Karlsruher Institut für Technologie

Stationary Energy Storage Systems

Nina Munzke

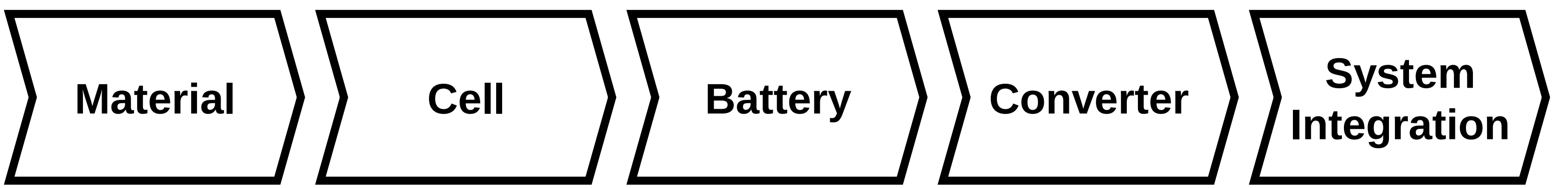
Competence E

Competence E

- Competence E combines research activities along the value chain for Li-Ion Batteries

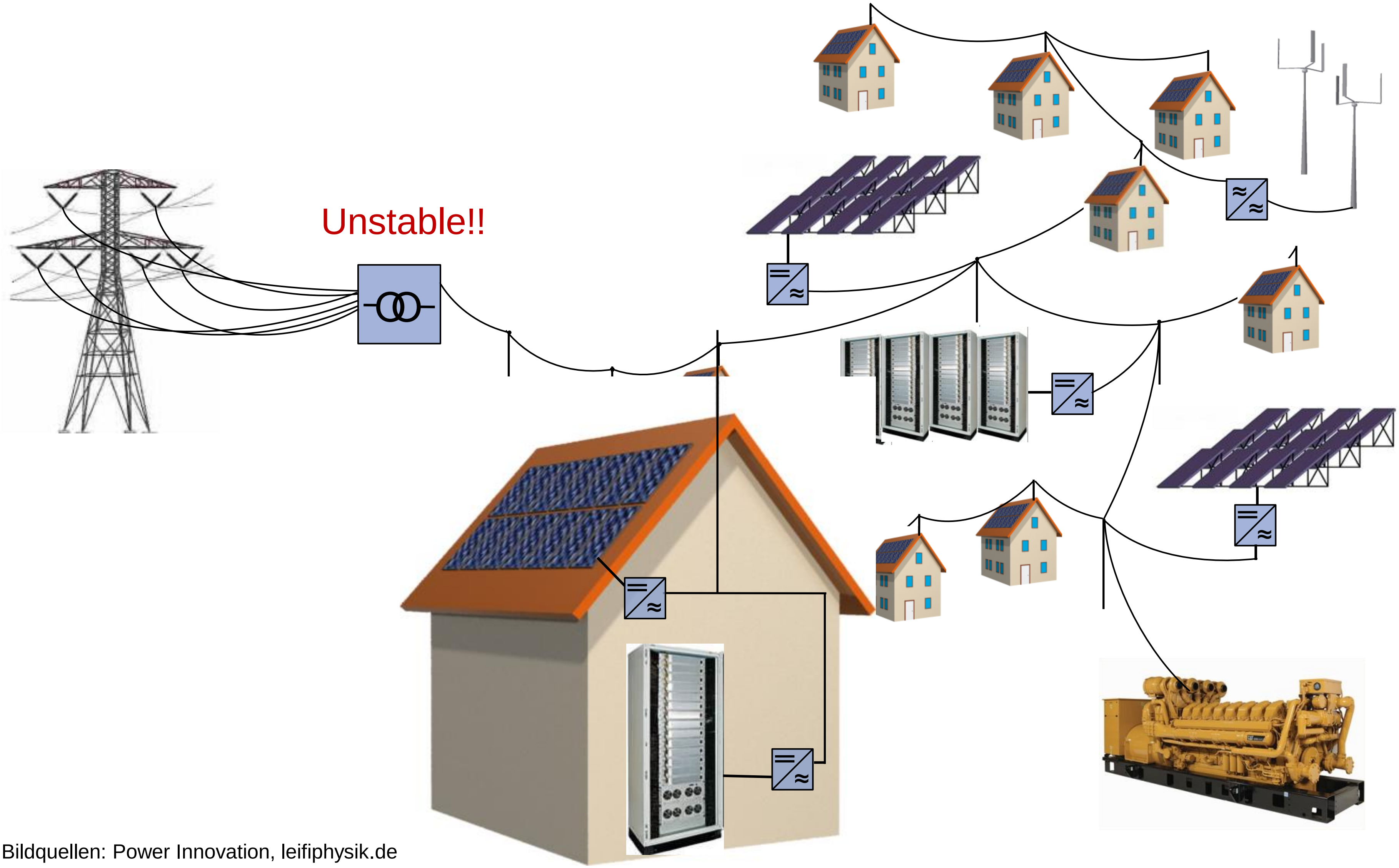
➡ stationary and mobile applications

- **Aim:** Cost-effective product design and production technologies



- **Research activities** : High-energy materials, Compact cell designs, Modular battery designs, System integration

