Karlsruher Institut für Technologie

Gefördert durch:

Bundesministerium für Wirtschaft und Technologie

aufgrund eines Beschlusses des Deutschen Bundestages

Reliable and Economic Island, Microgrid and Grid Supply with Renewable Energy using Electrochemical Storage

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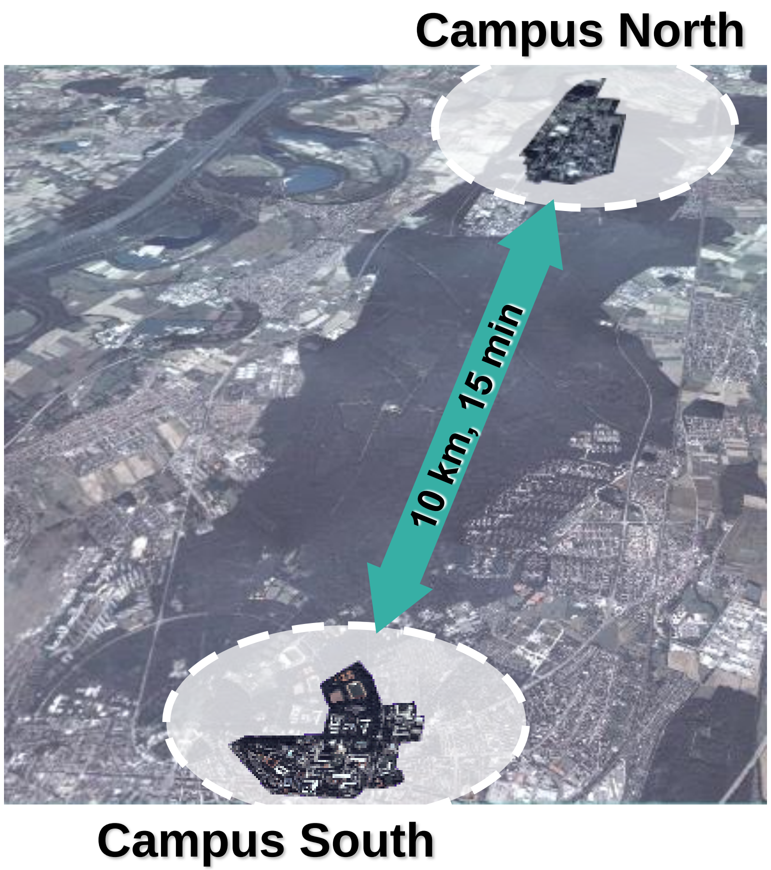
Competence E

KIT – Facts and Figures



- University AND Federal Gov. Lab
- 9.000 Employees
- 700 Mio.€ Budget
- 160 Institutes
- 372 Professors
- 22.800 Students

Competence E: System Competence along the Value Creation Chain

Alignment by continous management structure

Material → **Cell** → **Battery** → **Inverter** → **E-Motor** → **System**

New Materials

New Cell Designs

New Battery Designs

New Manufacturing Methods

250 €/kWh at 250 Wh/kg on system level in 2018

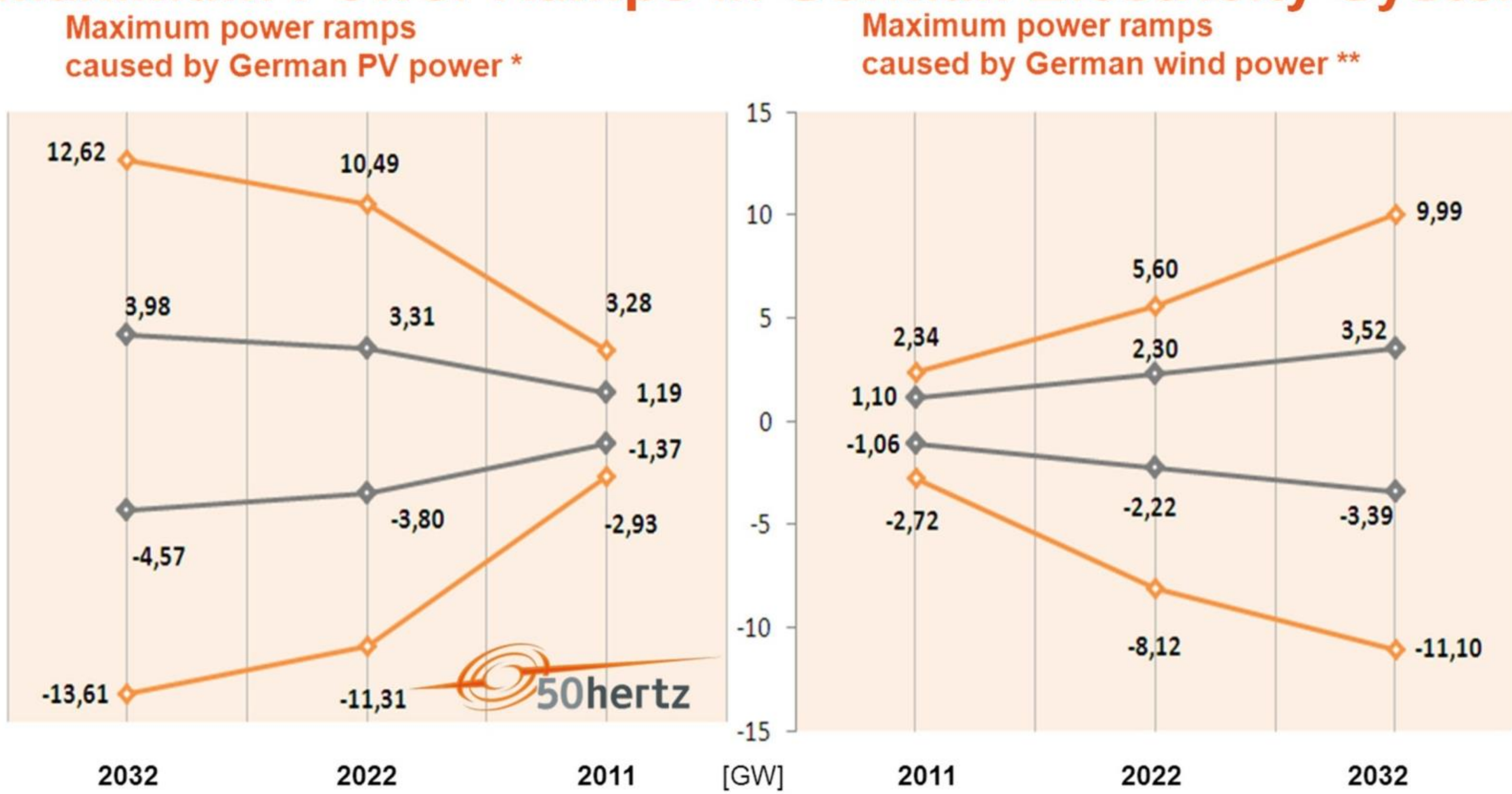
Energy Strategy of the German Federal Government

Competence E

	GHG Emissions	Replacement of Fossiles by Renewables		Reduction of Fossiles Consumption				End of Nuclear
	Treibhaus-gas-Emissionen	Erneuerbare Energien		Minderung Energiebedarf				Kern-energie
		Brutto-Endenergie	Strom-erzeugung	Primär-energie	Gebäude-Wärme	End-energie Verkehr	Strom-verbrauch	
2011								**-41%**
2015								**-47%**
2917								**-54%**
2019								**-60%**
2020	**-40%**	**18%**	**35%**	**-20%**	**-20%**	**-10%**	**-10%**	
2021								**-80%**
2022								**-100%**
2030	**-55%**	**30%**	**50%**					
2040	**-70%**	**45%**	**65%**					
2050	**-80 bis -95%**	**60%**	**80%**	**-50%**	**-80%**	**-40%**	**-25%**	
Basis	1990	-	-	2008	2008	2005	2008	2010

Quelle: BReg 2010/2011, Berechnungen des Öko-Instituts Freiburg im Auftrag des BMU vom 28. März 2012

Maximum Power Ramps in German Electricity System



* Installed **German PV power** for 2011 was **19,47 GW** (*source: "Stammdatenbank" of the four TSO's*)

** Installed **German wind power** for 2011 was **28,82 GW** (*source: IWES "Windenergiereport Deutschland 2011"*)
In 2022 and 2032 the data of the installed power as well as the 1 hour ramps can be found in "Leitszenario (B)" of the NEP (*source: plan for the development of the German transmission grid: "Netzentwicklungsplan 2012"*). The ¼ hour ramps for the years 2022 and 2032 are linearly extrapolated by using the maximal ramps per ¼ hour of 2011 (*source: feed-in data of the four German TSO's)*.

