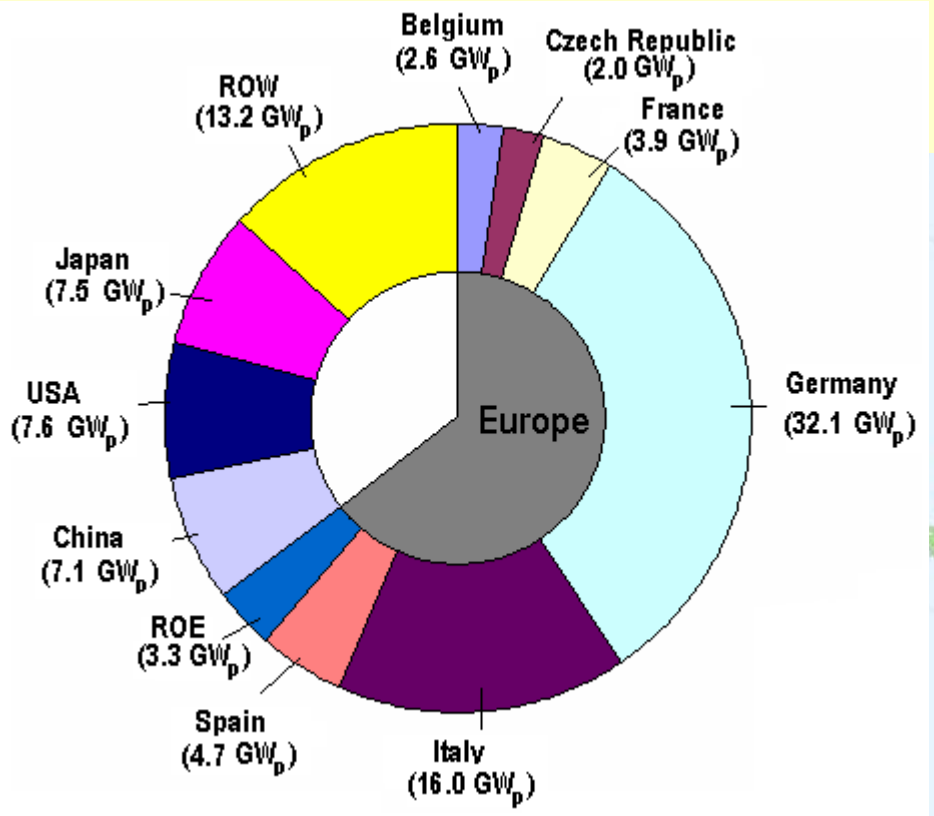
Germany	17 GW_p
ROE	12 GW_p
ROW	10 GW_p

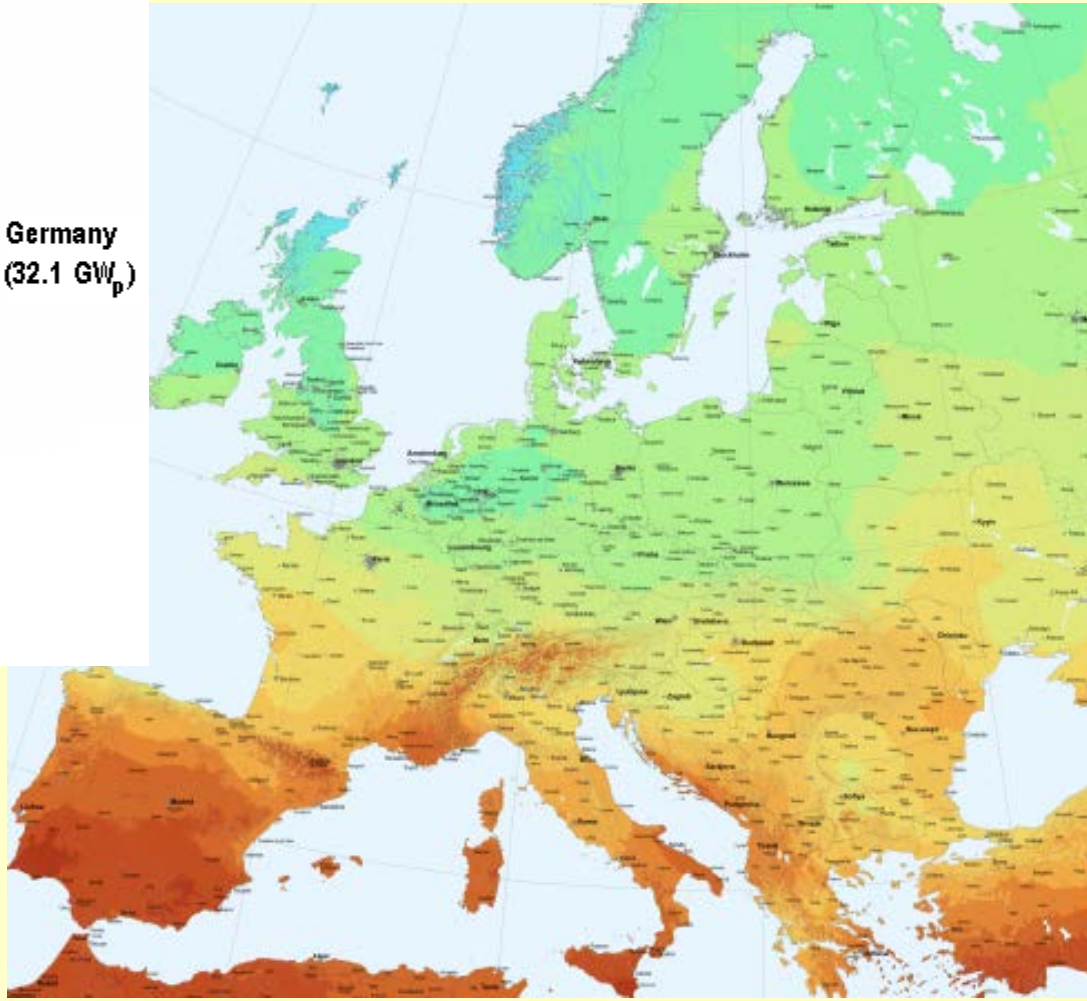
2011

Germany	25 GW_p
ROE	25 GW_p
ROW	17 GW_p

2012

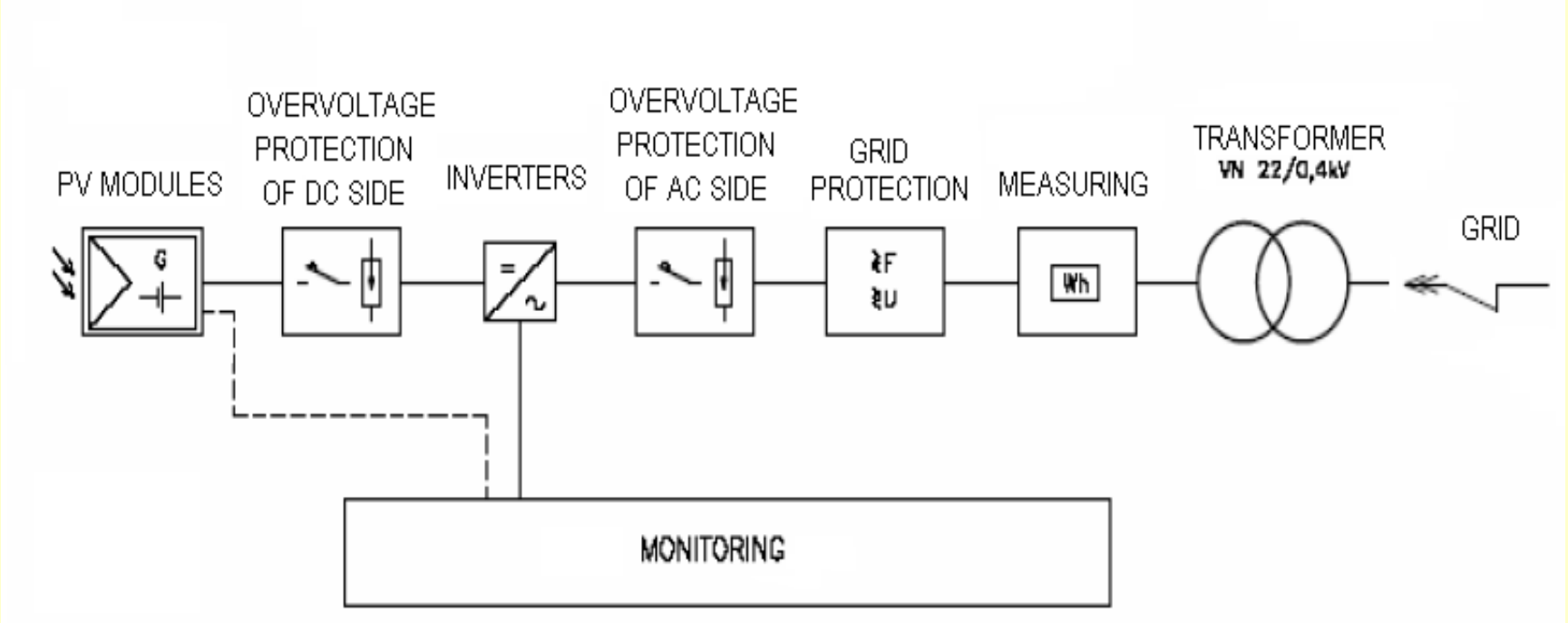
Germany	32 GW_p
ROE	31 GW_p
ROW	38 GW_p

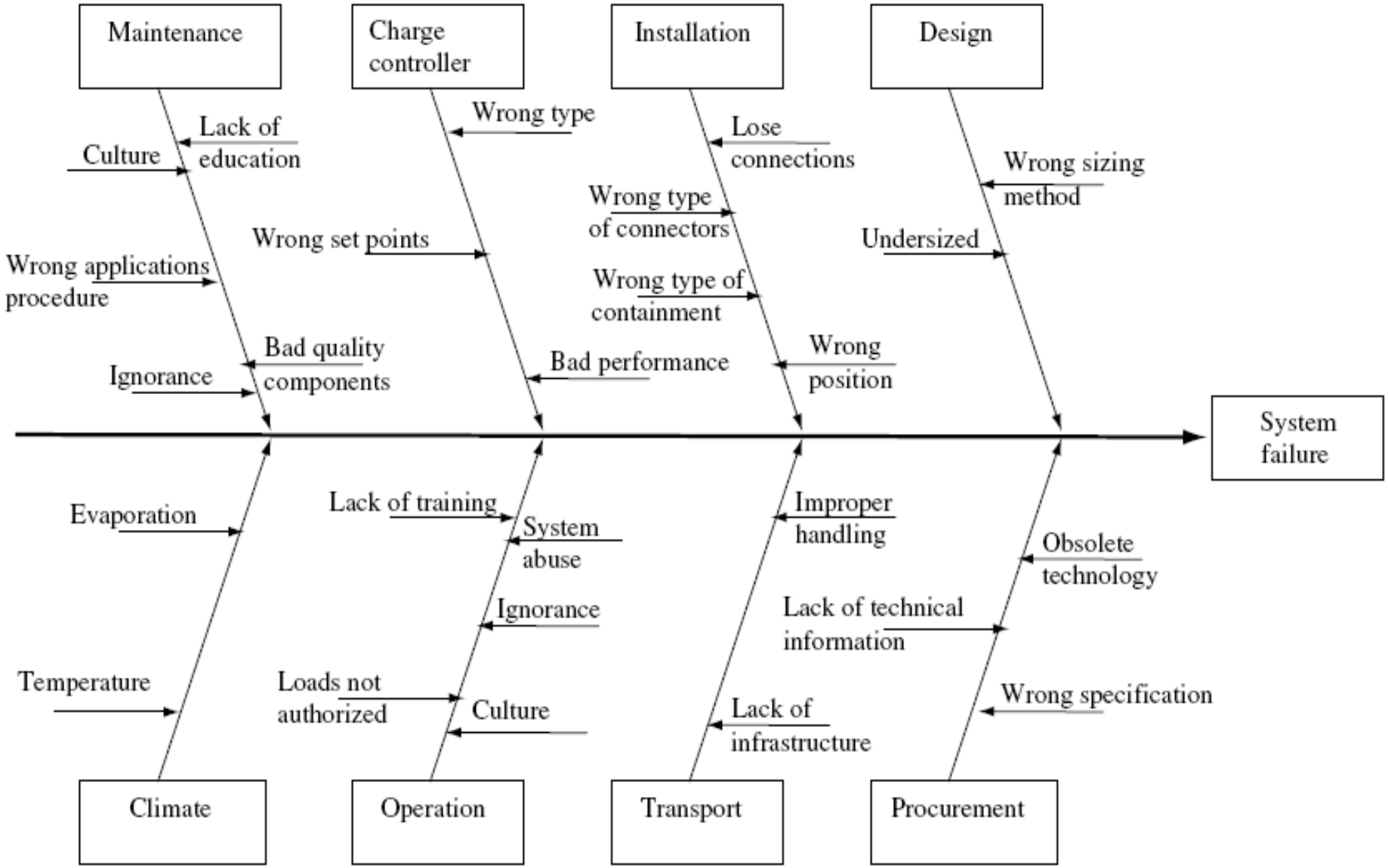




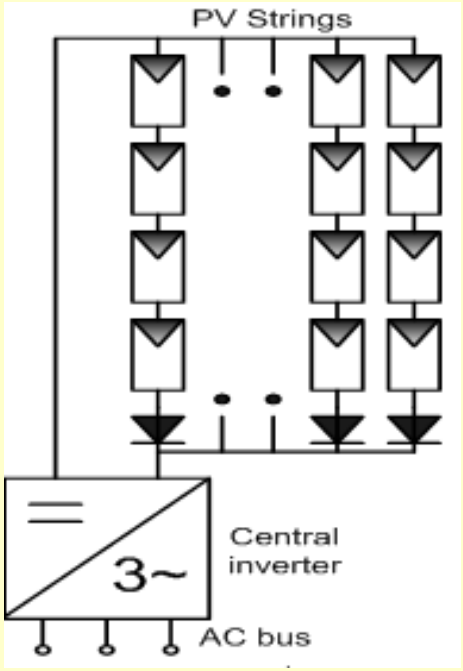
100 GW_p ~ 800 km^2 of PV modules