Island Grid - Micro Grid with Renewable Sources, Batteries and Diesel Generator



Bildquellen: Power Innovation, leifiphysik.de

Installation of BESS in DC coupling 50-250 kWp

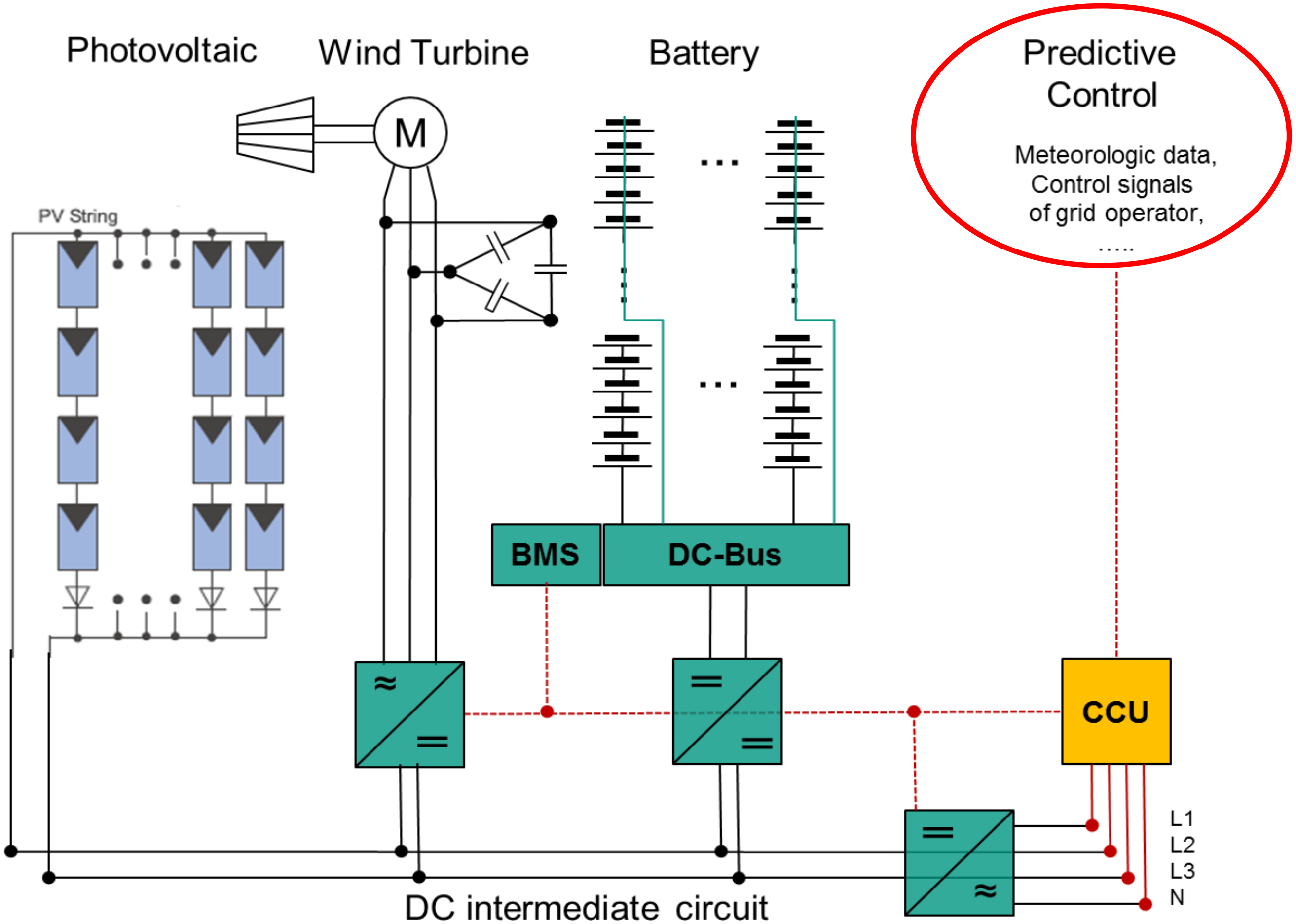
Power module 250 kWp

Energy module (battery) 50 kWh

PV field 37 kWp

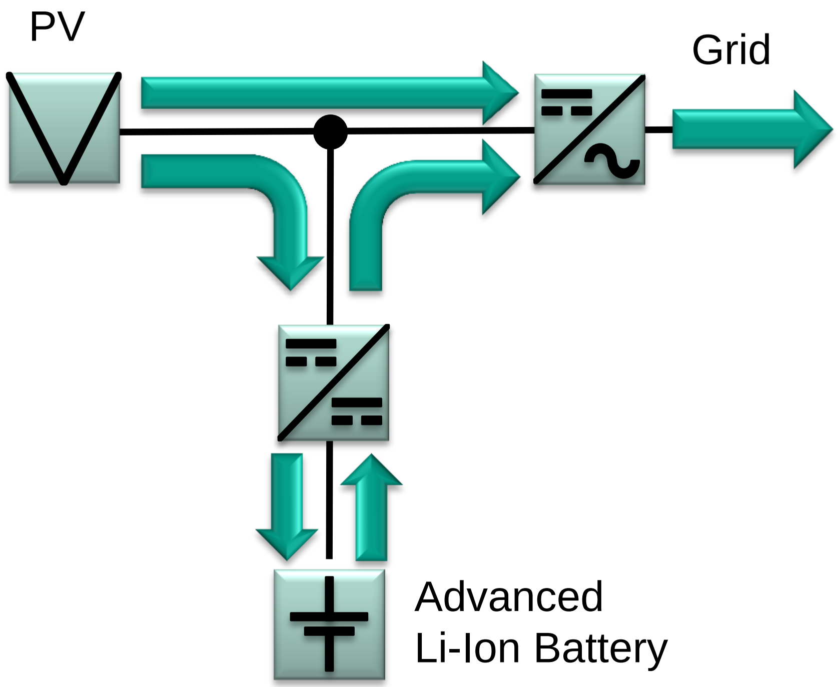
➔ System will start its operation on an Greek island beginning of 2015! Replacement of diesel generators

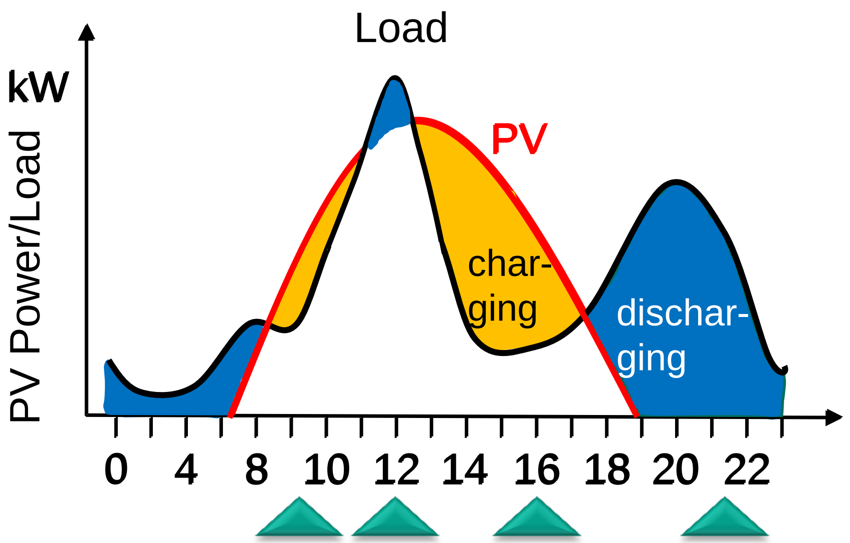
System Design - DC linked System



➡ Fluctuating energy production can be controlled by an intelligent predictive control!

Battery Energy Storage System "BESS"

