University of Cyprus

WinPV

Technical University of Denmark

DTU

Optimised Control of a 10MW Photovoltaic (PV) Plant with 1MW / 1MWh Battery

TWINPV WORKSHOP IN CYPRUS

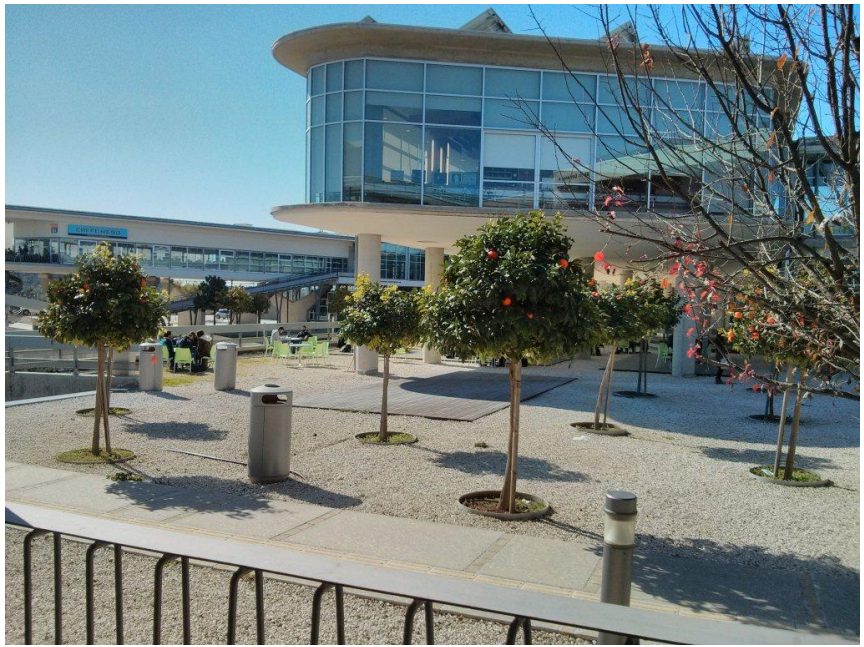
14-DEC-2016

Introduction

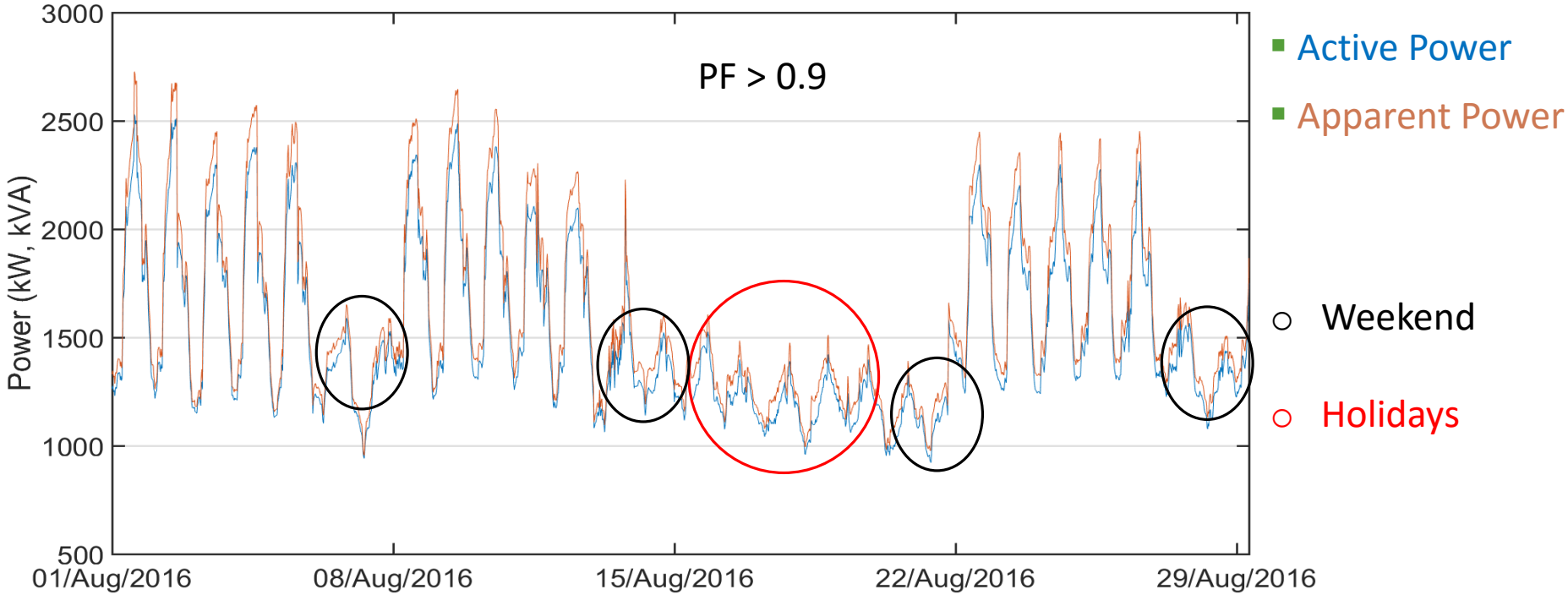
- The University of Cyprus (UCY) plans to transform its campus to a microgrid (PV + Battery)
- Developed an energy management algorithm
- Aiming to reduce UCY electricity bill
- Algorithm testing for voltage limits violation at the point of common coupling (PCC) required
- SYSLAB facilities (DTU) were used for the test