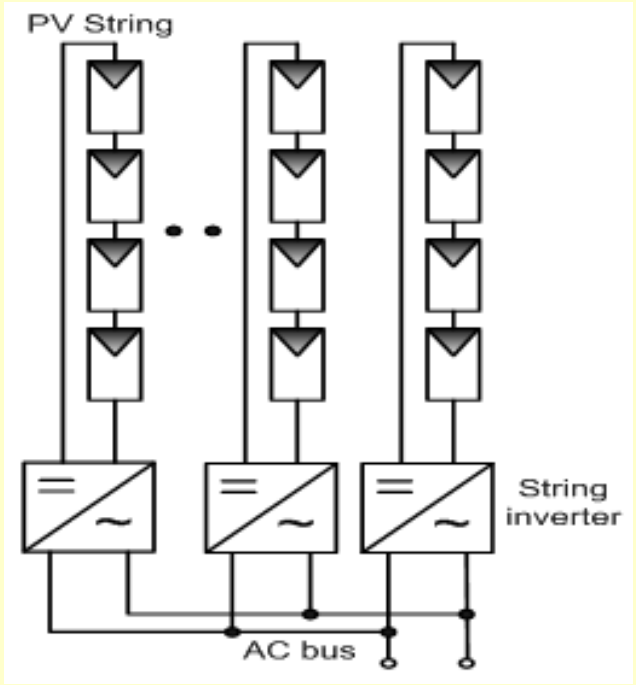
PV Power Station

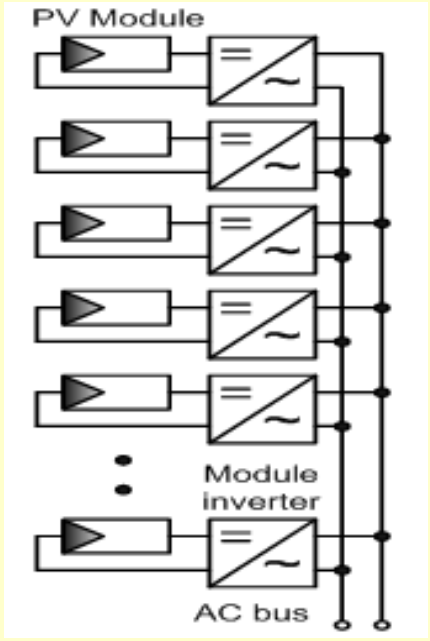



Maintenance
Charge controller
Installation
Design
Lack of education
Culture
Wrong type
Lose connections
Wrong sizing method
Wrong type of connectors
Wrong set points
Undersized
Wrong applications procedure
Wrong type of containment
Bad quality components
Ignorance
Bad performance
Wrong position
System failure
Evaporation
Lack of training
System abuse
Improper handling
Obsolete technology
Ignorance
Lack of technical information
Temperature
Loads not authorized
Culture
Lack of infrastructure
Wrong specification
Climate
Operation
Transport
Procurement

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

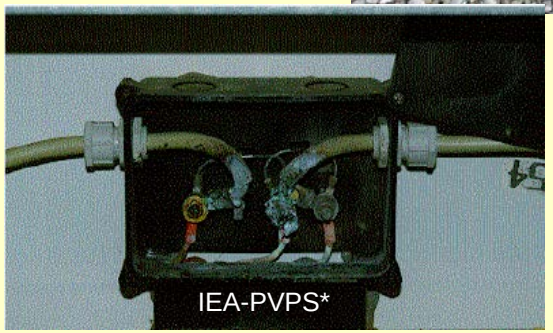
- 50-180W, each panel has its own inverter enabling optimal MPPT
- Lower efficiency, difficult maintenance
- Highercost/kWp

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_p power station in Veprek (20 km from Prague)

- 186 960 panels rated at 185W_p and 190W_p 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)