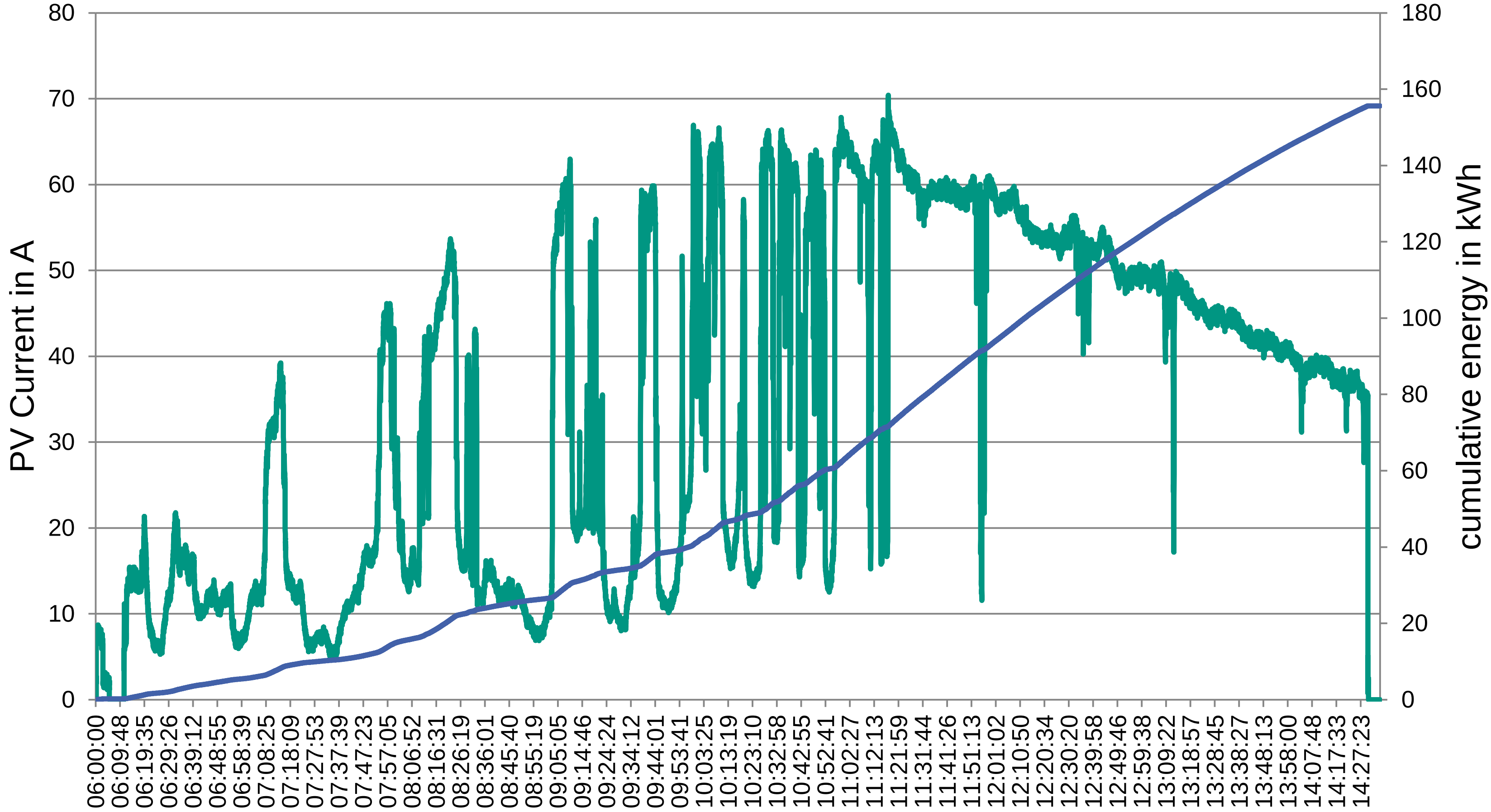




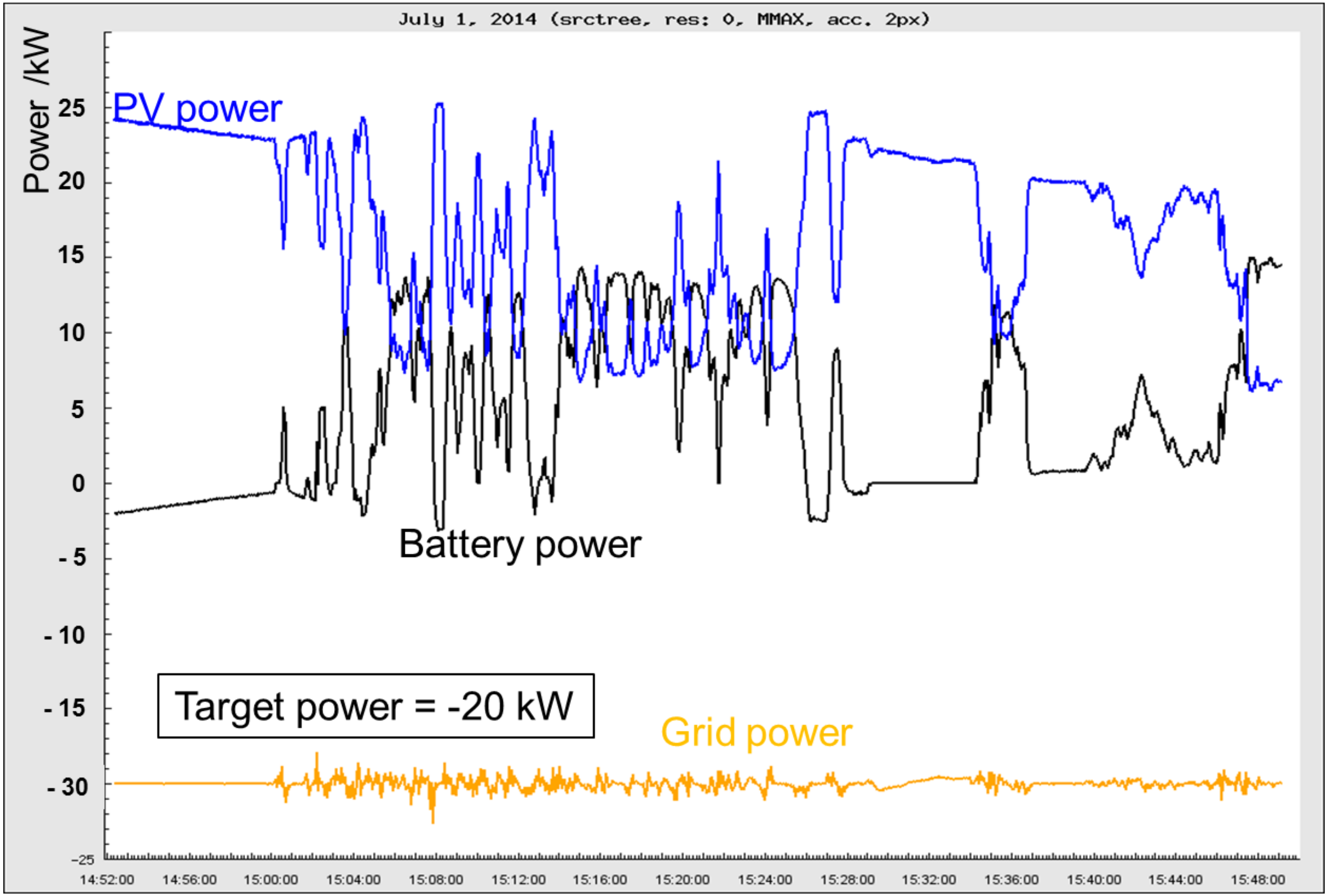
Areas where challenges are faced according to "Big Data":

- System control
- Data analysis
- System sizing

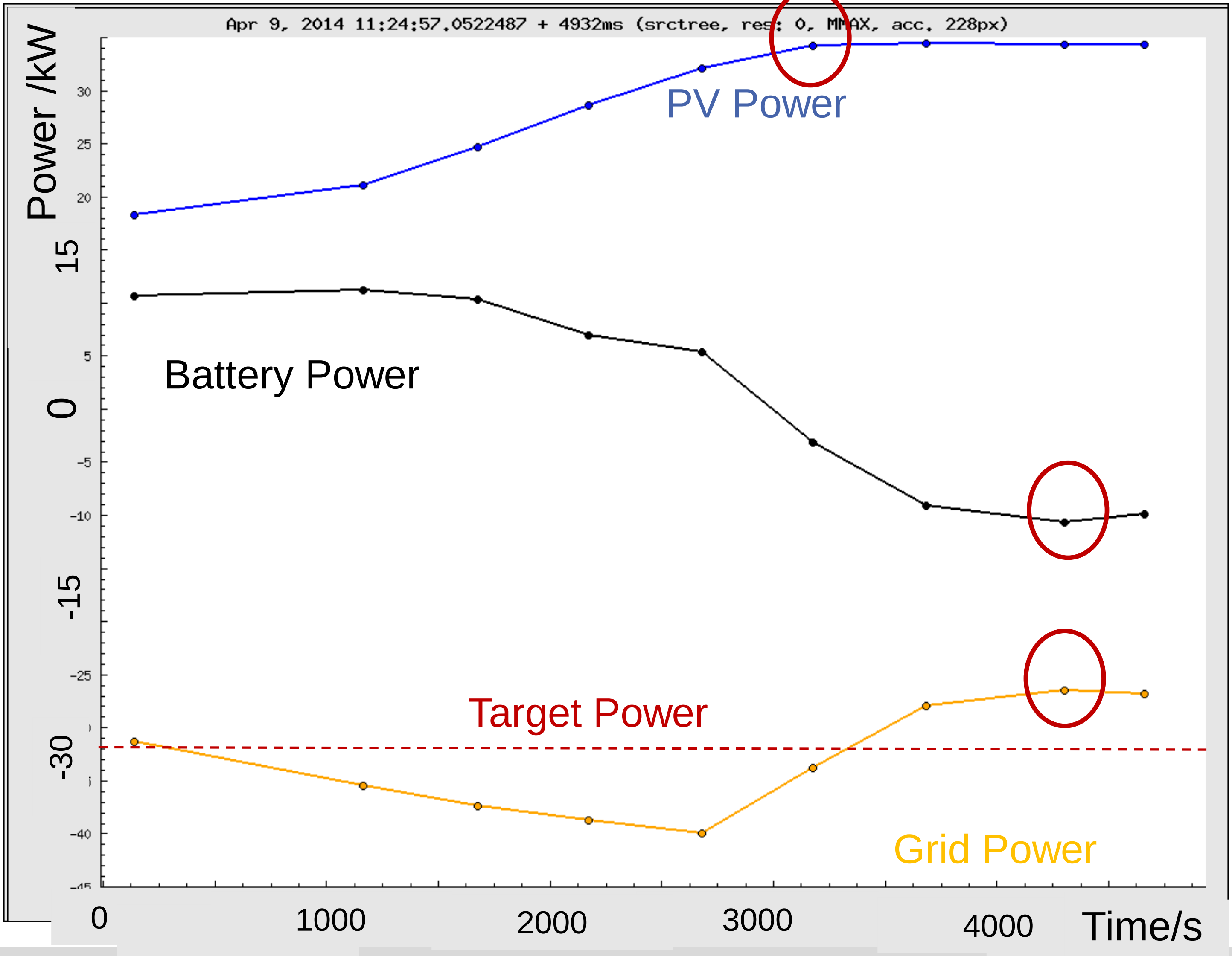
Characteristic Fluctuation Frequencies of PV-Generators