University of Cyprus (UCY) Campus

- Connected to the national grid via a point of common coupling (PCC)
- Ideal for a µG transformation
- Peak load of 2.4MW
- 400kWp PV systems connected and used as self-consumption
- Campus is expanding
- Load demand expected to double by 2017



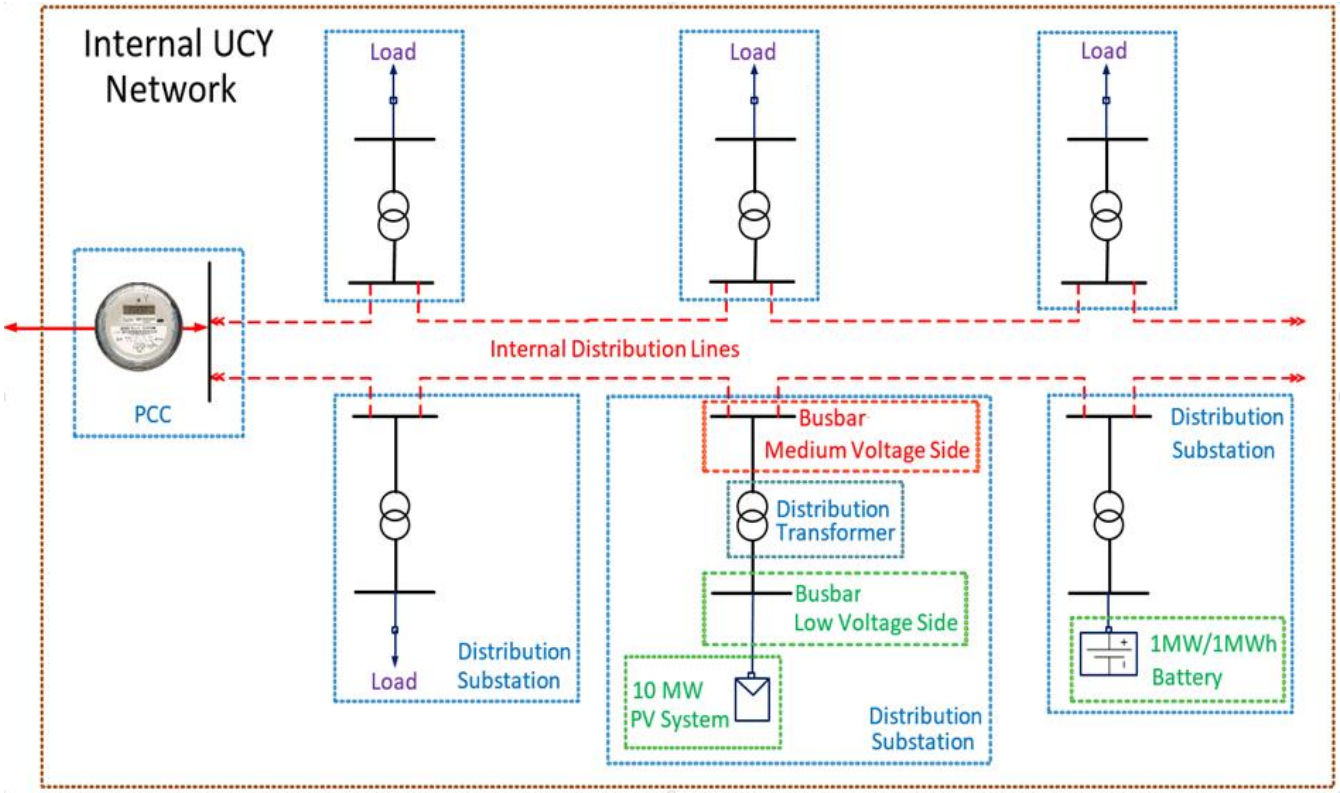
UCY Load Example (measured, August 2016)



UCY Future Microgrid Plan

- 10MWp PV + 1MW / 1MWh Battery (estimated values but not optimized)
- Net-metering scheme based on Time-of-Use (ToU) tariffs
- Bi-directional electricity meter at the PCC
- Bi-directional Fiber Optic and Power Line Communication (PLC) with local DSO