Electricity Costs for PV+Battery Energy Storage Systems (BESS®)

Total Cost of Ownership (TCO)

$$\text{Costs} = \underbrace{\frac{\text{electricity production costs}}{\text{system efficiency}}}_{\text{production cost}} + \underbrace{\frac{\text{invest + maintenance costs + interest rate}}{\text{full cycle equivalent until end of life}}}_{\text{storage cost}}$$

PV

5-8 cent/kWh

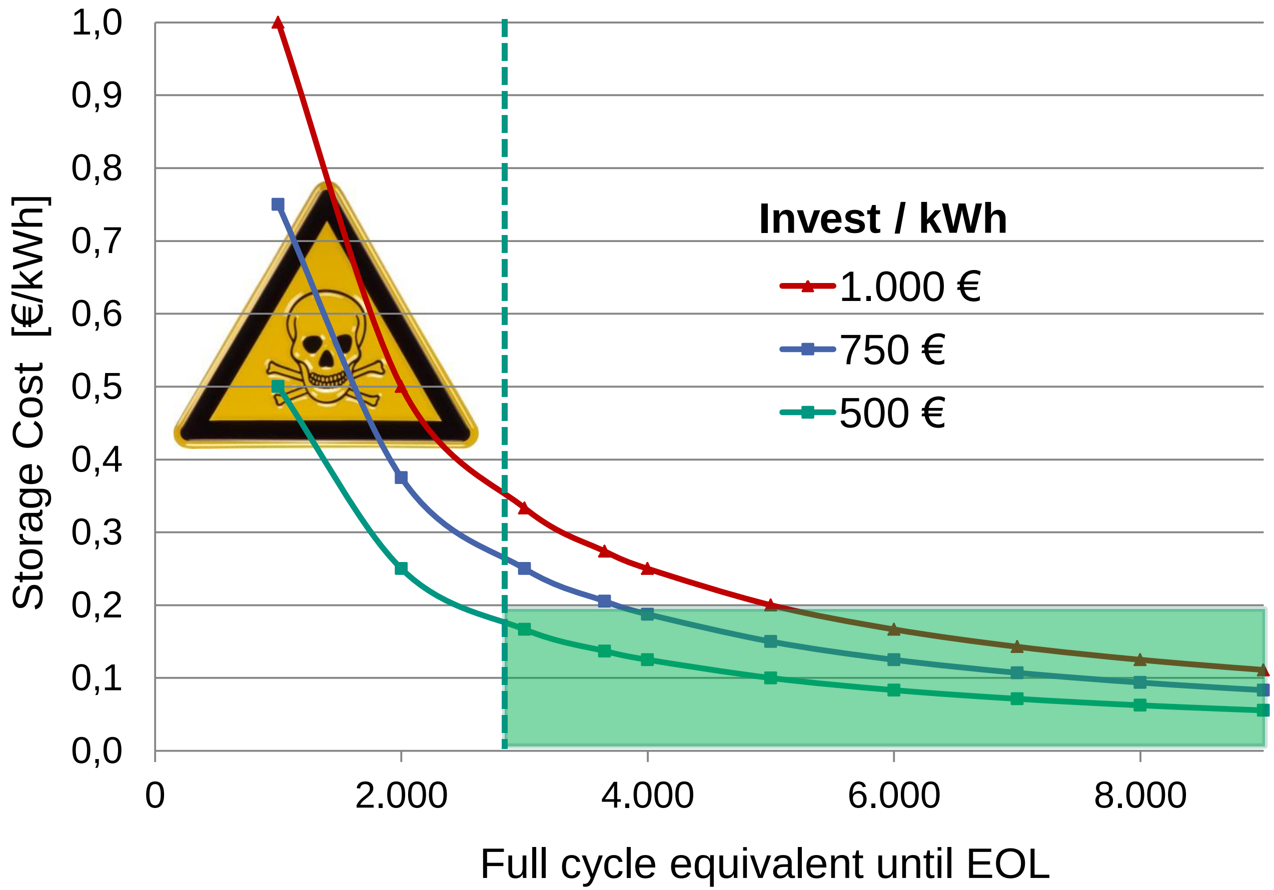
Power Electronics

? cent/kWh

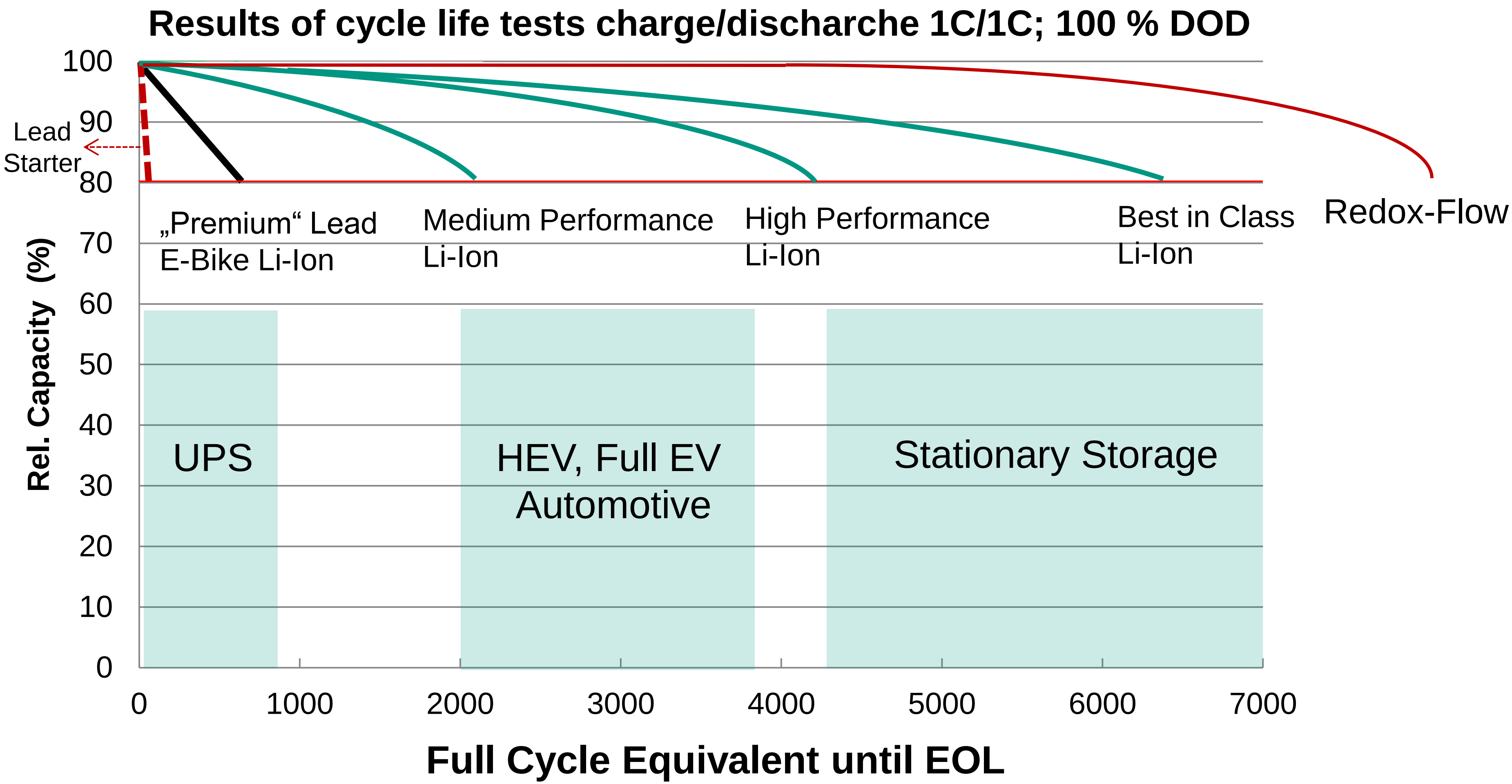
Battery

? cent/kWh

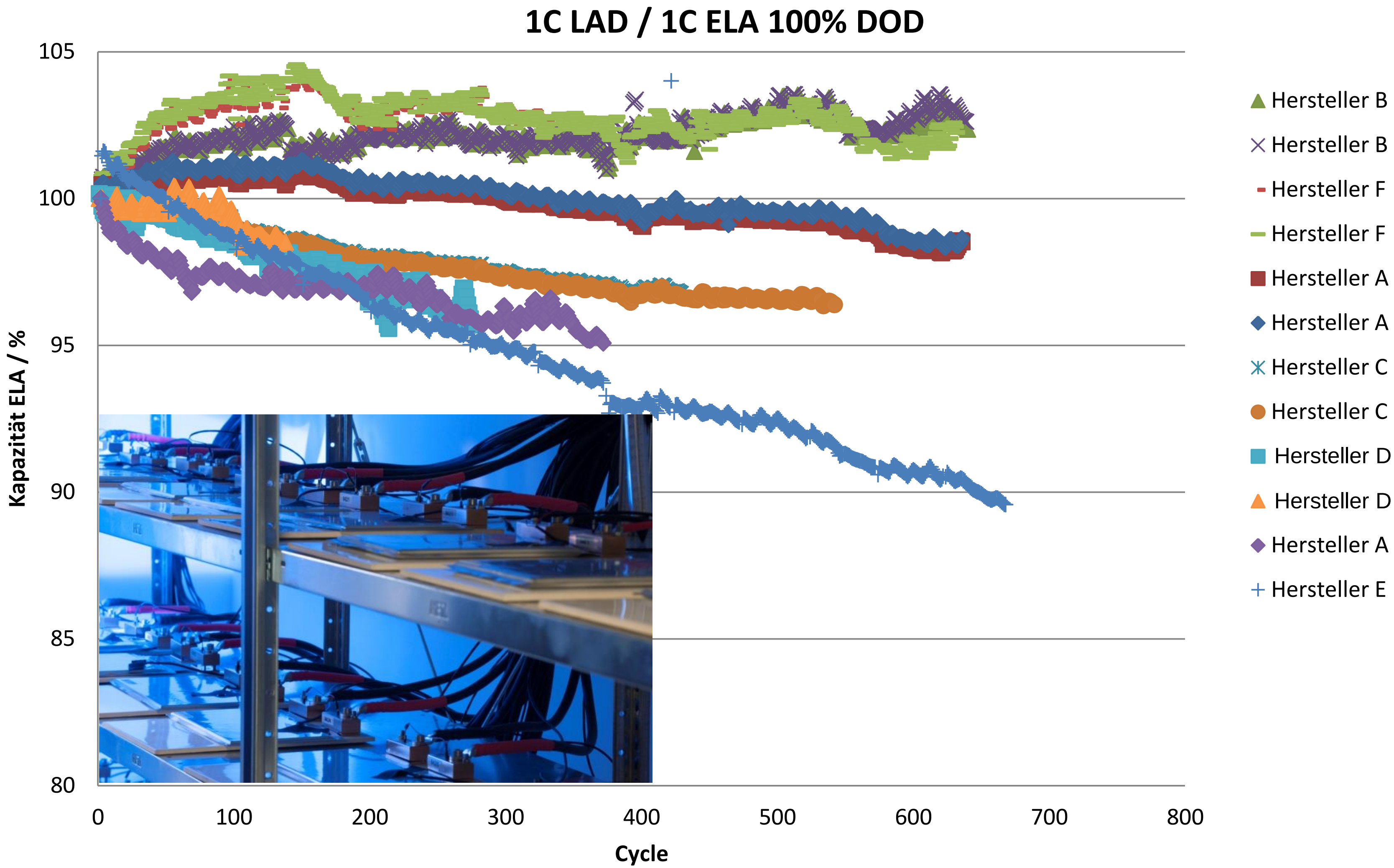
Total Cost of Ownership for Energy Storage
(w/o: PV, interest, maintenance)