Measurement 1st July 2014 - Constant Load Profile

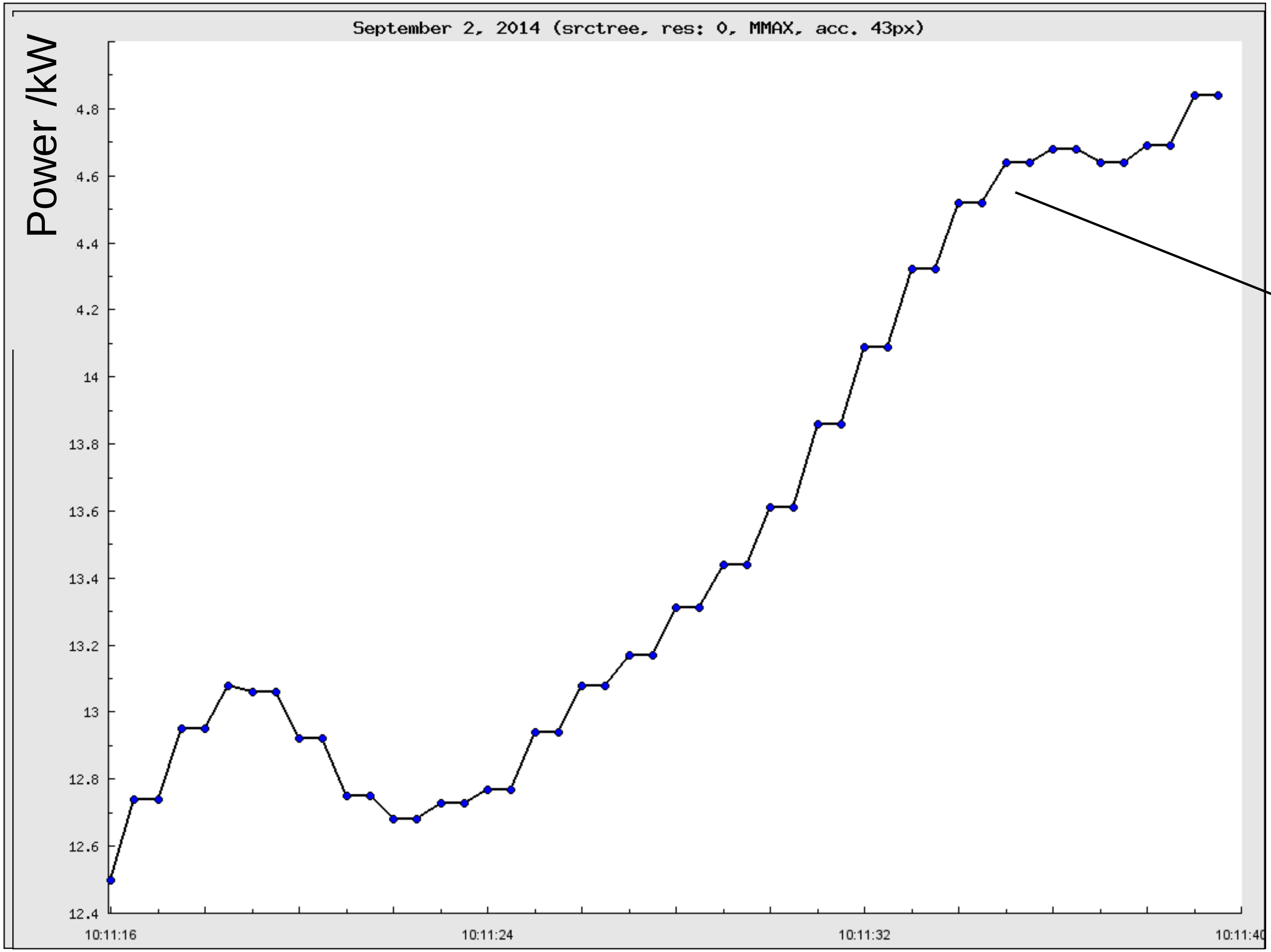


Importance of Fast Data in Storage Systems



➔ **Forward looking algorithm is needed – prediction of PV-power**

Importance of Fast Data in Storage Systems



Problem: slow rates of sensors

Importance of Fast Data in Storage Systems

Karlsruher Institut für Technologie

- Reliable and accurate control algorithms ➔ fast and accurate data

- Slow data ➔ to dead time in the control algorithm
  - Changes in the process variable are only observed after they take place
  - System is slow to respond to control commands

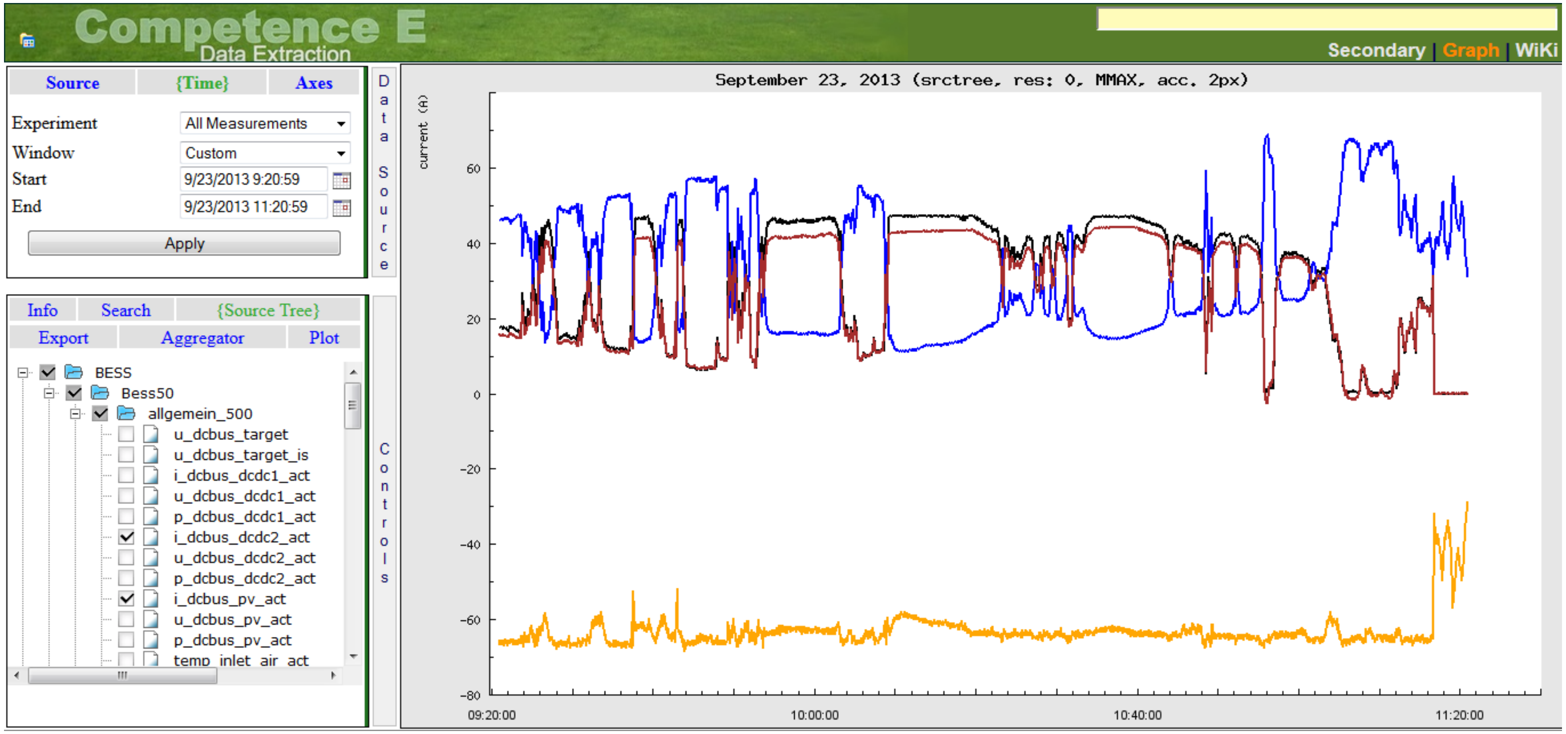
- Cloudy weather ➔ fluctuations of up to 10% /s of peak PV power
  - Battery storage systems can compensate these fluctuations but data rates of around 5 - 10 Hz are required