UCY Future Microgrid Diagram

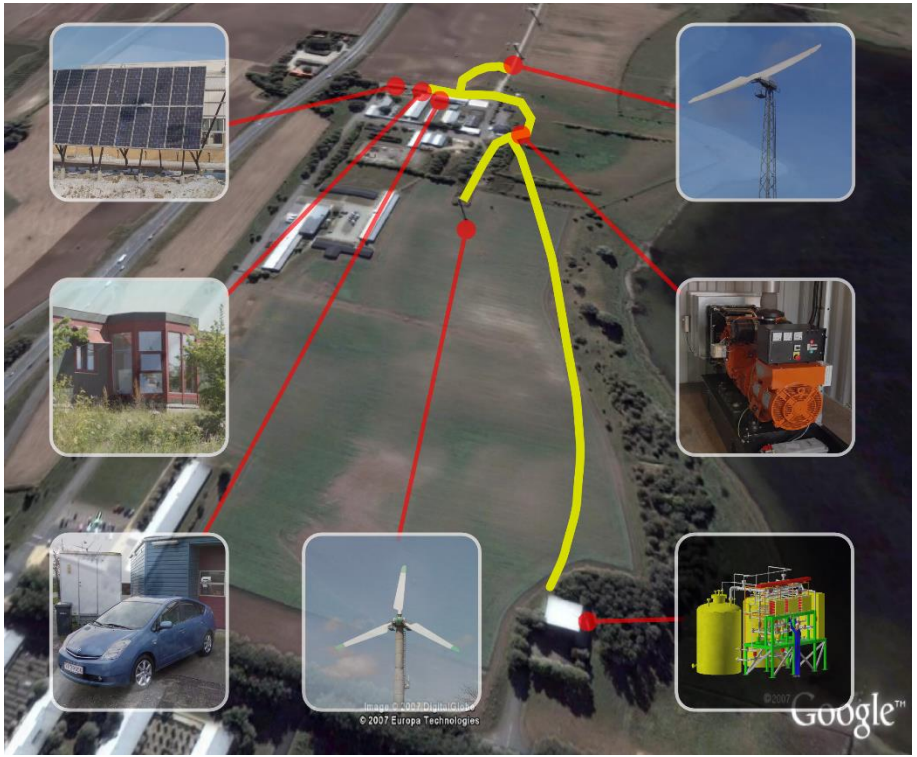


Laboratory Environment Testing

- Real life µG testing is difficult or even impossible
- µGs combine different technologies
- Modelling can be inaccurate
- Lab testing – face real problems (communication, delays, transients, etc.)

SYSLAB Experimental Facility

- Research Lab for distributed energy resources (DER)
- Facilities located at four main sites
- Sites can be connected via a centralized cross-busbar
- Flexible configuration
- Virtually any configuration of DERs
- Flexible control via MATLAB Script

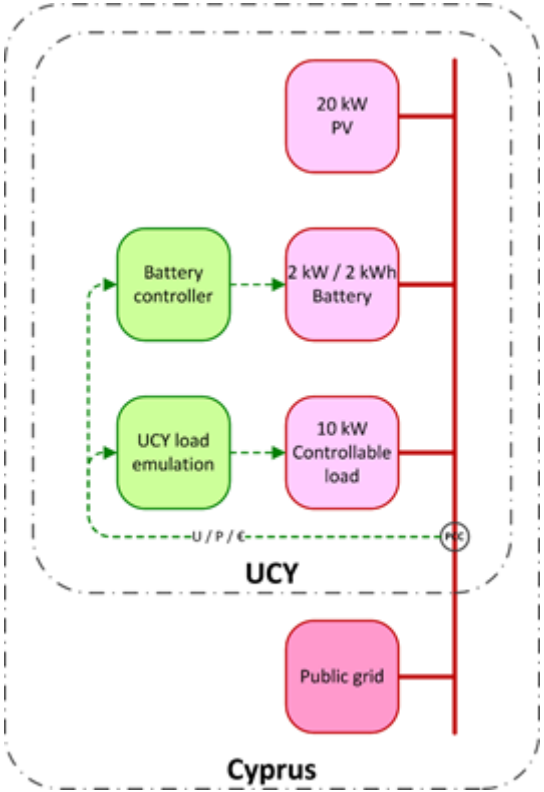


SYSLAB Facilities

- 25kWp distributed photovoltaics (PV) (3 sites)
- 20kW distributed wind turbines (2 sites)
- 50kW diesel power plant
- 75kW dump load/load bank
- 3x mobile dumb loads
- 15kW / 120kWh vanadium redox battery (VRB)
- 45kVA back-to-back converter
- 3x intelligent buildings (2 residential + 1 office)
- Electric Vehicles (EV)
- EVs with vehicle-to-grid (V2G) capabilities