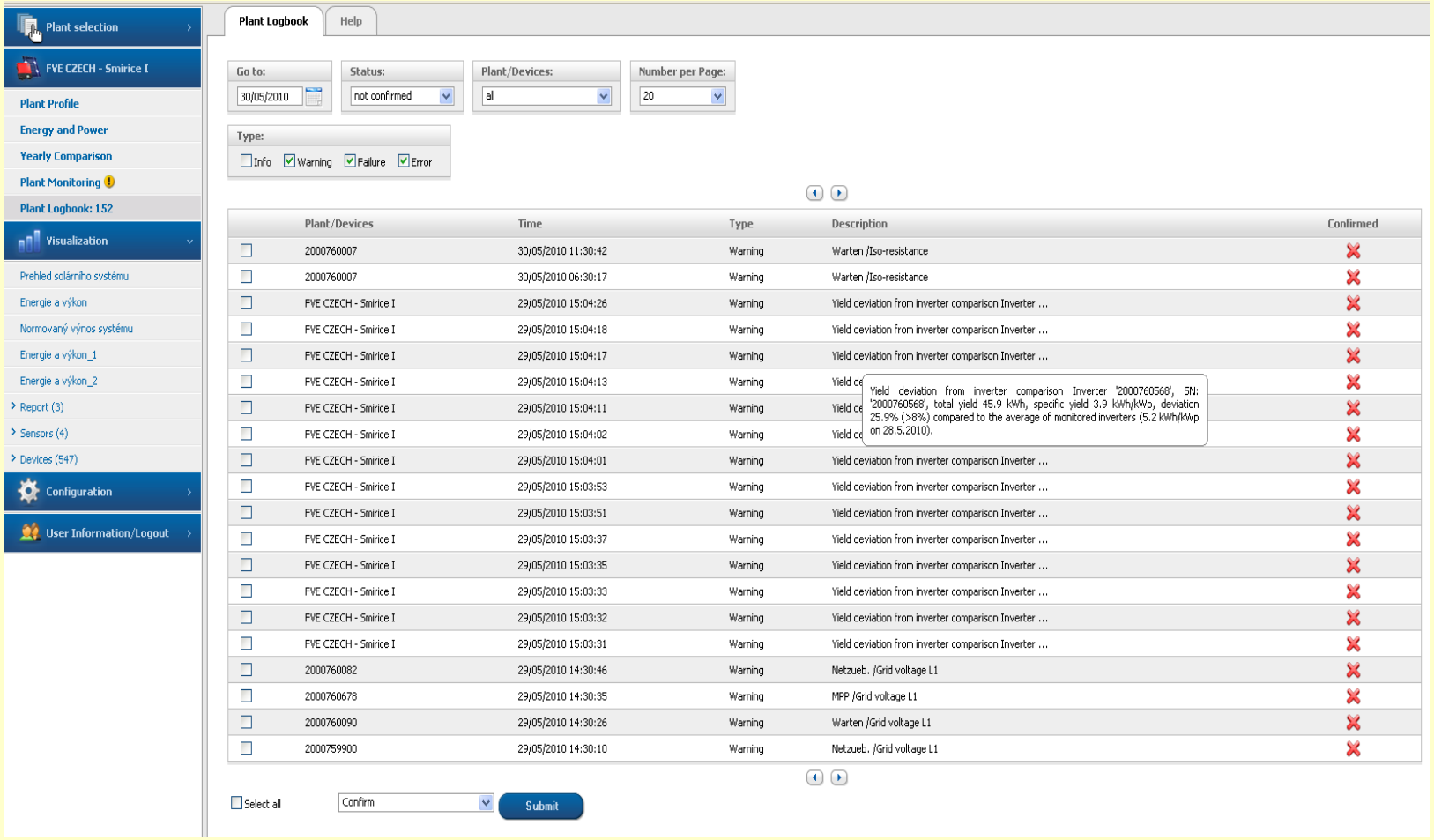
A) Data collection system

• 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)



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)

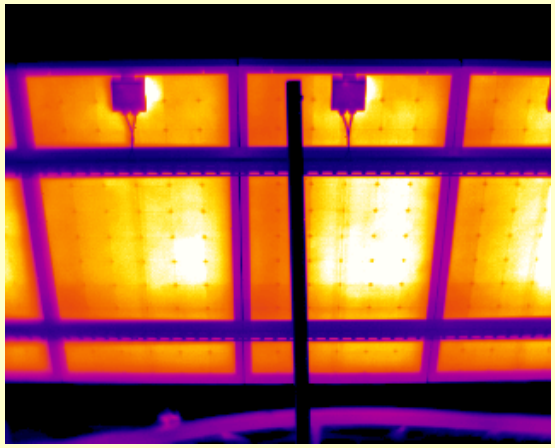
D) checking the faulty string

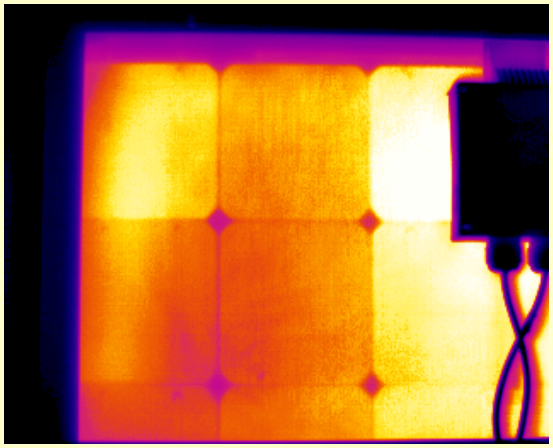
- should be done and voltage measurement conducted
- to localize a faulty connector, it is necessary to measure the modules as pairs