Cycle Life of commercially available Batteries



Cycle Life of different Automotive Li-Ion Cells



Total System Efficiency

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REMINDER: Costs $=\dfrac{\text{energy production costs}}{\textbf{system efficiency}}$

η = 1

η = 0,972

$\eta_{max} = 0{,}92$

so far measured 0,88

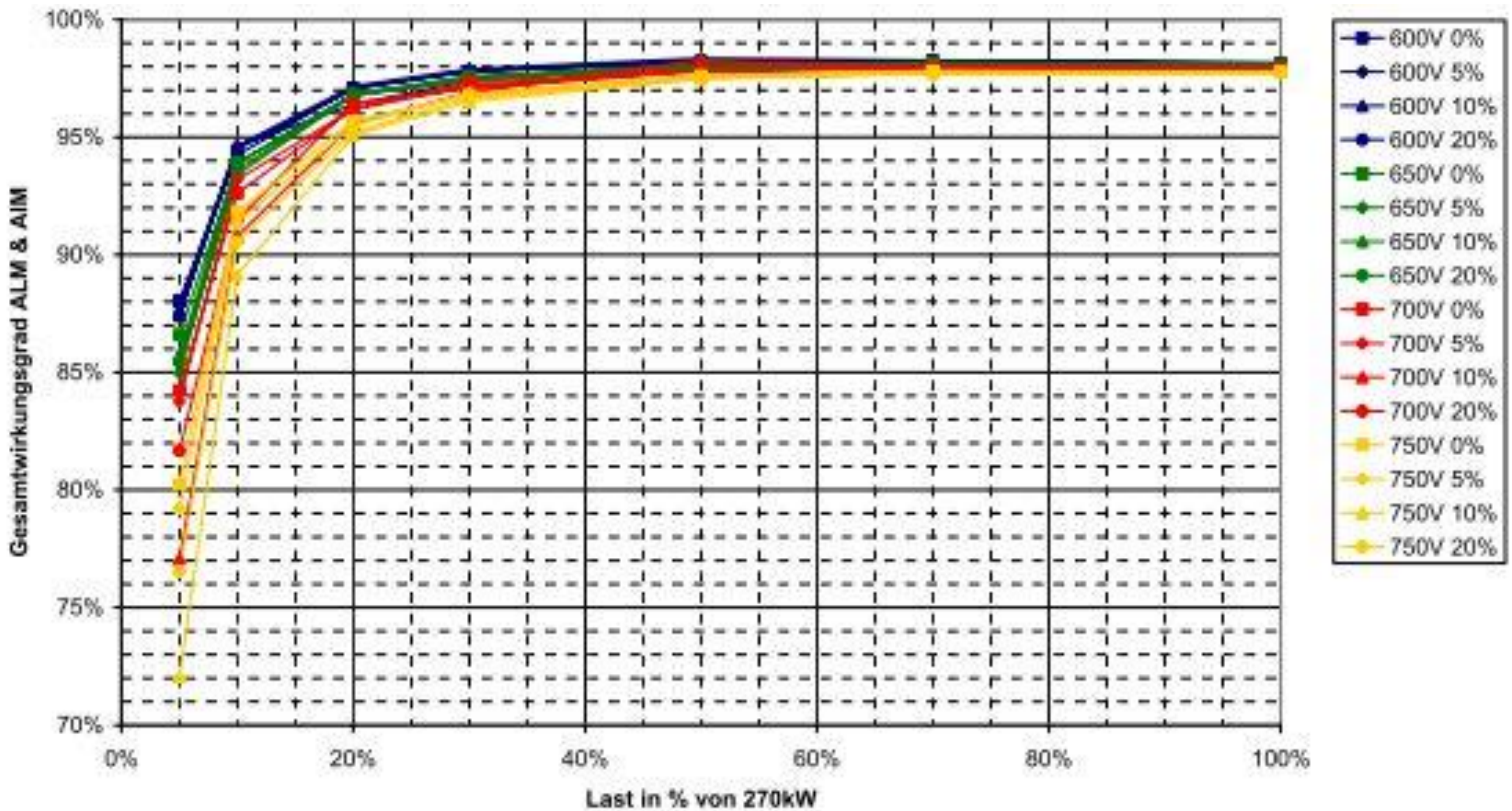
η = 0,98 **η = 0,98**

η = 0,99

Ri < 2mΩ (cell and interconnect)

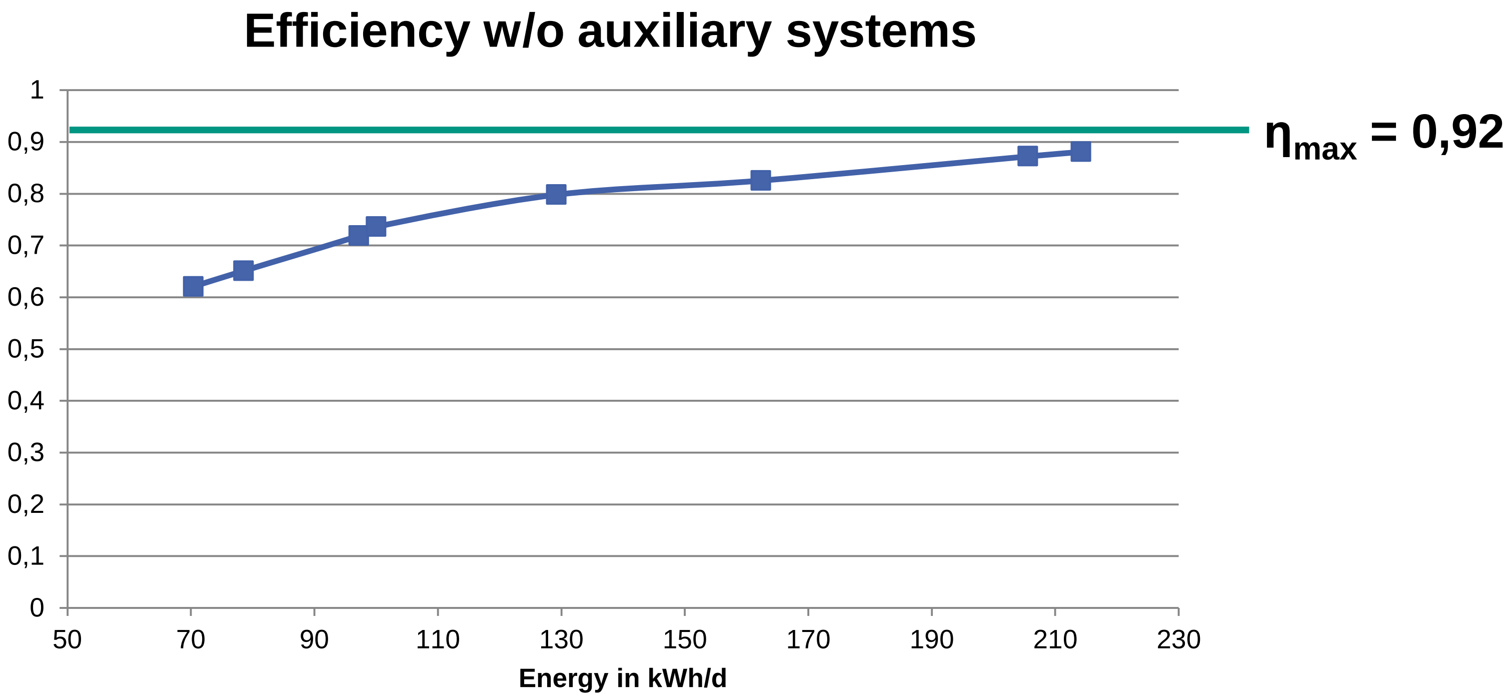
P_{cell} = 0,8 W @ 500 V, 20 A (10 kW)

Converter efficiency measured



η = 0,972 according to EU test procedure (w/o auxiliary systems)