Power System Modelling: UCY Campus

- **Scale down factor**: 1:500
- **Load**: 4.8MW to 9.6kW
  (modelled by a resistive load)
- **PV**: 10MWp to 20kWp
  (modelled by the distributed PV)
- **Battery**: 1MW / 1MWh to 2kW / 2kWh
  (modelled by the VRB battery)
- **Public grid of Cyprus**: 1458MW
  (not affected by UCY microgrid, assumption in this test)
- **PCC**: connected to public grid via a long cable
  (possible voltage regulation issues at the PCC)

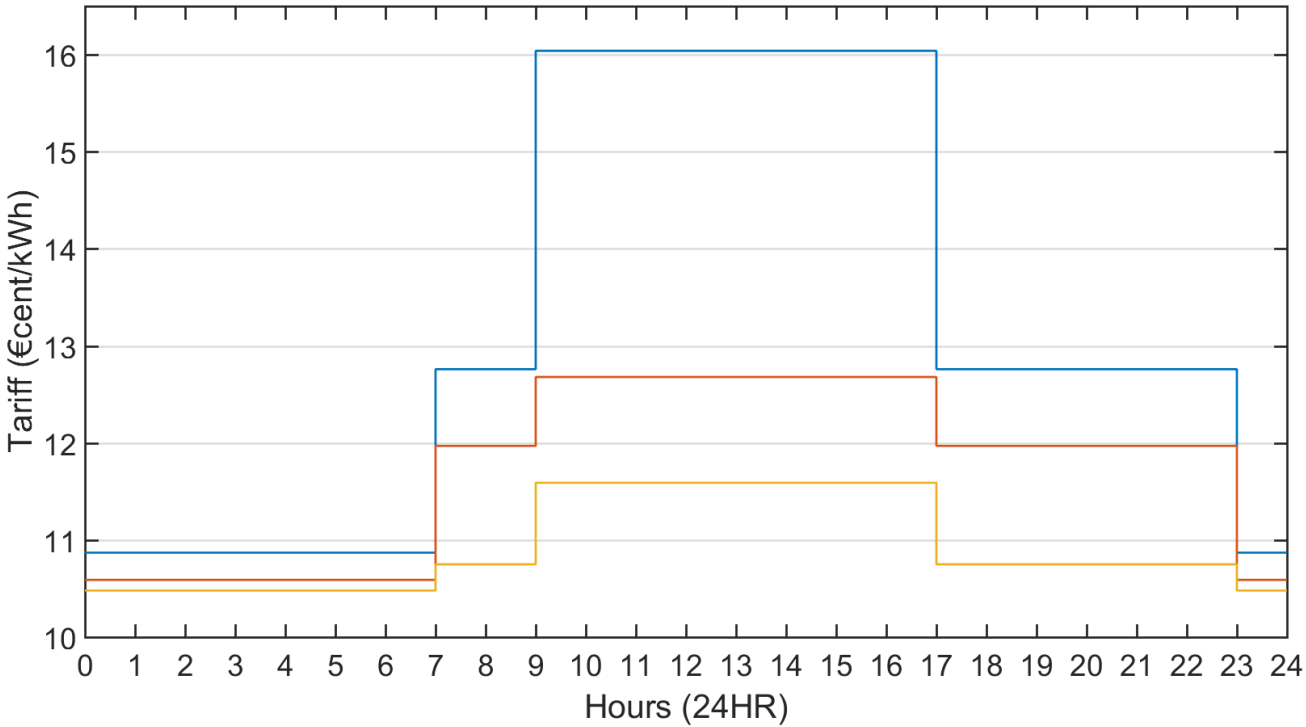


Billing Scheme: Time-of-use Tariffs

Period	Hours	Charge	Monthly Load Factor (LF)		
			0-30%	*31-60%*	*61-100%*
Peak	09:00 – 17:00	kWh	€0.1604	€0.1268	€0.1159
		kVA (monthly maximum demand)	€13.99	€15.81	€16.99
Intermediate	All remaining hours	kWh	€0.1276	€0.1197	€0.1075
		kVA (monthly maximum demand)	€1.36	€1.97	€4.54
Off-Peak	23:00 – 07:00	kWh	€0.1087	€0.1059	€0.1048