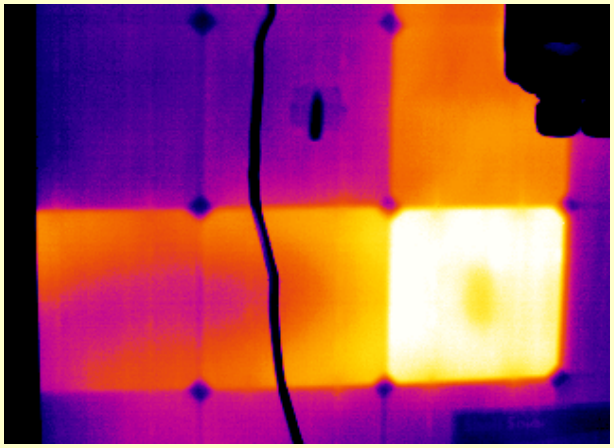
E) check the temperature distribution

- under load over the modules can be evaluated using IR camera

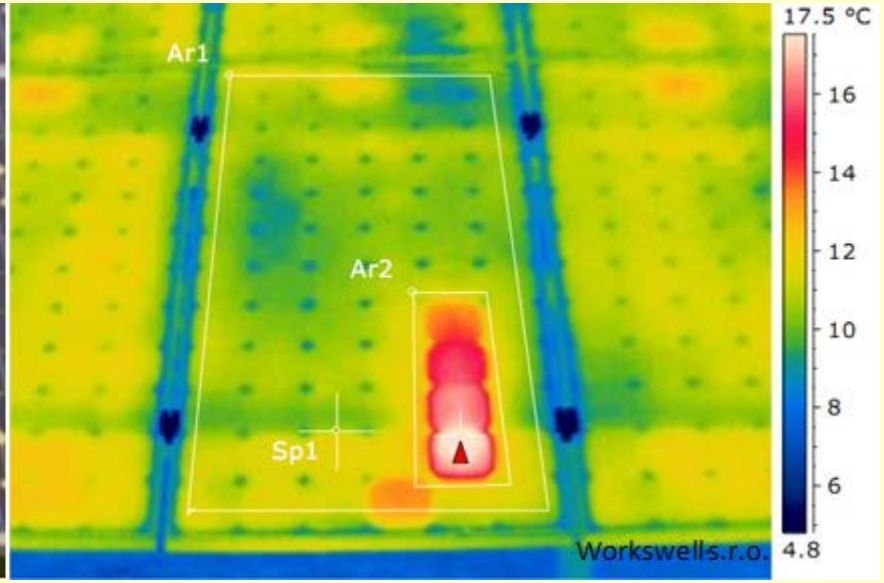
- ”Hot spot” appears together with the presence of local shading or when a single cell is cracked/damaged