- Factors that affect data rates
  - Sensors: many current sensors on the market operate at much slower rates (around 1 – 5 Hz)
  - Hardware-software interface
  - Time synchronization of system components

Data Analysis - Status and Performance of PV-Storage Systems

Karlsruher Institut für Technologie

Adei: Web based tool to visualize and export data



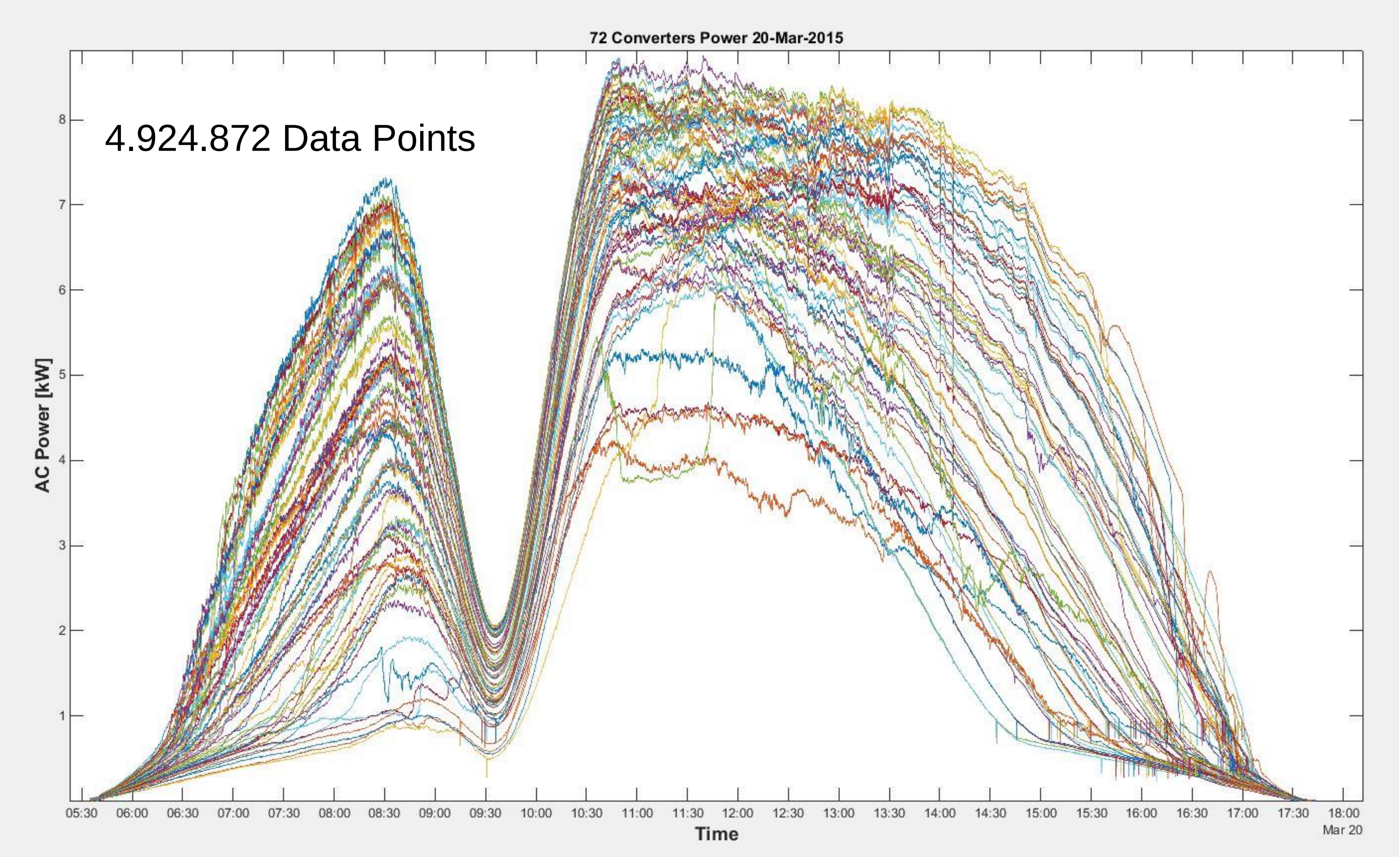
- Data is updated every 1 minute - 5 minutes
- Data sampling rate: 500 ms
- DC-coupled storage system: ~90 status bits, ~ 90 process variables

Experience in Data Analytics in PV and PV-Storage Systems

1 MW PV-plant at KIT starting its operation in July 2014

➔ **102** different tables - **30** different variables per table
➔ **54** different angles
➔ **4** different types of converters, **6** different types of solar panels