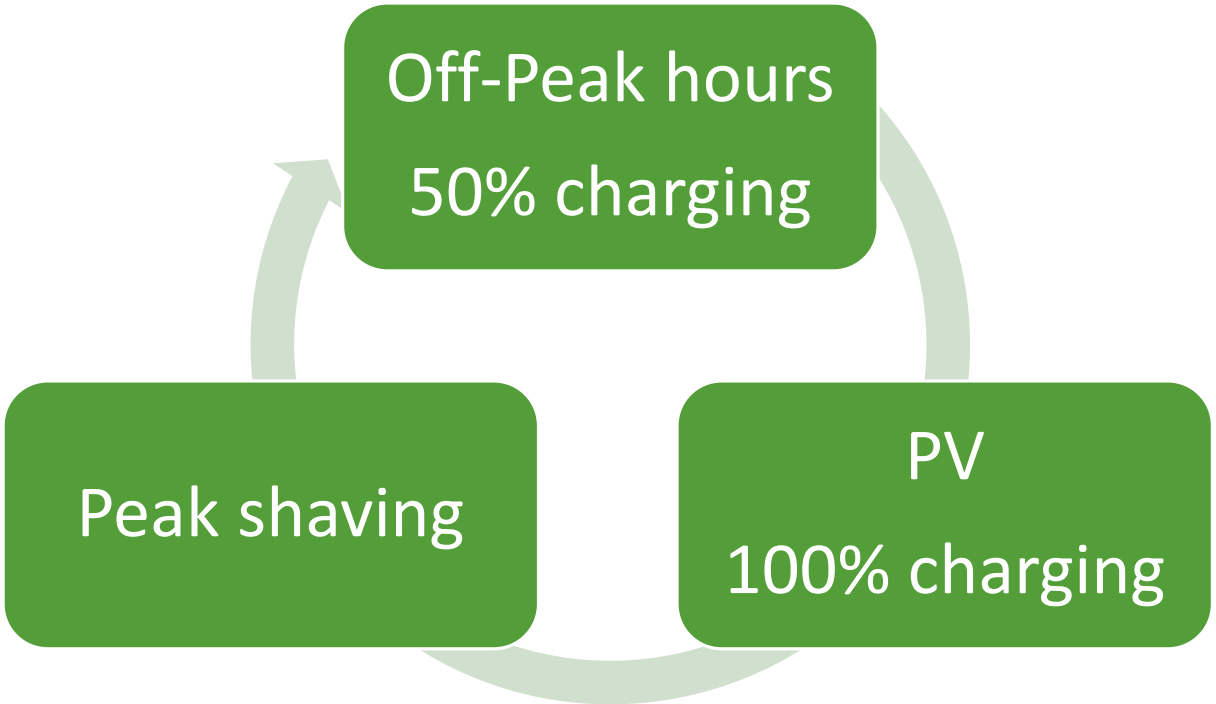
- kVA charge in Peak period: valid from June to September

Billing Scheme: Time-of-use Tariffs



- LF = 60-100%
- LF = 30-60%
- LF = 0-30%

Control Algorithm: Peak shaving

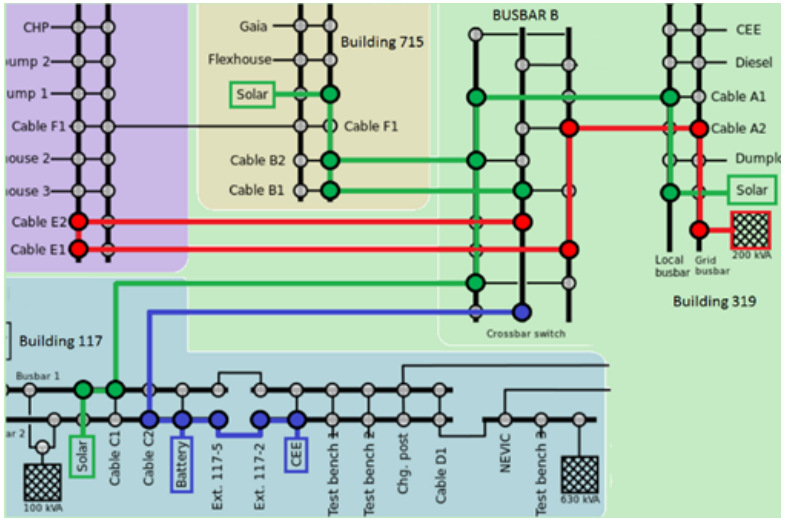


Control Algorithm: Peak Shaving

- **Electricity Cost**: monthly kVA charged at a high premium
- **Peak shaving algorithm**: reduce cost
- **Battery**: used for achieving peak shaving
- **Peak shaving value**: optimized through simulations
- **Optimum value**: 4.8kW (downscaled value)
- **Savings**: €138,600 per month