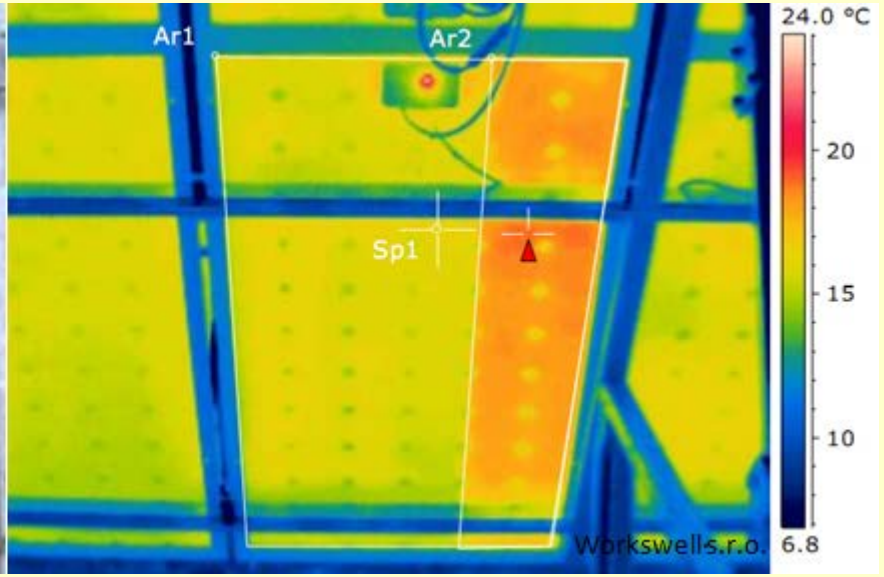




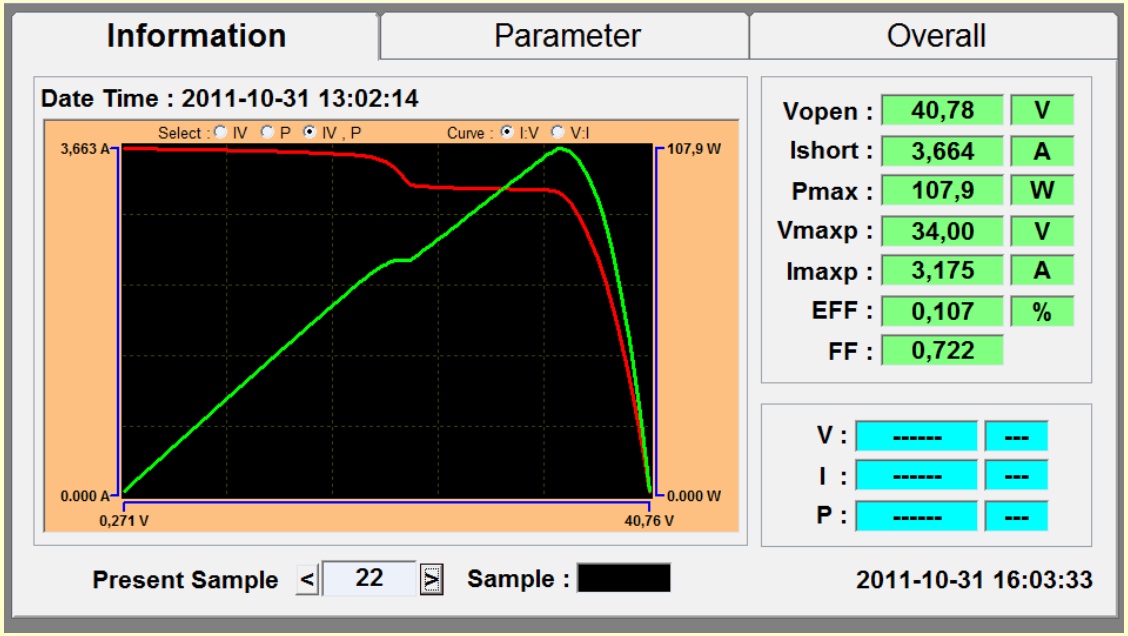


Problematic parts of the PV systém can be detected

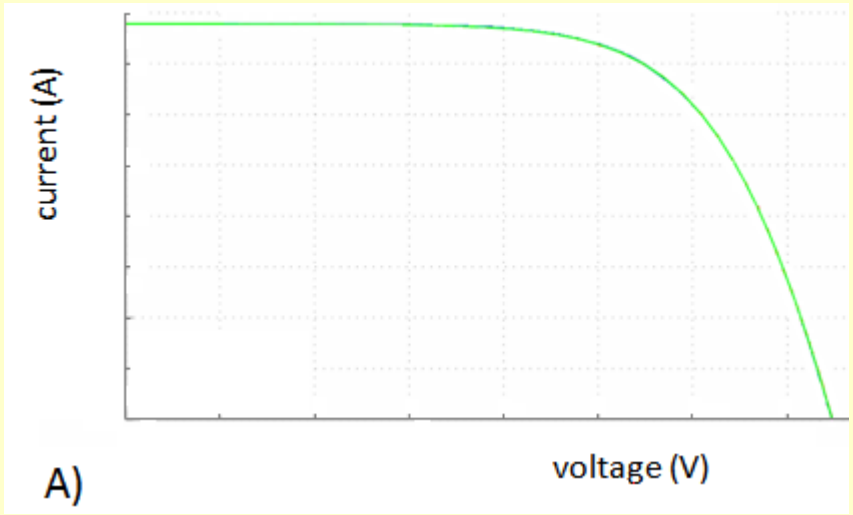

Ar1
Ar2
Sp1
Workswells.r.o.
17.5 °C
16
14
12
10
8
6
4.8


Ar1
Ar2
Sp1
Workswells.r.o.
24.0 °C
20
15
10
6.8

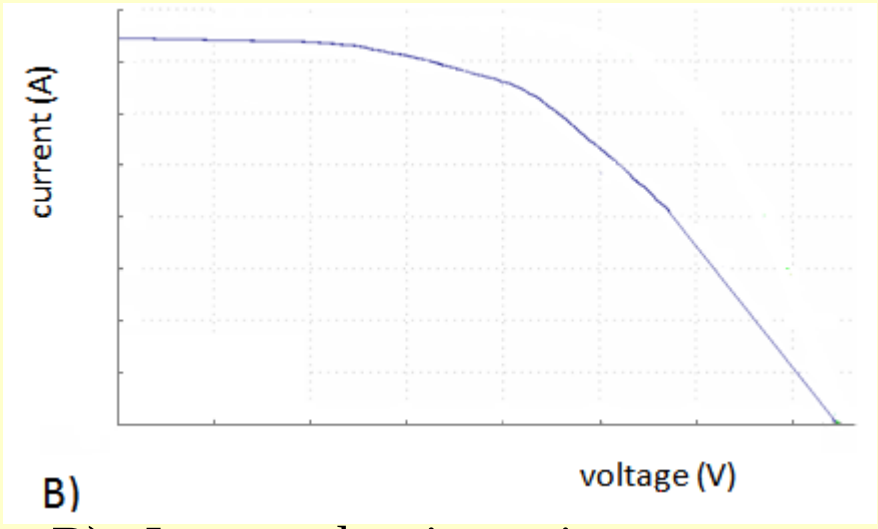
F) checking the I-V characteristic (in field)