Effect of the Eclipse of last Week over 72 different Array Configurations



Different Converters Sampling Rates & Time „Framing“

[4:30 – 23:30] every day

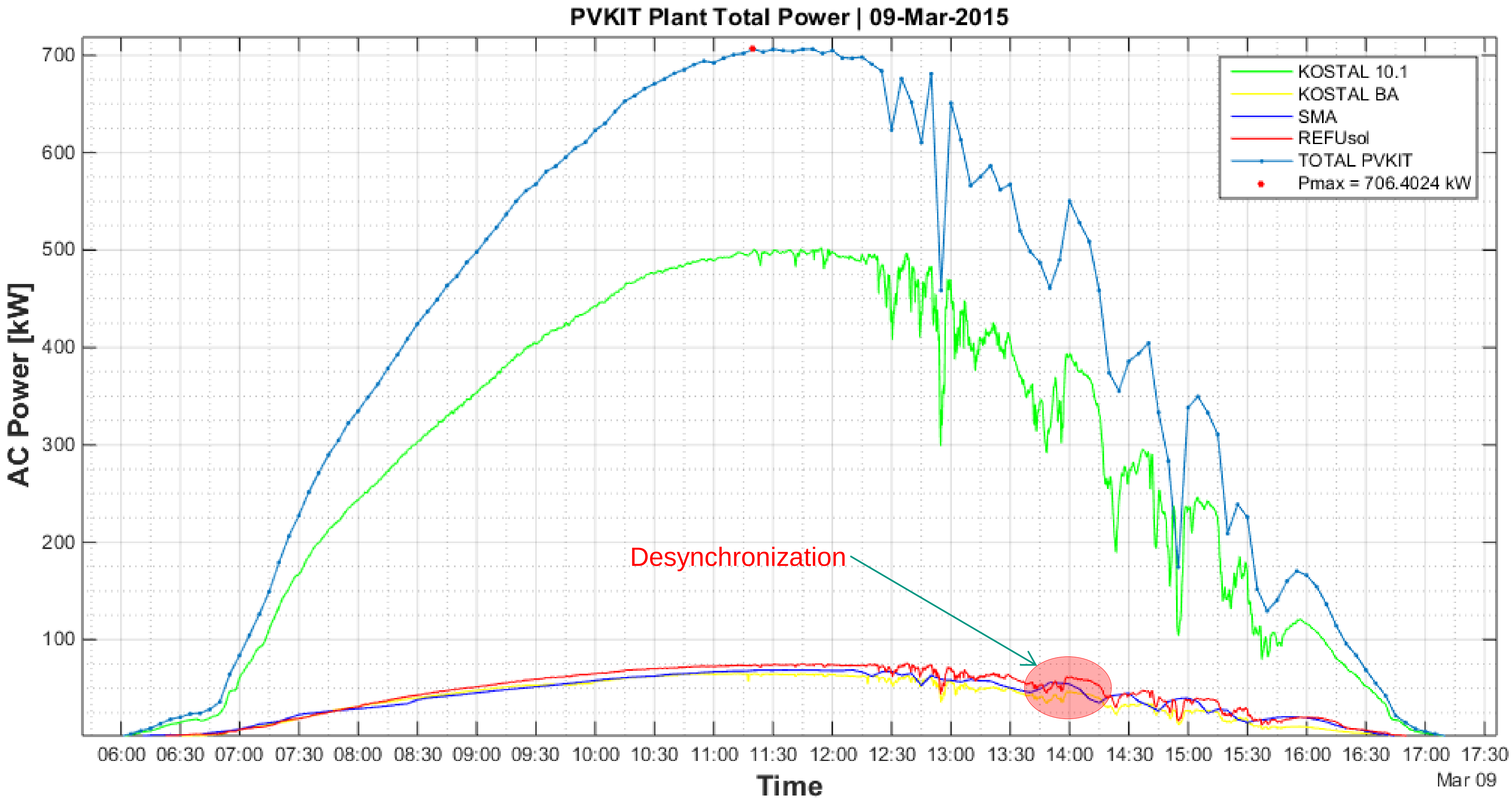
(SR = 5 min) -> 230 values every day

7 kB per table

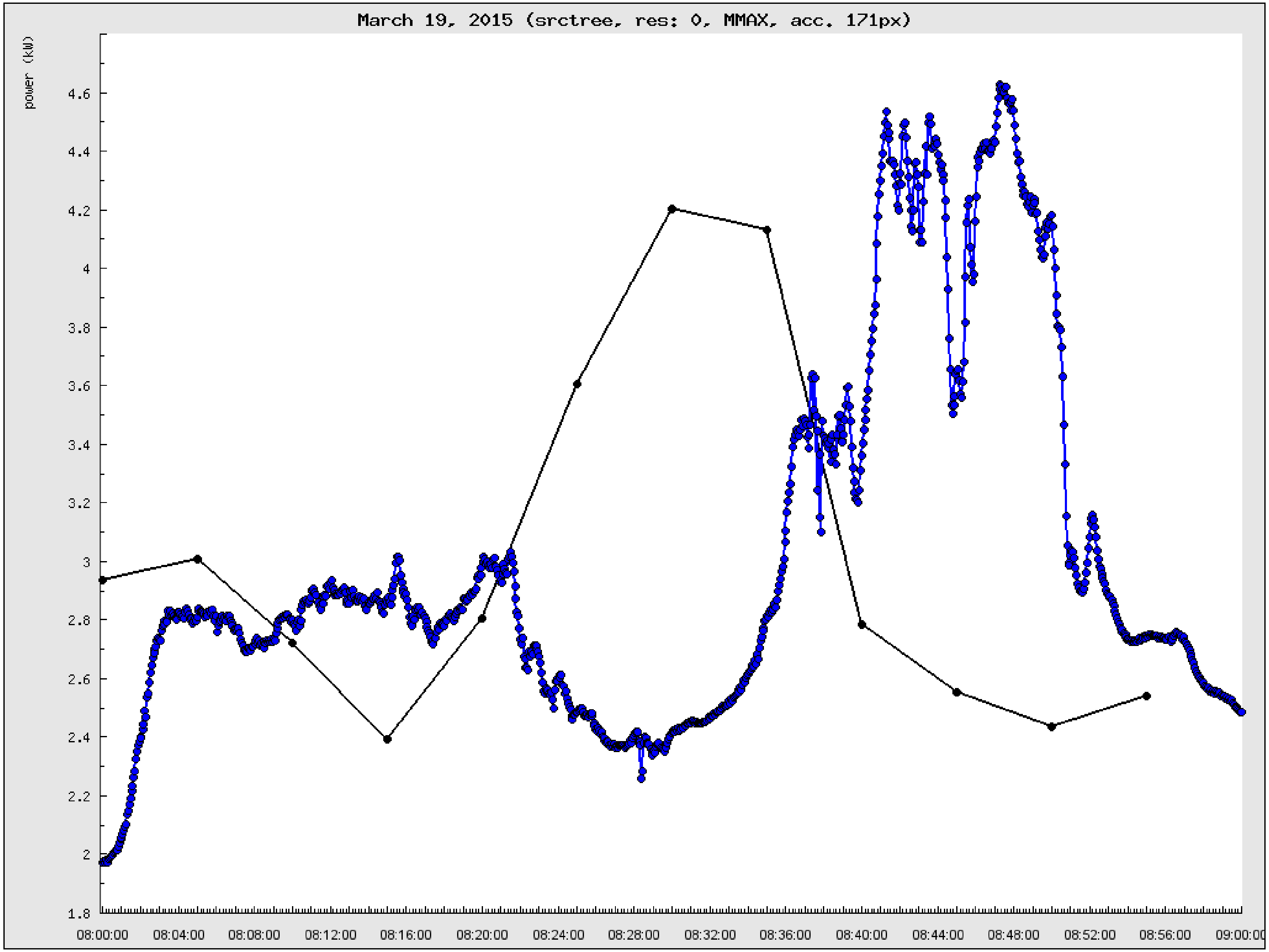