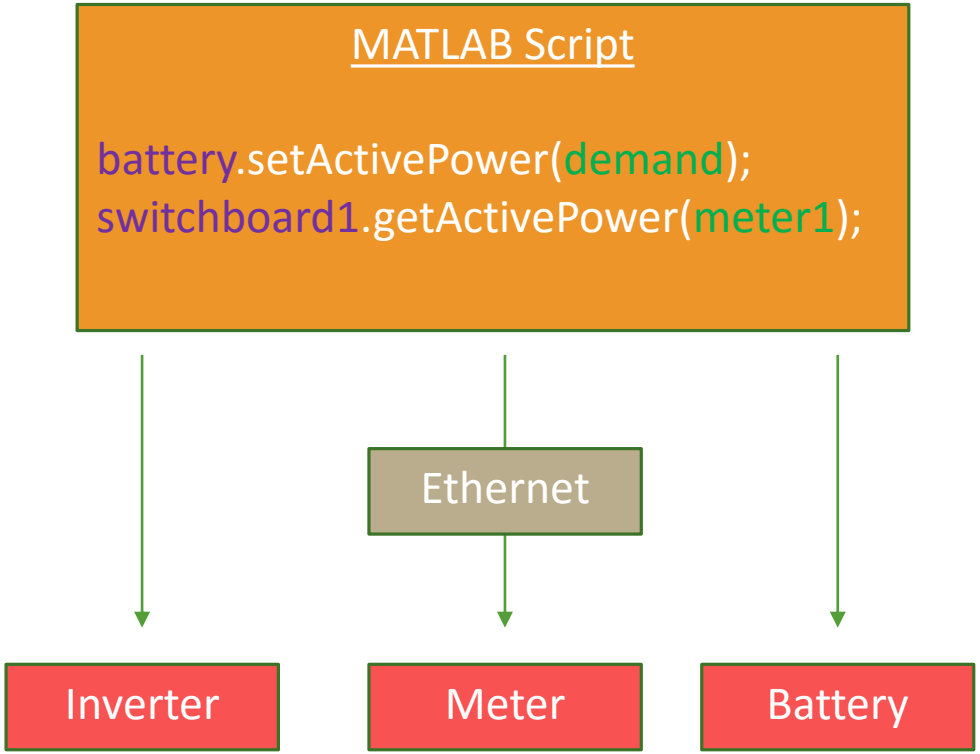
Condition	Monthly Demand and Cost				
	Load Shave (kW)	*Cost kWh per Month (€)*	*Peak Hours Cost kVA per Month (€)*	*Intermediate Hours Cost kVA per Month (€)*	*Total Cost per Month (€)*
no PV no BESS	NA	289,740	80,190	7,940	377,870
PV+ BESS	1.8	188,540	55,450	7,770	251,760
PV+ BESS	2.8	188,540	55,450	7,770	251,760
PV+ BESS	3.8	188,540	55,450	7,770	251,760
PV+ BESS	4.8	188,630	42,880	7,770	239,270
PV+ BESS	5.8	188,740	48,260	7,770	244,770
PV+ BESS	6.8	188,850	55,450	7,050	251,360
PV+ BESS	7.8	191,020	55,450	7,770	254,240
PV+ BESS	8.8	191,020	55,450	7,770	254,240

SYSLAB Test (DTU)