System efficiency measured for 8 days in 2013



Indication of Electric Energy Costs of BESS®

$$\text{Costs} = \underbrace{\frac{\text{electricity production costs}}{\text{system efficiency}}}_{\text{production term}} + \underbrace{\frac{\text{invest + maintenance costs + interest rate}}{\text{full cycle equivalent until end of life}}}_{\text{storage term}}$$

$$\text{Realistic Indication} = \frac{0{,}07\ €/\text{kWh}}{0{,}8} + \frac{1400\ €/\text{kWh} + 50\ €/\text{kWh} + 300\ €/\text{kWh}}{6000} = 0{,}38\ €/\text{kWh}$$

$$\text{Optimistic Indication} = \frac{0{,}05\ €/\text{kWh}}{0{,}8} + \frac{1000\ €/\text{kWh} + 50\ €/\text{kWh} + 200\ €/\text{kWh}}{7000} = 0{,}24\ €/\text{kWh}$$

BESS® at KIT March 2013

Jointly devoloped by: KIT AccuSol GmbH SIEMENS e-WOLF

Power-Module 250 kW

Battery-Module up to 300 kWh

PV 36 kWp installed

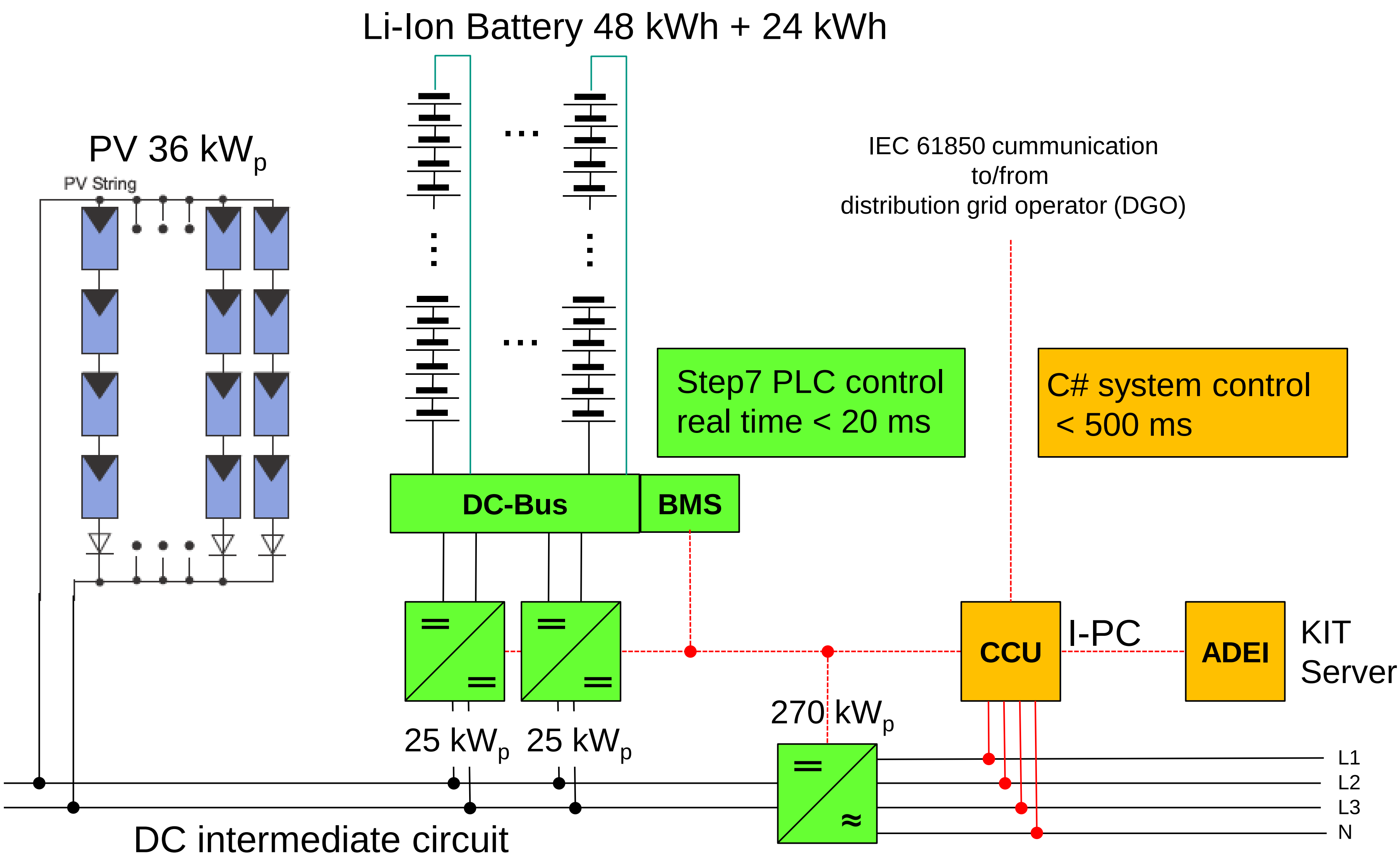
PV 1 MWp in installation

Siemens Power Electronics 270 kW_p

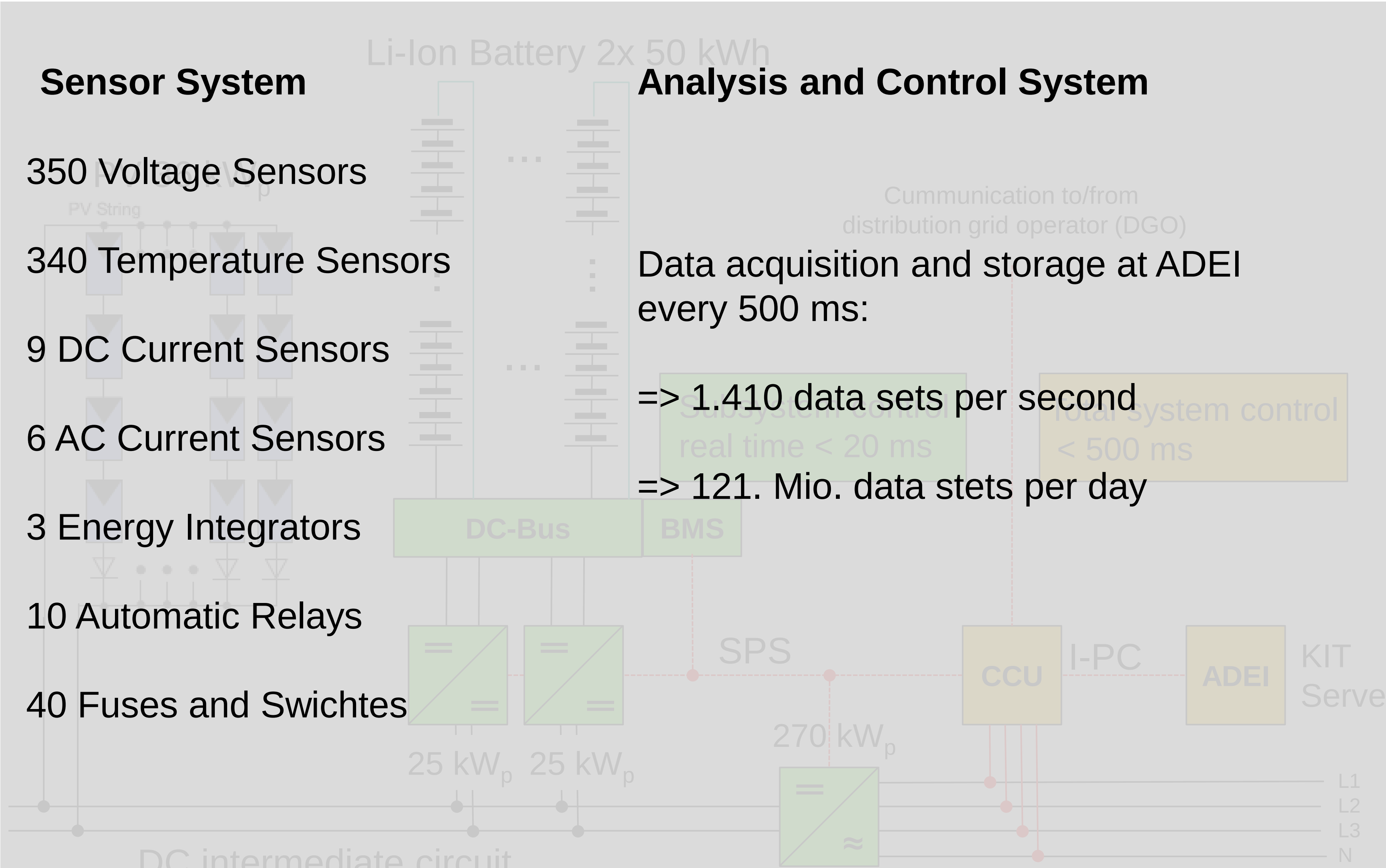
Hardware including frequency, voltage, reactive power / cos φ control

Fully modular Ceramic Li-Ion Technology, 100% made in Germany

Electrical and Control Design of BESS® (DC coupling)