(SR = 1 sec) -> 68.401 every day

~2065 kB per table

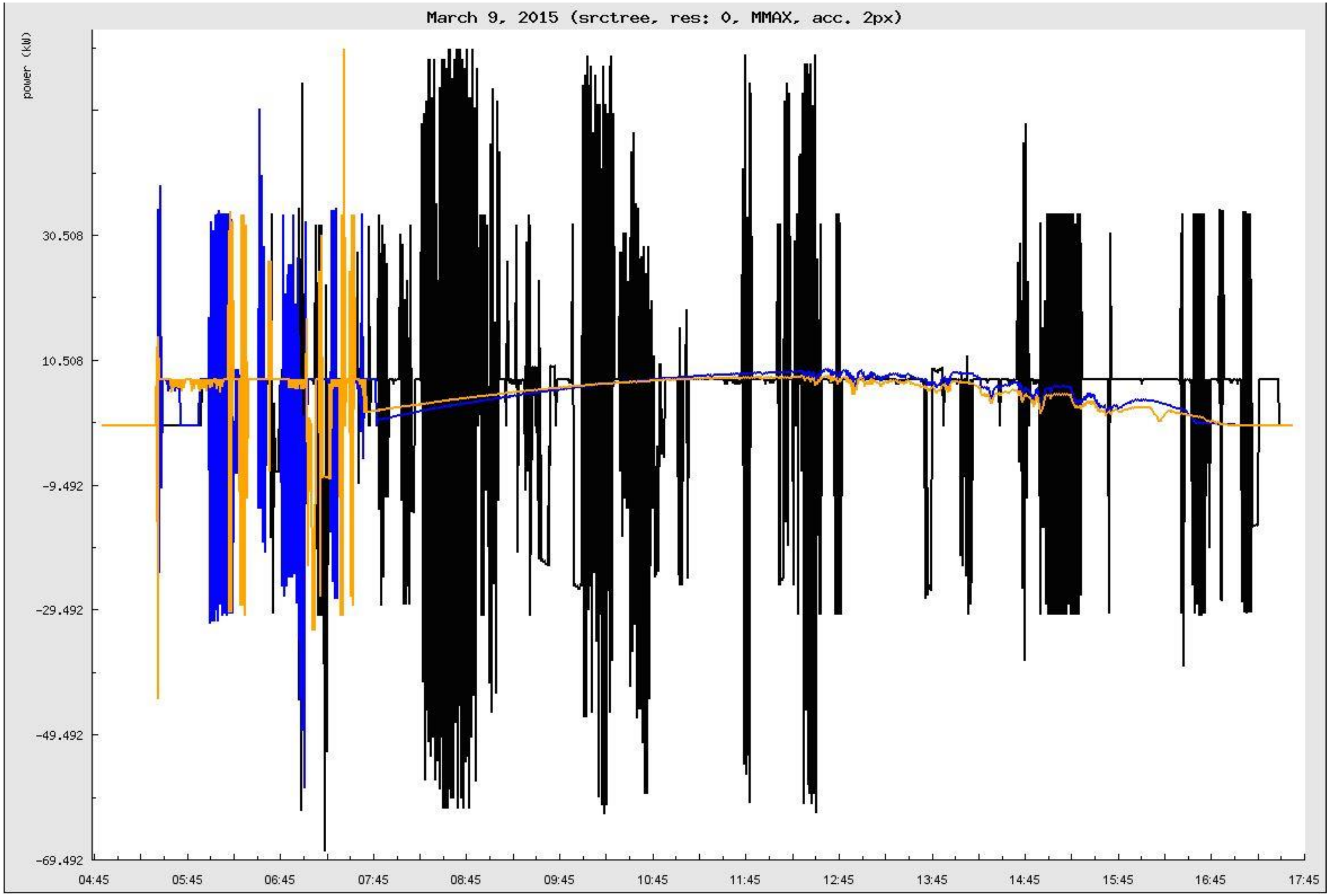
Calculating the Daily Peak Power



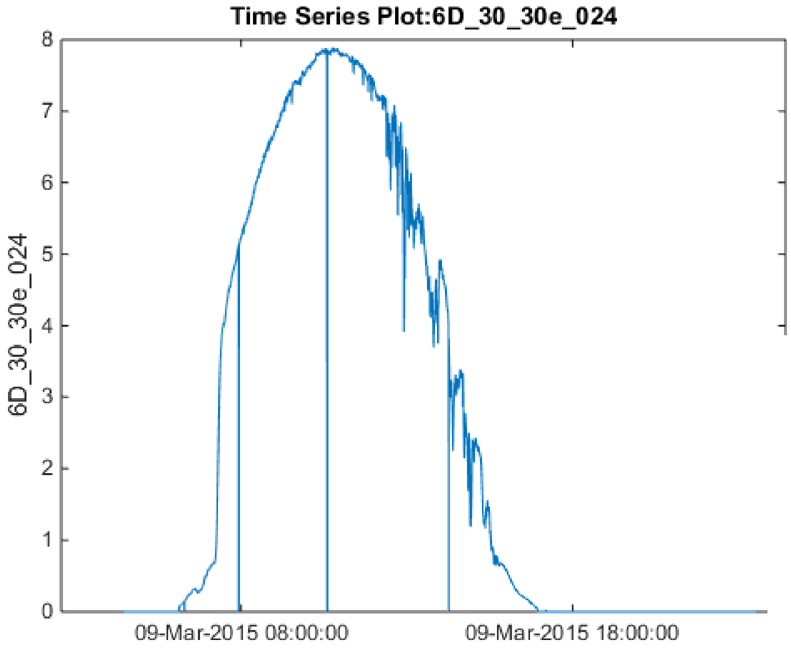
Example of Out of Sync Data



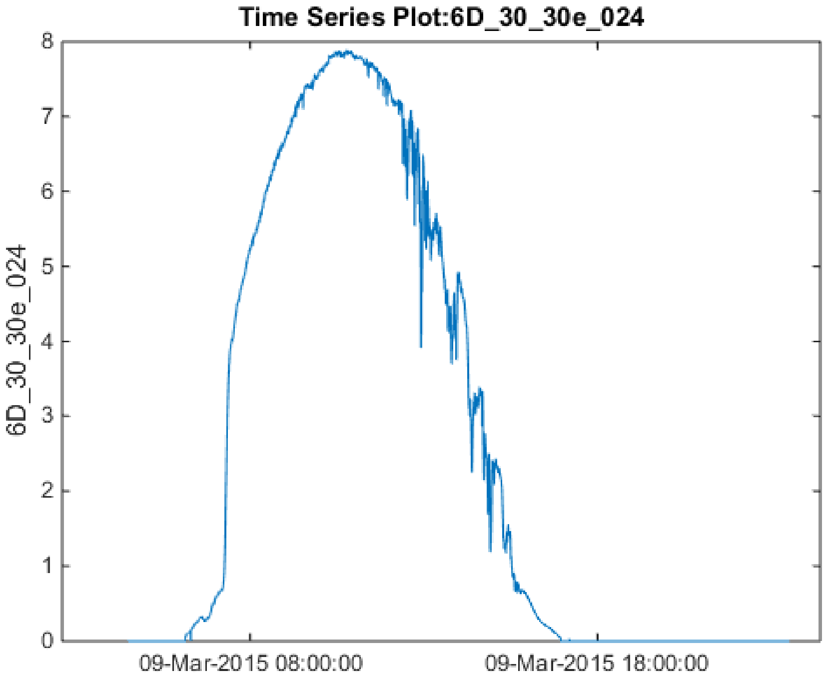
Typical Worst-Case-Scenario of AC Power Noisy Readings during the Day