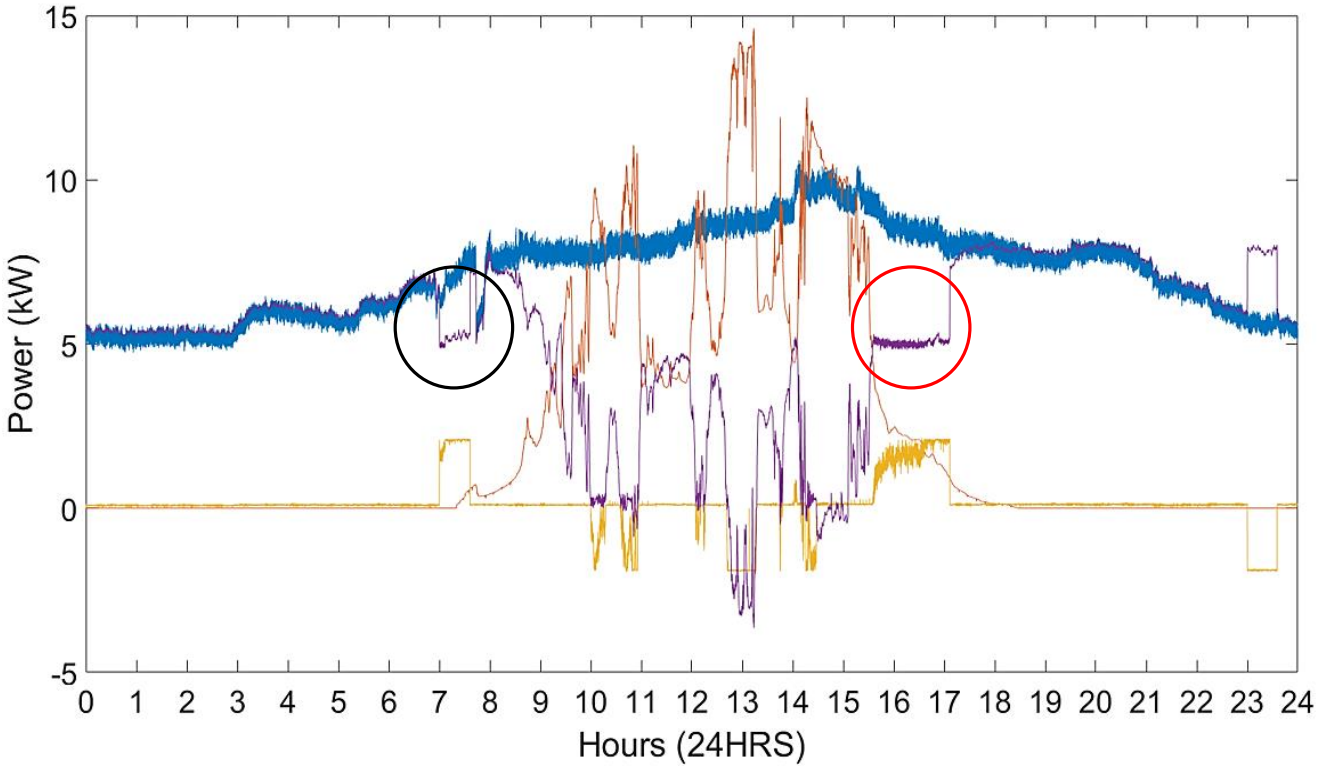


SYSLAB User Interface

- MATLAB Script
- Embedded Java commands
- Communication over Ethernet
- With hardware and meters