Sensor and Control Technology



Sensor System

350 Voltage Sensors

340 Temperature Sensors

9 DC Current Sensors

6 AC Current Sensors

3 Energy Integrators

10 Automatic Relays

40 Fuses and Swichtes

Analysis and Control System

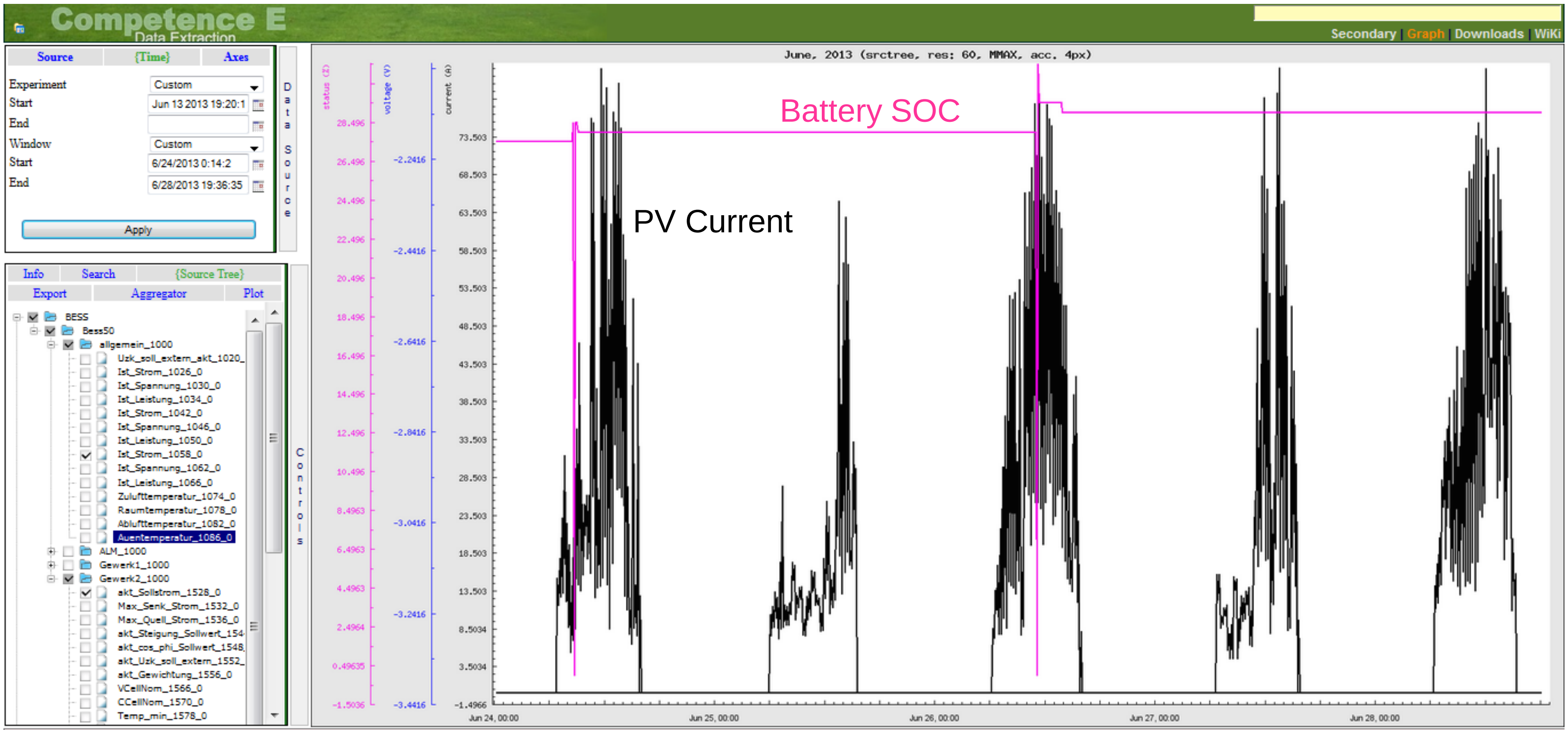
Data acquisition and storage at ADEI every 500 ms:

=> 1.410 data sets per second

=> 121. Mio. data stets per day

Validation of ADEI Data Acquisition

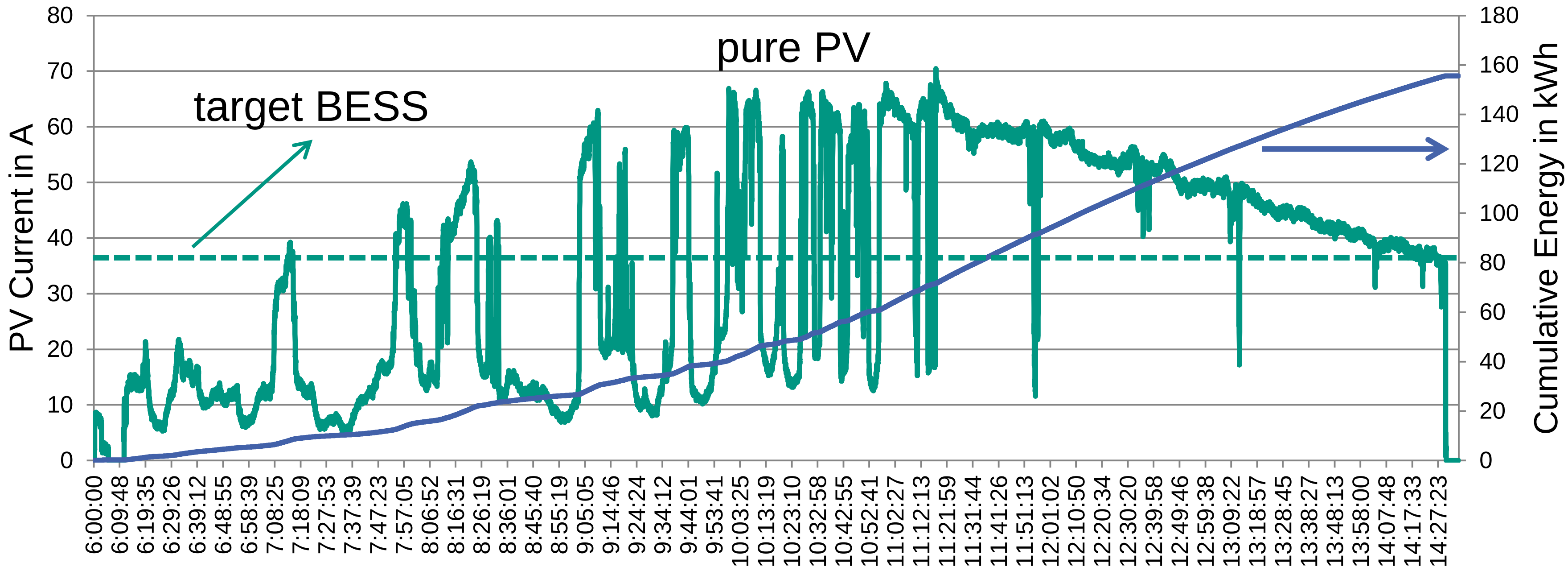
(world wide web access)