Filtering Noise and Filling Missing Data

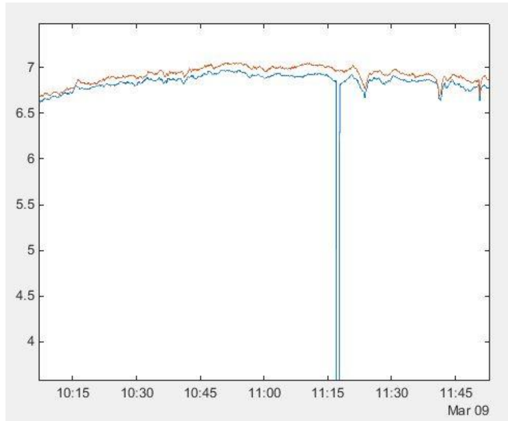


Artificial extreme ramps do not represent cloud-caused events

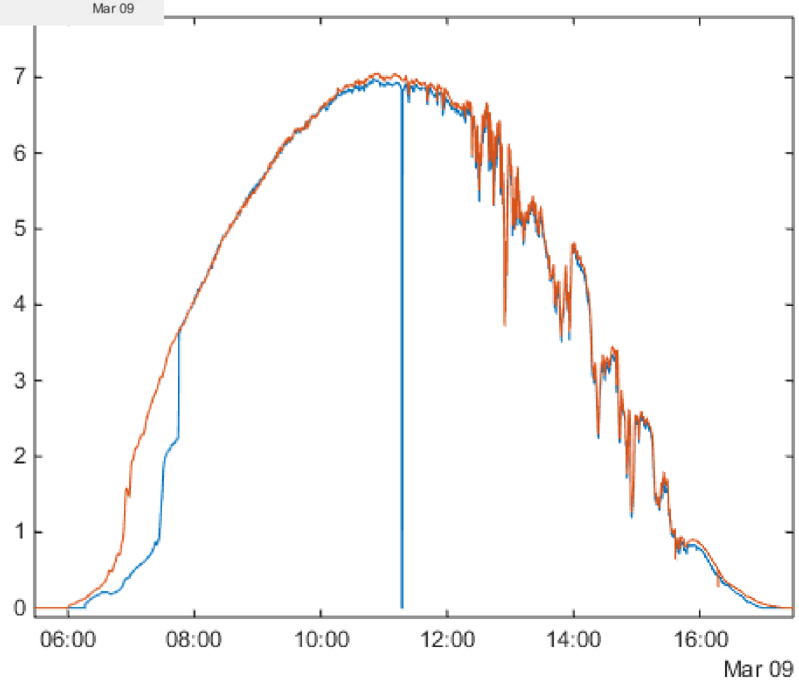


Sensors „Blackouts“

'09-Mar-2015 11:16:57'	6,84900000000000
'09-Mar-2015 11:16:58'	6,84900000000000
'09-Mar-2015 11:16:59'	6,84900000000000
'09-Mar-2015 11:17:00'	6,84900000000000
'09-Mar-2015 11:17:01'	0
'09-Mar-2015 11:17:02'	0
'09-Mar-2015 11:17:03'	0
'09-Mar-2015 11:17:04'	0
'09-Mar-2015 11:17:05'	0
'09-Mar-2015 11:17:06'	0
'09-Mar-2015 11:17:07'	0
'09-Mar-2015 11:17:08'	0
'09-Mar-2015 11:17:09'	0
'09-Mar-2015 11:17:10'	0
'09-Mar-2015 11:17:11'	0
'09-Mar-2015 11:17:12'	0
'09-Mar-2015 11:17:13'	0
'09-Mar-2015 11:17:14'	0
'09-Mar-2015 11:17:15'	0
'09-Mar-2015 11:17:16'	0
'09-Mar-2015 11:17:17'	0
'09-Mar-2015 11:17:18'	0
'09-Mar-2015 11:17:19'	0
'09-Mar-2015 11:17:20'	0
'09-Mar-2015 11:17:21'	0
'09-Mar-2015 11:17:22'	0
'09-Mar-2015 11:17:23'	0
'09-Mar-2015 11:17:24'	0
'09-Mar-2015 11:17:25'	0
'09-Mar-2015 11:17:26'	0
'09-Mar-2015 11:17:27'	0
'09-Mar-2015 11:17:28'	0
'09-Mar-2015 11:17:29'	0
'09-Mar-2015 11:17:30'	0
'09-Mar-2015 11:17:31'	0
'09-Mar-2015 11:17:32'	0
'09-Mar-2015 11:17:33'	0
'09-Mar-2015 11:17:34'	0
'09-Mar-2015 11:17:35'	0
'09-Mar-2015 11:17:36'	0
'09-Mar-2015 11:17:37'	0
'09-Mar-2015 11:17:38'	0
'09-Mar-2015 11:17:39'	0
'09-Mar-2015 11:17:40'	0
'09-Mar-2015 11:17:41'	3,28600000000000
'09-Mar-2015 11:17:42'	3,28600000000000
'09-Mar-2015 11:17:43'	3,28600000000000
'09-Mar-2015 11:17:44'	3,28600000000000
'09-Mar-2015 11:17:45'	3,28600000000000
'09-Mar-2015 11:17:46'	6,28800000000000



T019 Normal (10.1)
T020 Missing (BA)



Experience in Data Analytics in PV Systems

- Different brands and types of converters ➔ different type of sensors, sampling rates and methods to retrieve the data
- Dealing with missing and erroneous data ➔ repeated time-stamps, converters that are out of service
- Synchronizing all the data ➔ displacing measured values to a common time reference in order to be sum or compared - Time-Server ?
- Resampling data to a different Sampling Rate ➔ comparison or just for compressing.

Experience in Data Analytics in PV Systems

- Run Test of all the converters➔ avoid errors due to extraordinary scenarios, e.g. no working array (empty array)

- Visualizing and plotting tools must be efficient

- Data processing and filtering is important
  - Large volumes of data need to be filtered
  - Desired information should be extracted from data before plotting

Simulation and Sizing of Systems

Simulation and Sizing of Systems

- Components of the System: PV (size and orientation) + Battery (size) + power electronics (size)

- Aim: Identifying the optimal size of the different components
  - ➔ adjusted to the load profile of the future system operator
  - ➔ most cost effective combination

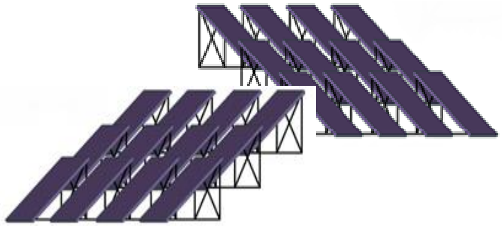
- Input data: Load curve of the system operator
  Solar radiation at the specific location

February June

Simulations and Sizing of PV-Storage Systems

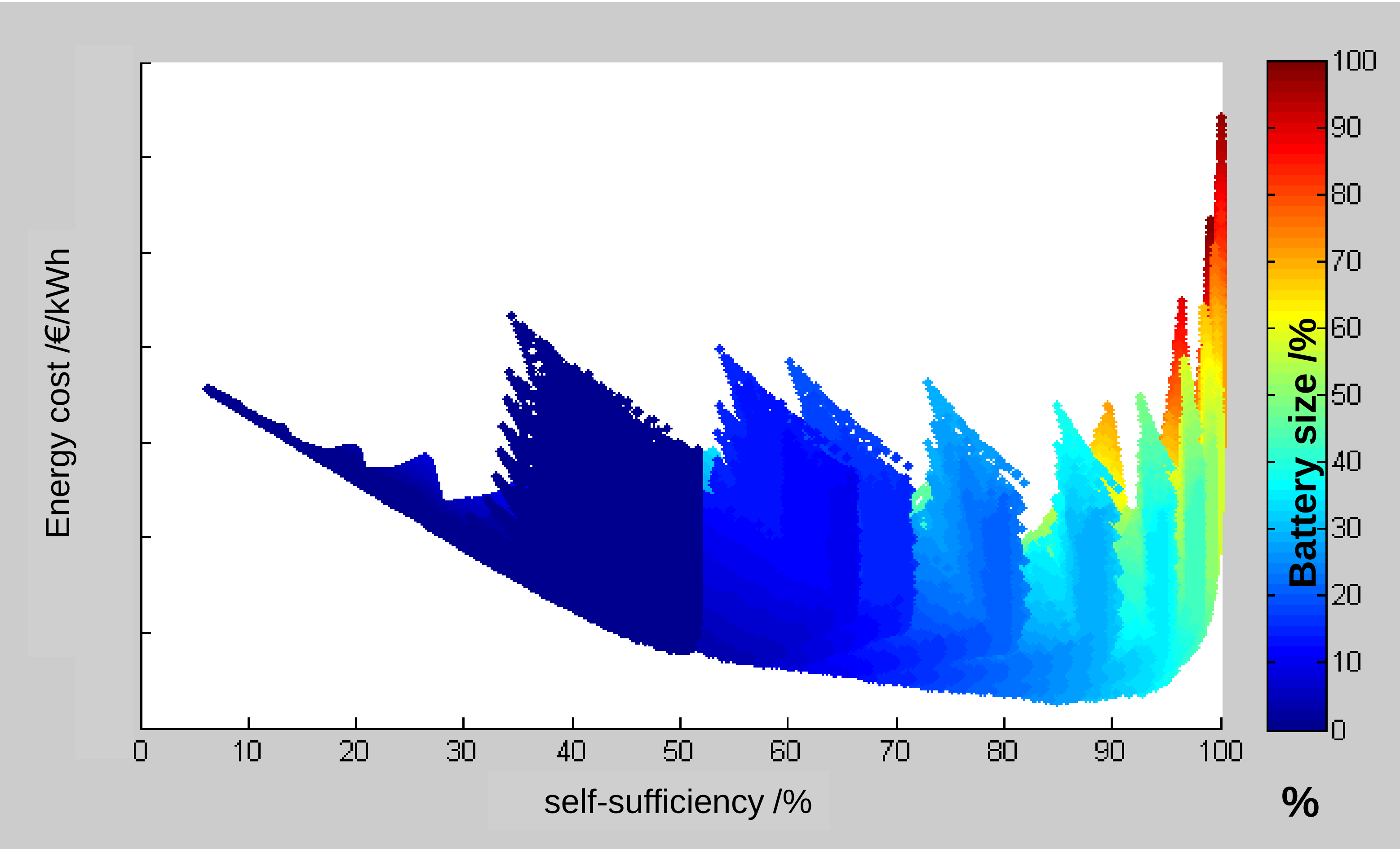
Variety of different configurations :

- PV:
  - 10 different sizes of the total PV field
  - 10 different sizes of PV field one
  - 8 different angels of orientation
  - 4 different angels of inclination
- Battery:
  - 10 different sizes
- DCDC:
  - 5 different sizes
- DCAC
  - 5 different sizes



52.800 * 10 * 5 * 5 = 13.2 Mio.

Energy Costs - Comparison of Different Orientations of the PV Plant and Battery Sizes



Optimal size of a PV-storage system can be detected out of around 2.5 Mio alternatives

Storage and big data

Karlsruher Institut für Technologie

- Simulation and data analysis are becoming important parts of storage system development
- Many software tools used in industry struggle to handle large volumes of data
- Computing power affects simulation:
  - Software must be correctly designed to use memory effectively
  - Software tools with graphic user interfaces are often too slow

Thank you very much for your attention!