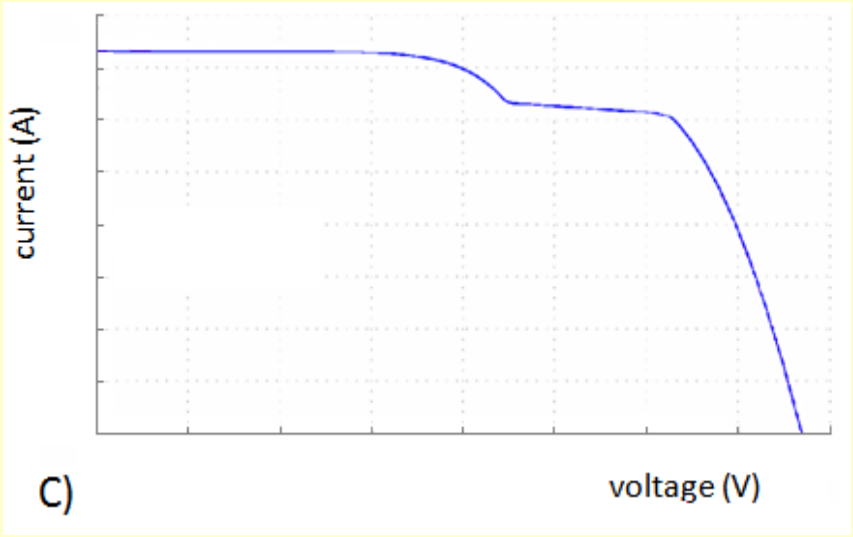
F) checking the I-V characteristic



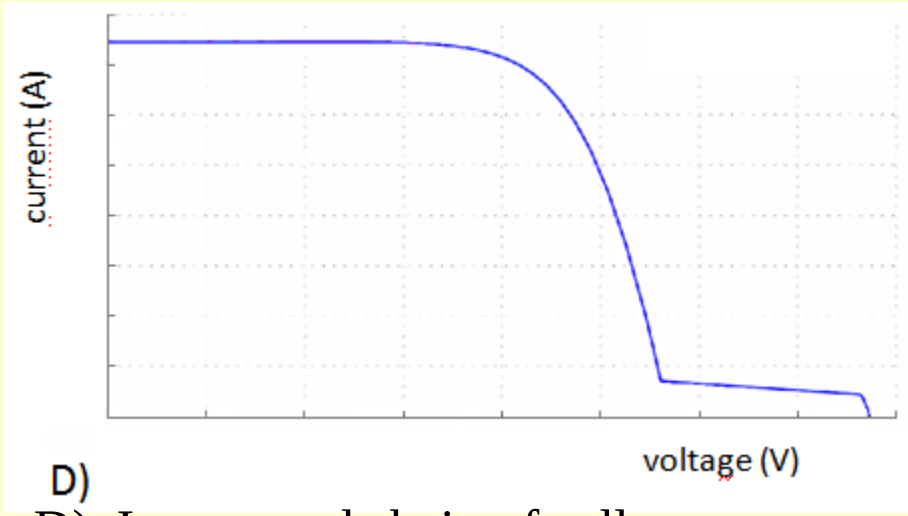
A) Common I-V curve characteristics



B) Increased series resistance



C) Cracked or partially shaded cell

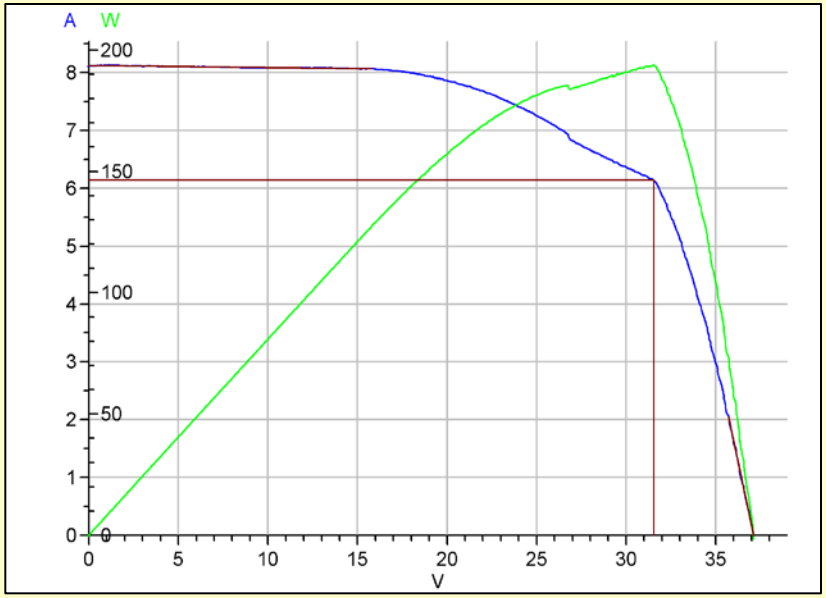


D) Interrupted chain of cells or completely shaded cell

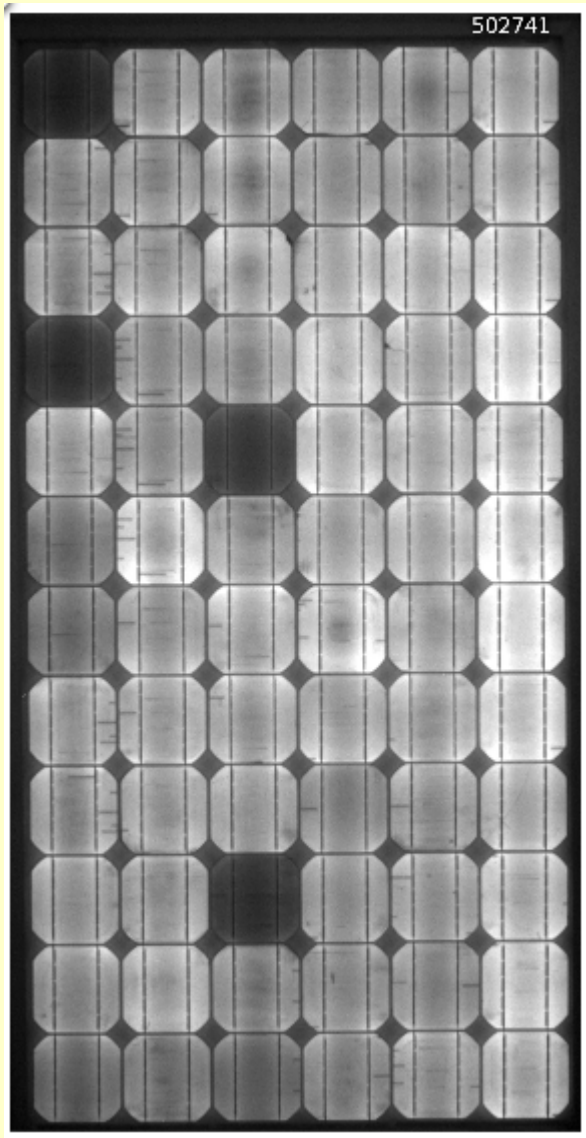
Changing defect parts

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.