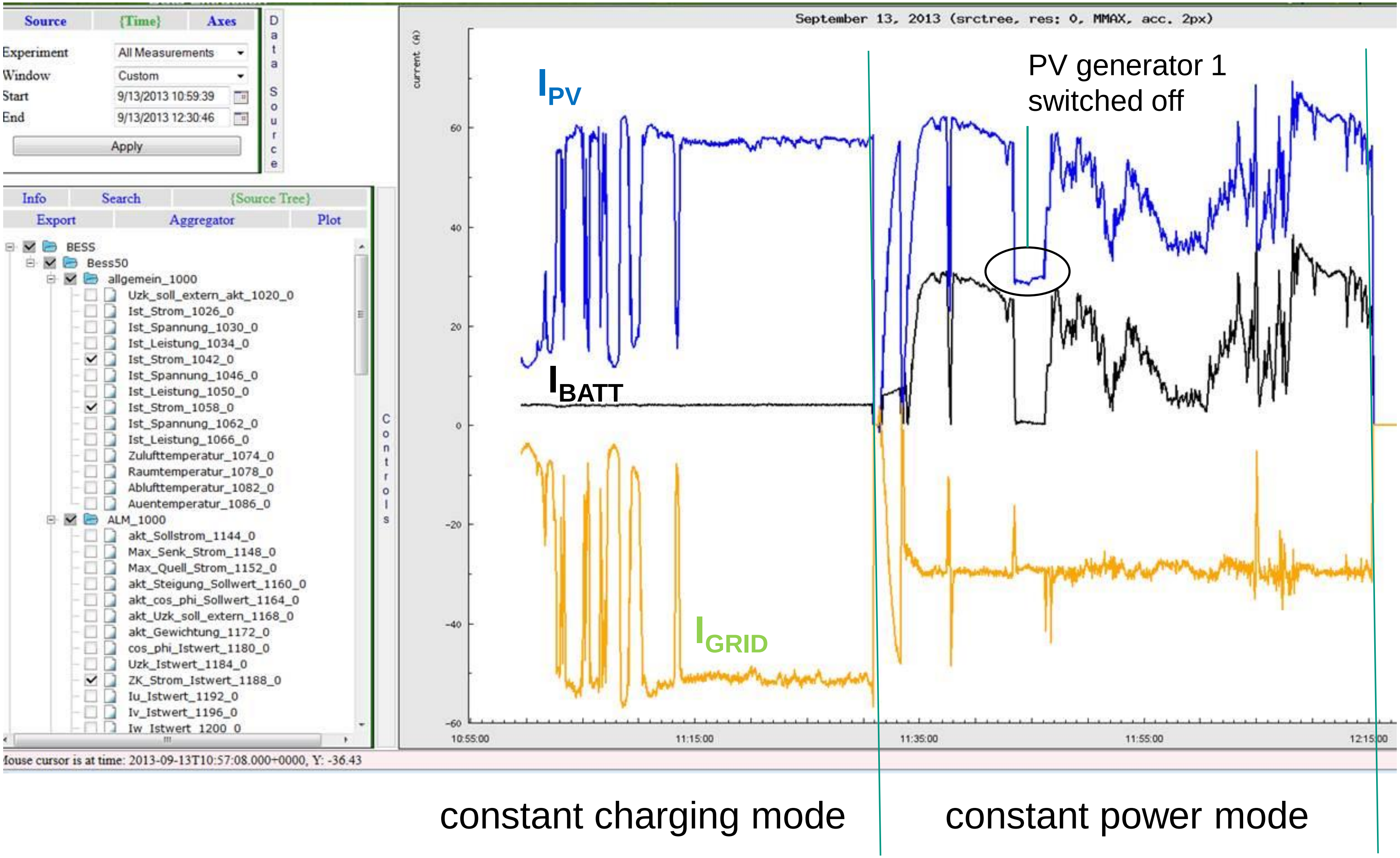
Example: 5 Days in June

Analysis of Fluctuation Frequencies of PV

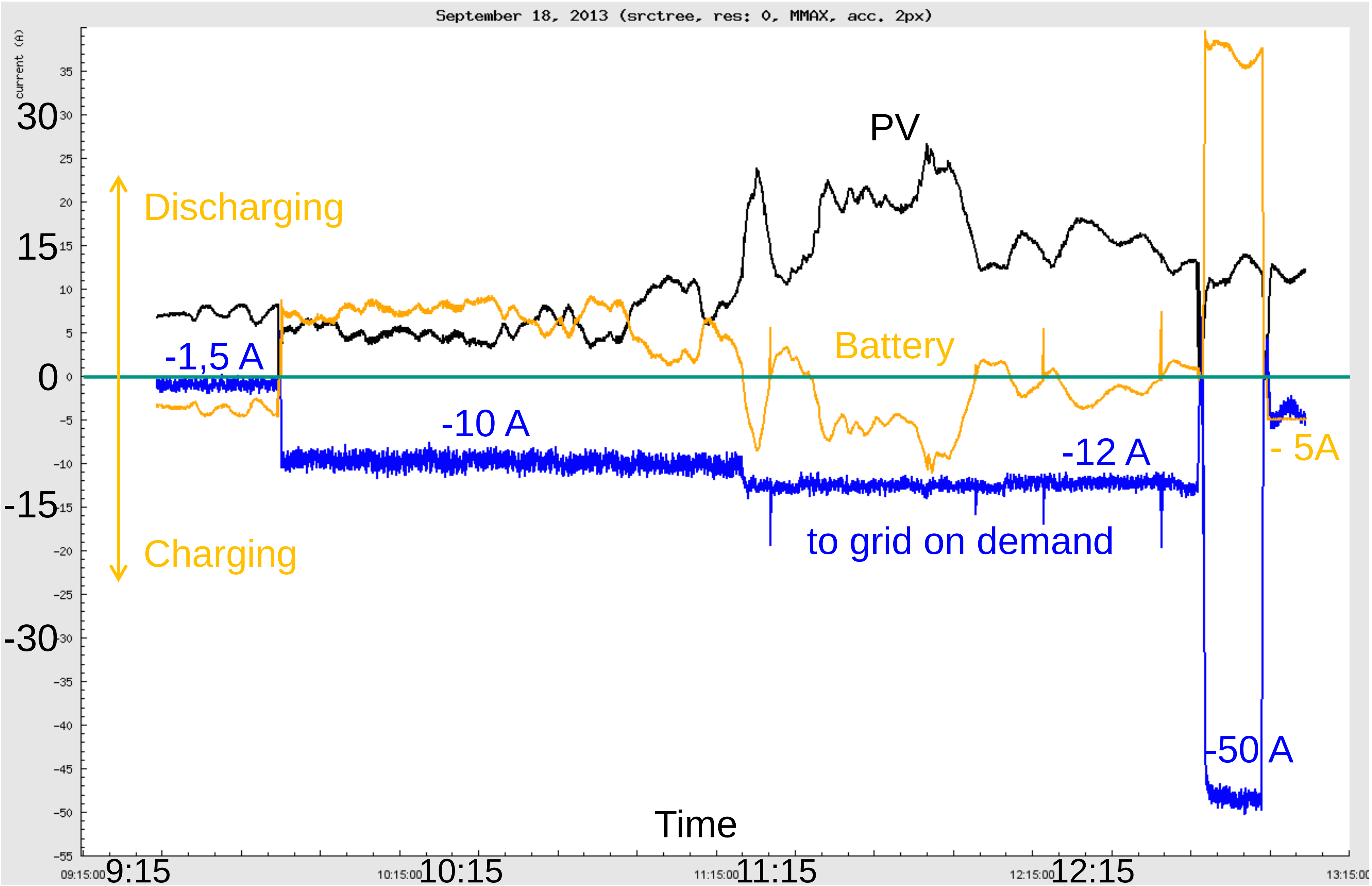
Characterisitic frequency is required for optimized control algorithm of BESS®



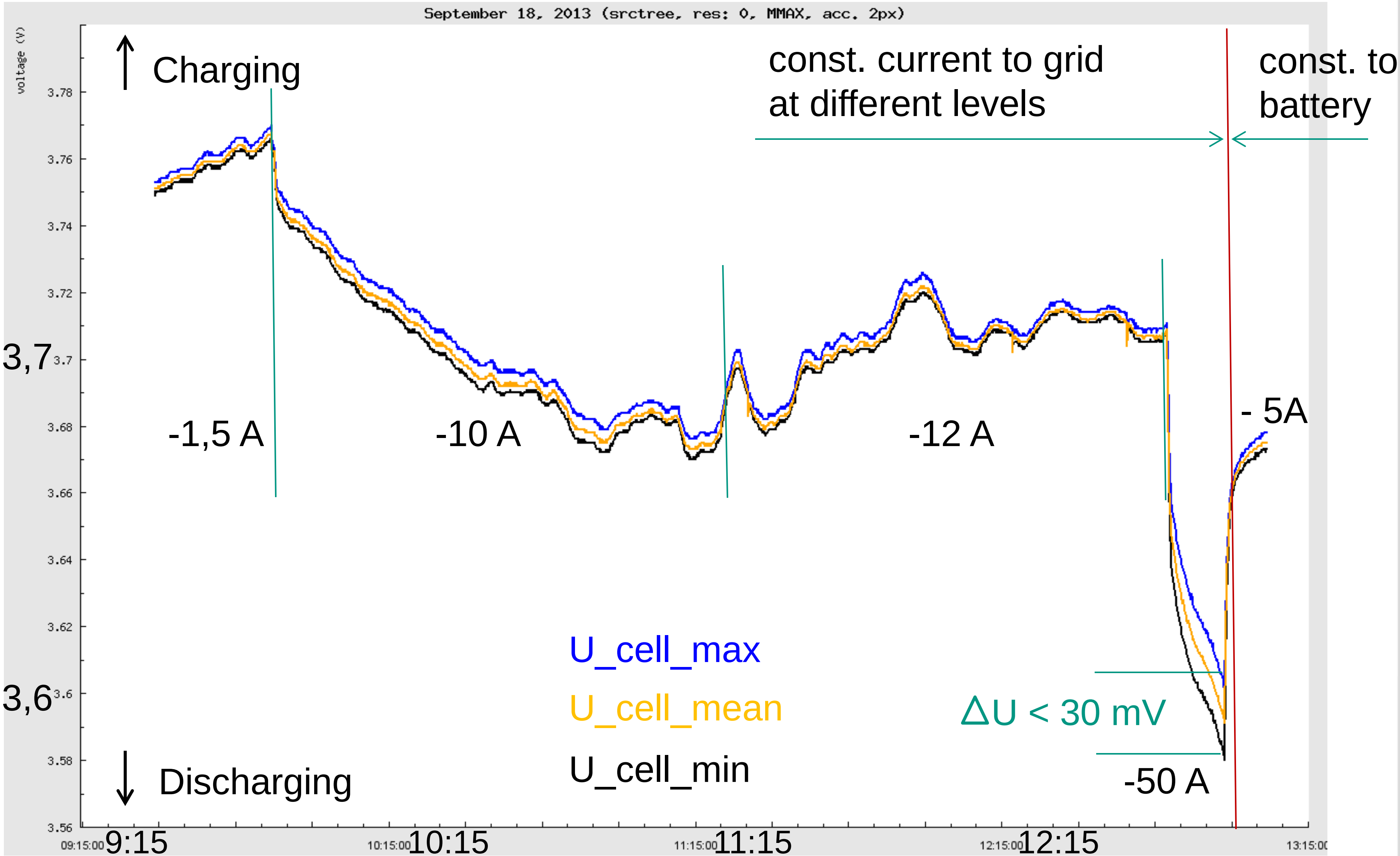
BESS® operation in constant power mode



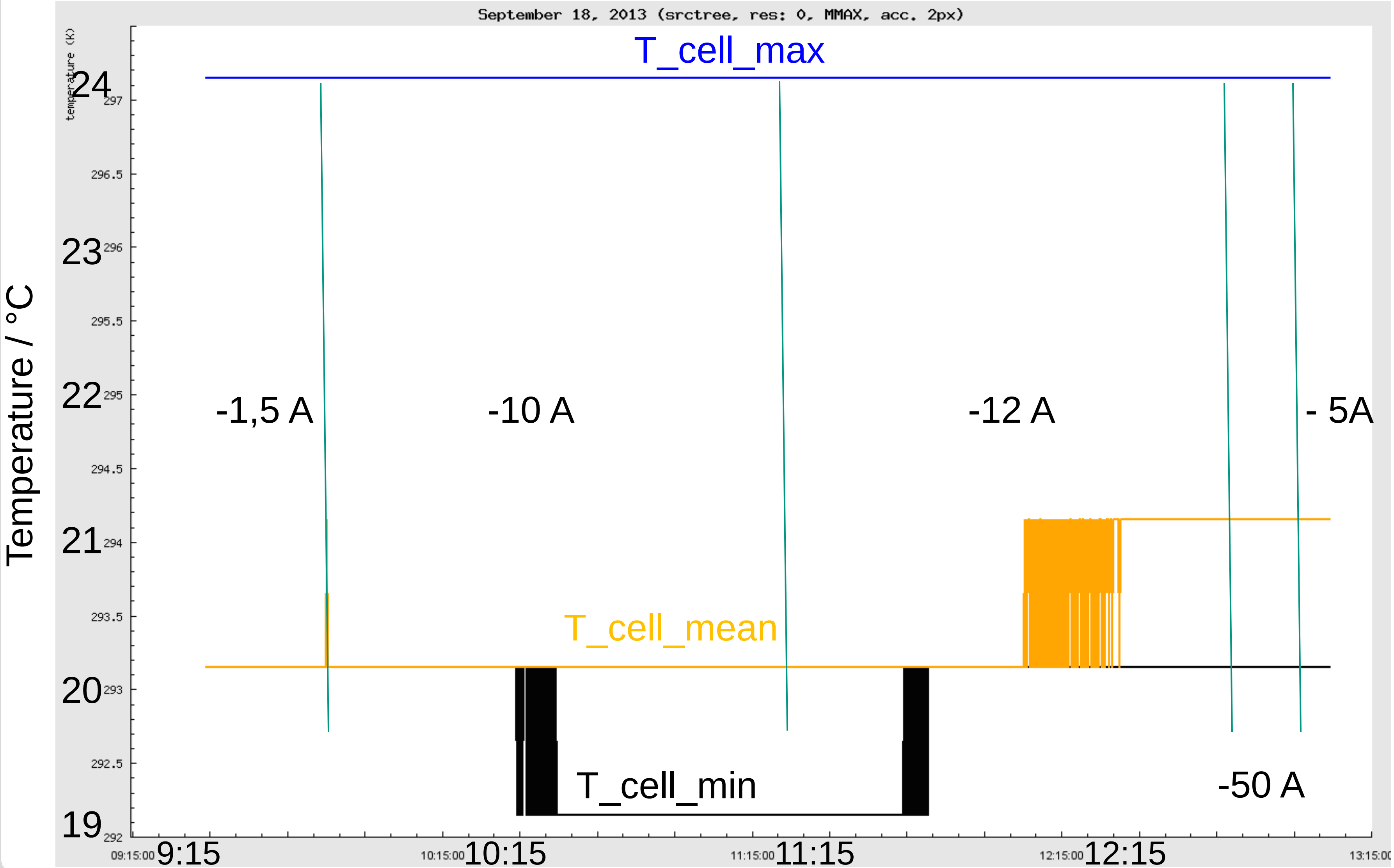
System Currents as of Sept. 18, 2013



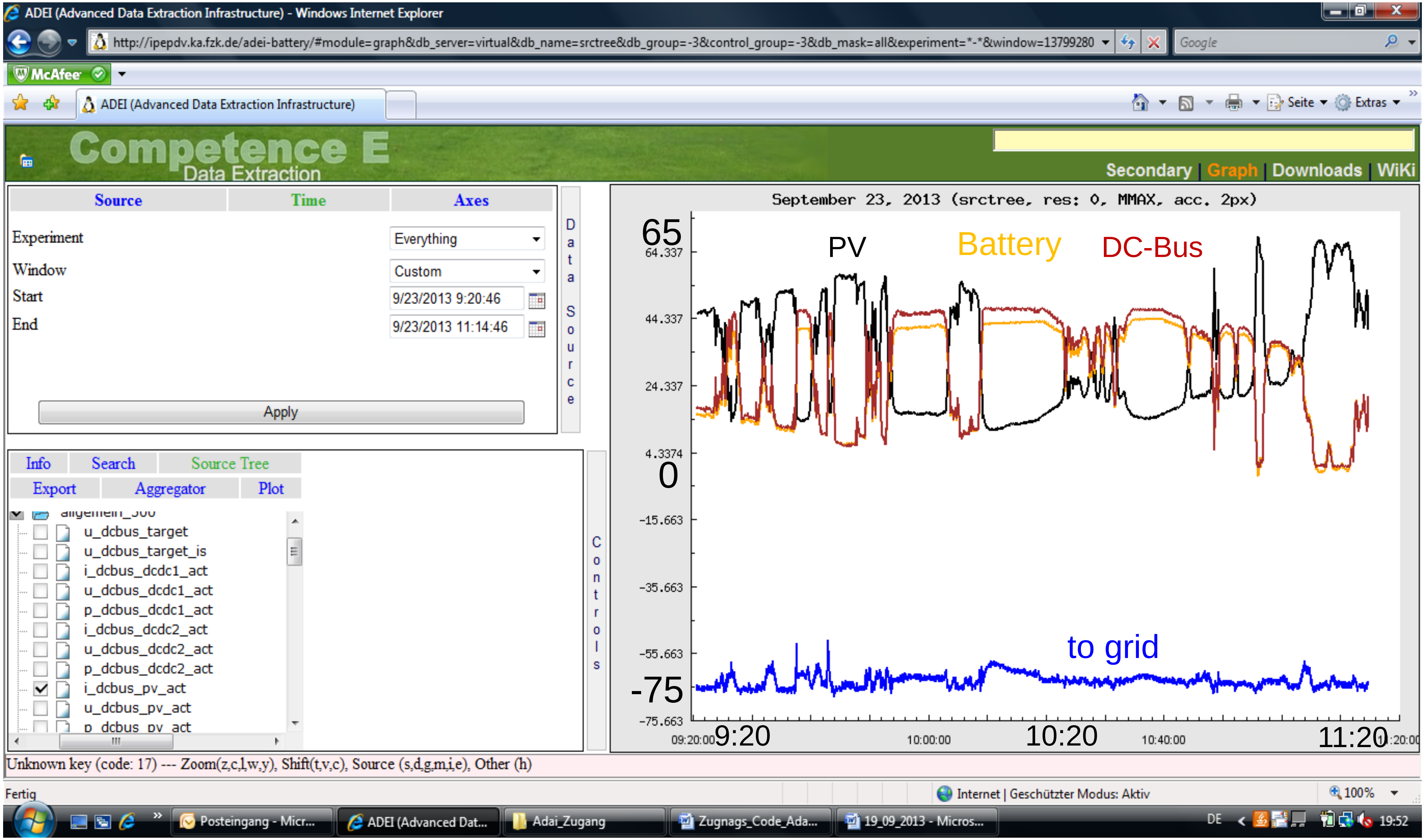
Single Cell Voltages of 168 Cells at Sept. 18, 2013



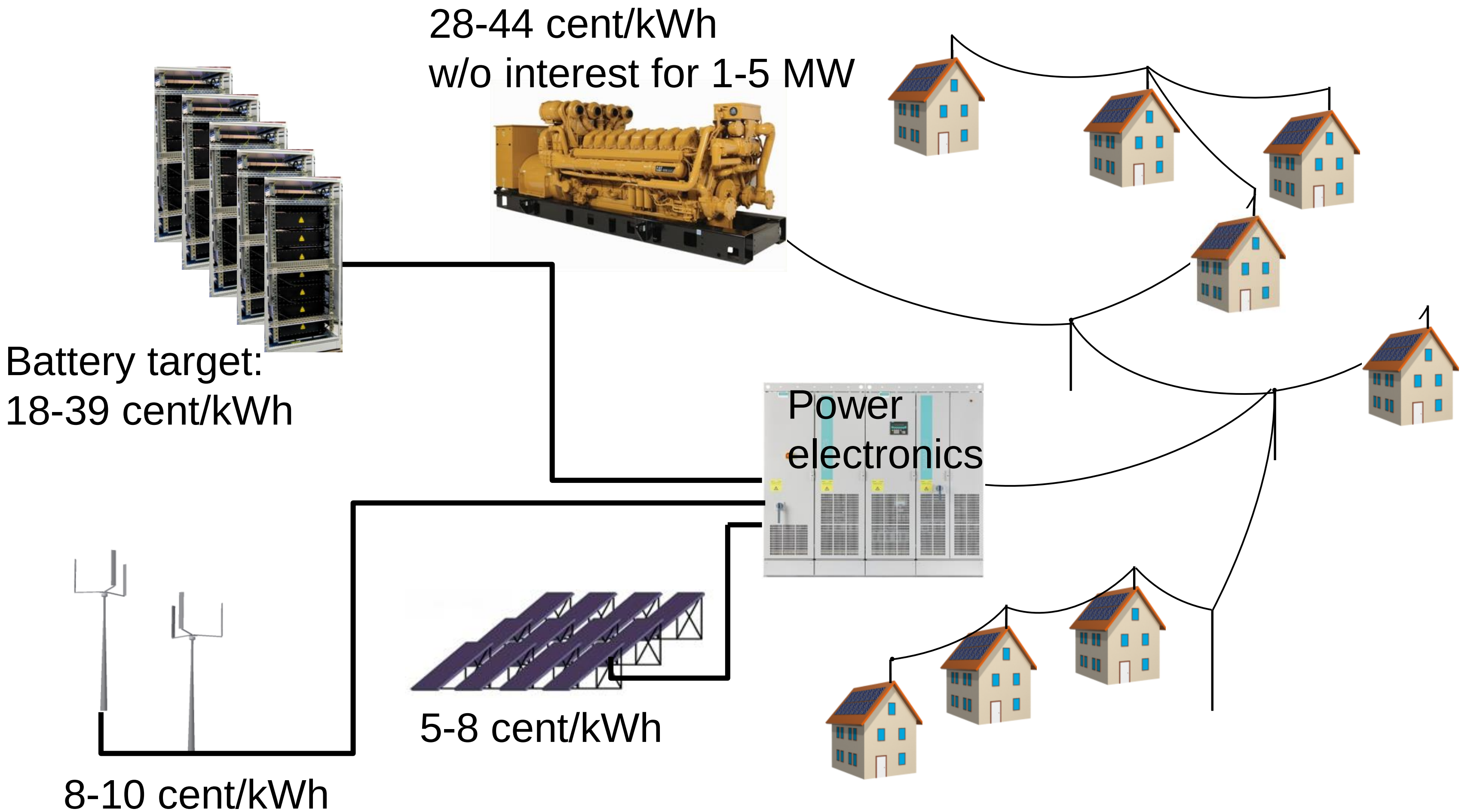
Single Cell Temperatures on Sept. 18, 2013



Searching for the Limits: System Currents



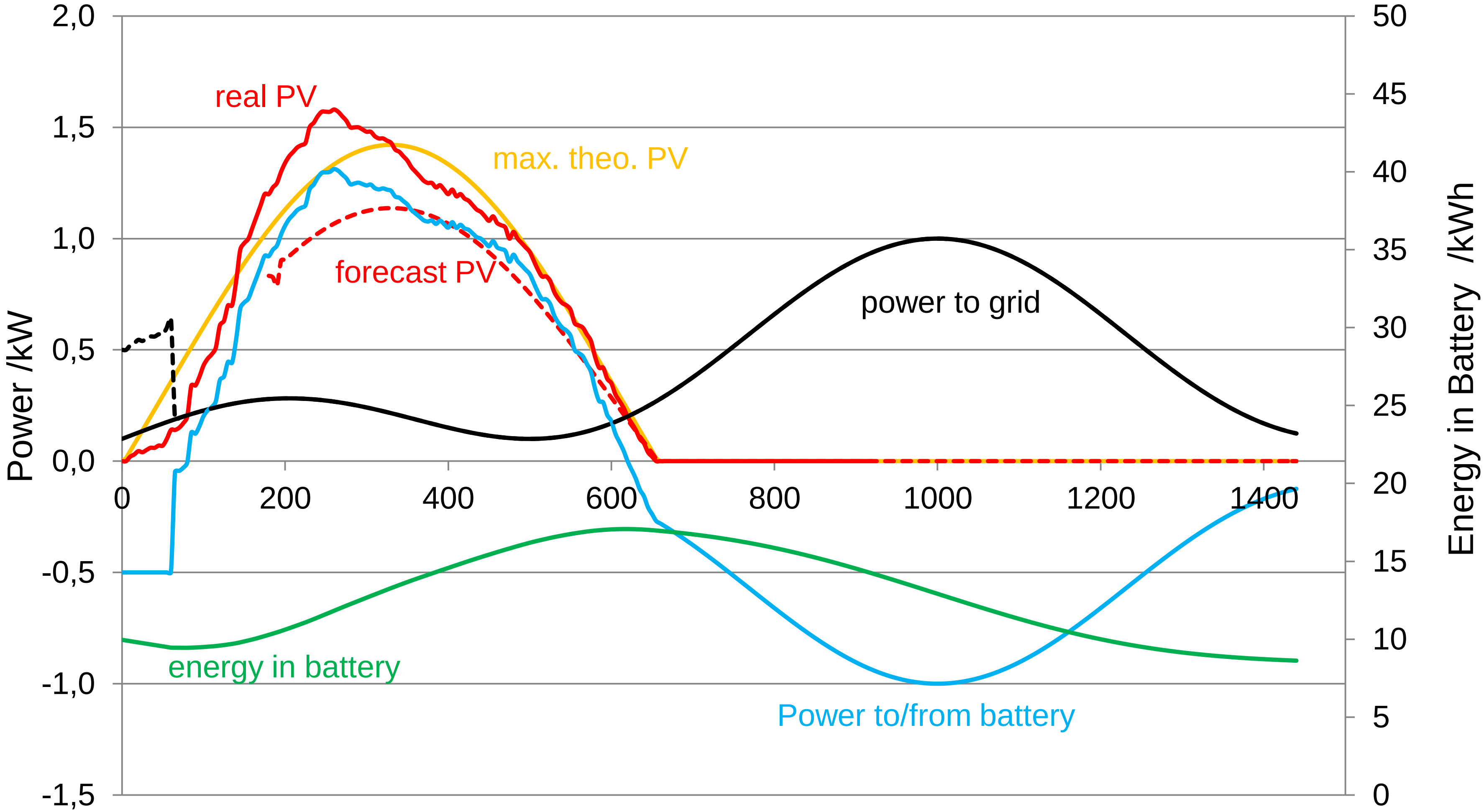
Intregration of BESS® in Island Grids



Challenges for the system control of a renewable energy microgrid

- Frequency control
- Voltage control
- Reactive power control / cos φ control
- SoC control and prediction
- Renewables production forecast

BESS® predictive control for 04.03.2013



Finally: Safety is not negotiable !!!

Overcharge of a stationary Li-Ion battery without redundant safety protection
e.g.:

w/o ceramic Li-Ion cell technology

w/o single cell temperature protection

w/o automatic relay
w/o ……

Our Believe: Safety is not negotiable

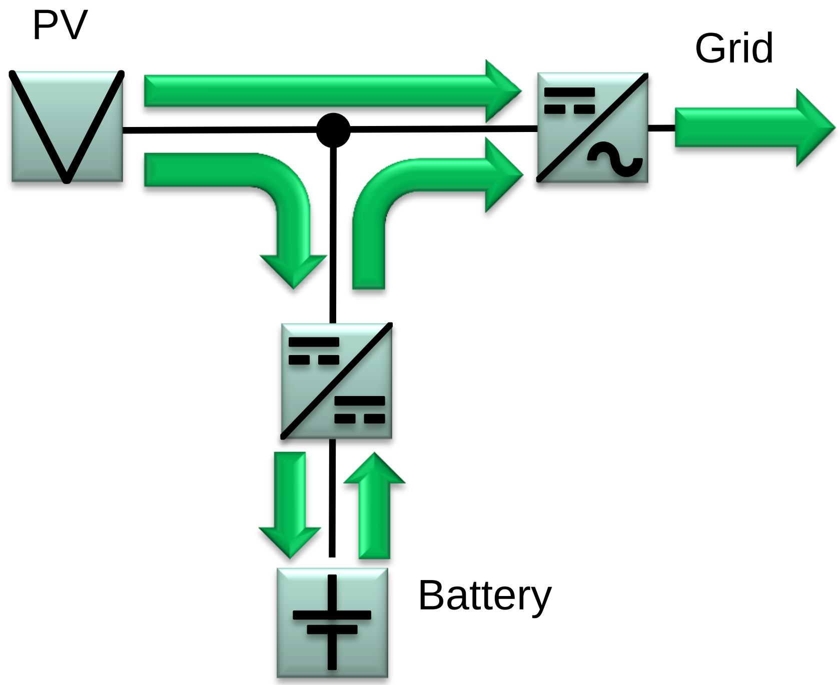
End of the overcharge of a stationary Li-Ion battery without redundant safety protection

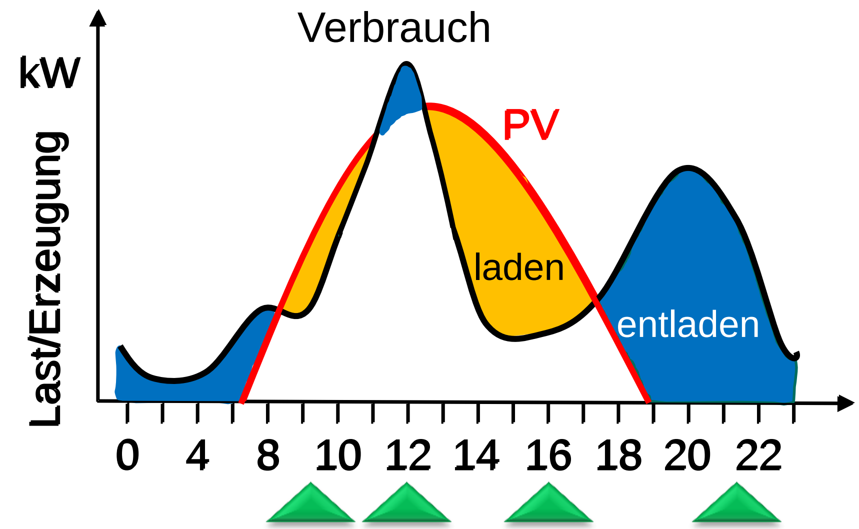
Thank you for your attention!

Competence E

Back-UP

Basic Concept of PV and Battery





Profitability is determined by:

- System design (AC and/or DC coupling)
- System design (power electronics + battery in relation to PV and load)
- System design (control software, relability, efficiency, maintenance, availability)
- Life time of battery and power electronics