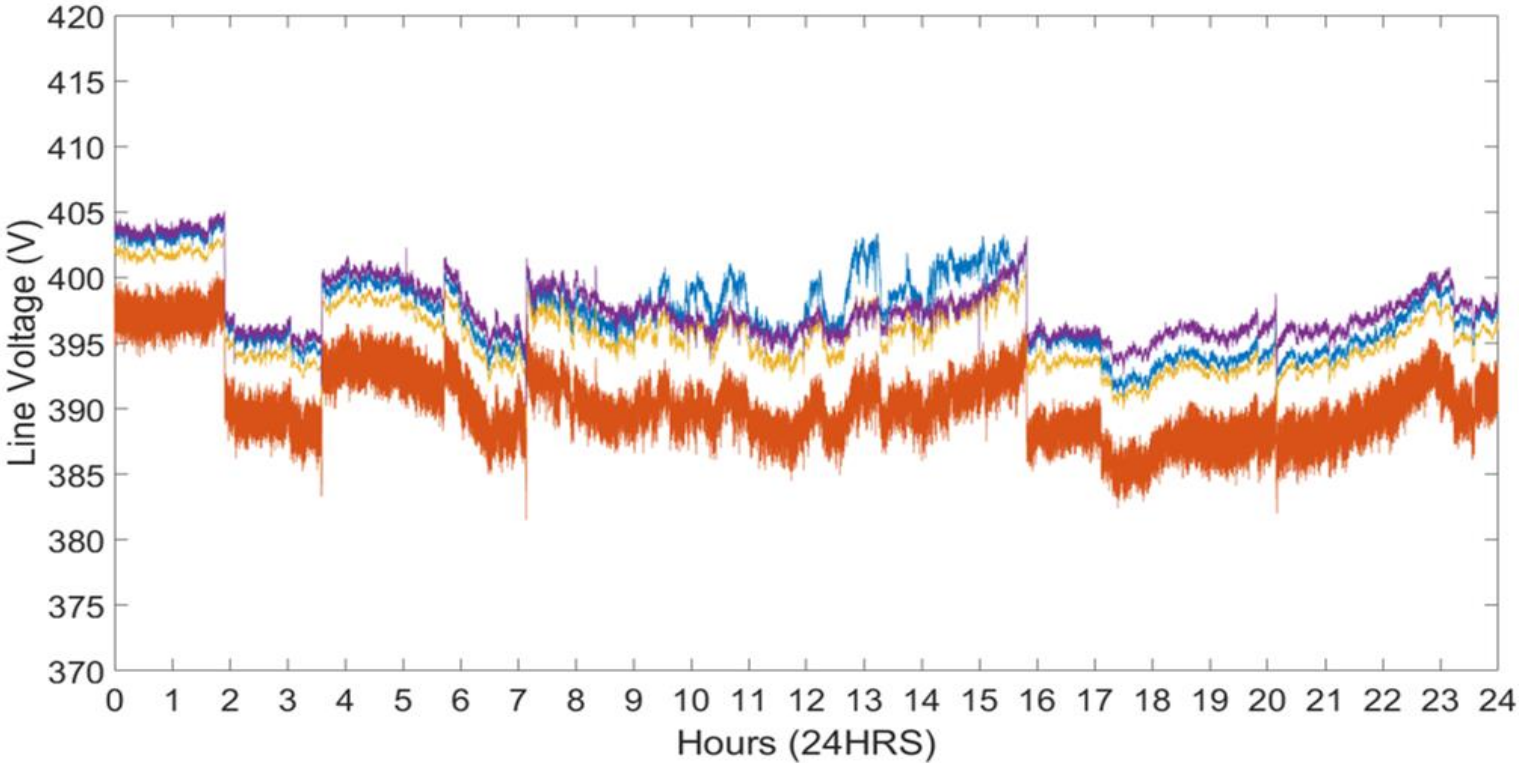


Results: Power Measurements



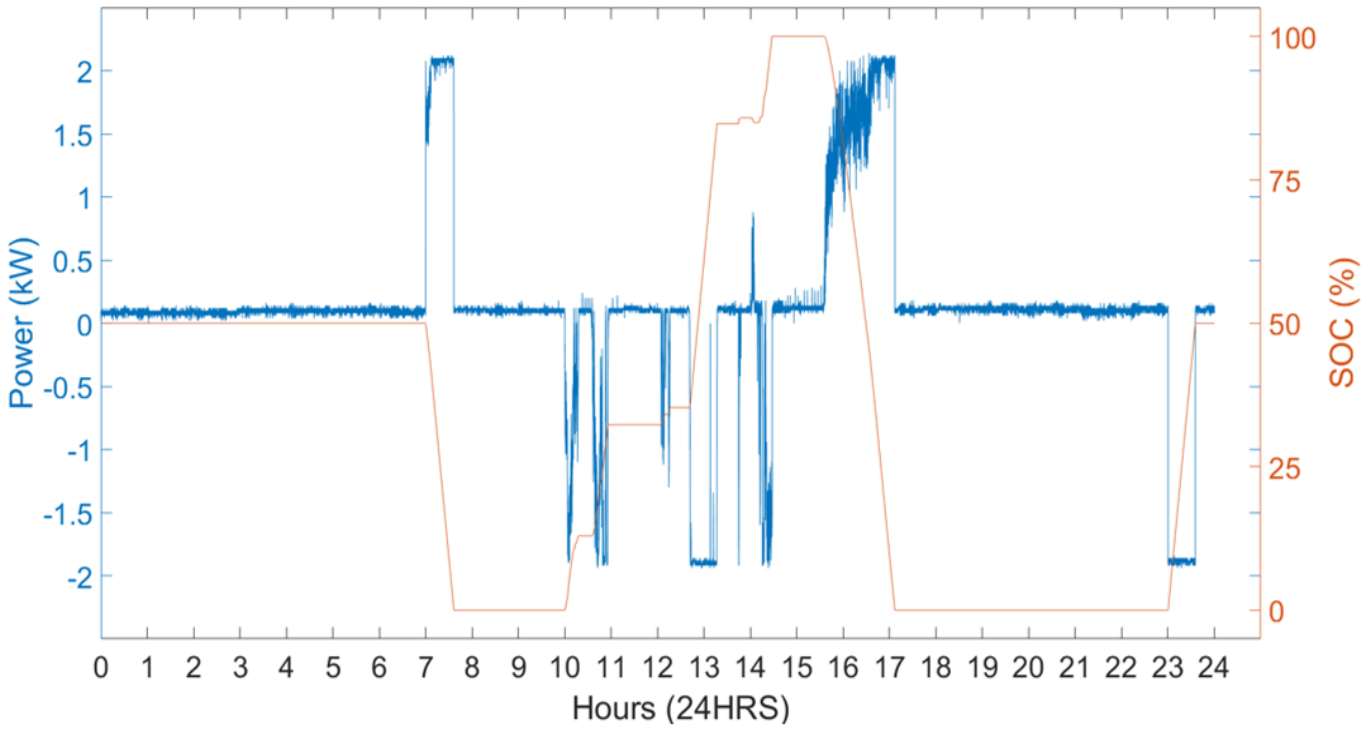
- UCY Load
- PV Production
- Battery Demand
- Grid Load

Results: Voltage Measurements



Voltage Limits +/-10%

Results: Battery Measurements



- Battery Demand
- State-of-Charge (SOC)

Summary

- **UCY future microgrid**: 10MWp PV + 1MW / 1MWh Battery (estimated but not optimized)
- **SYSLAB Facilities (DTU)**: Flexible configuration of DERs (peak shaving algorithm testing)
- **Experimental results**: The voltage limits at the PCC were not violated
- **Peak shaving algorithm**: Promising, provided there is enough PV production, otherwise a large expensive battery is required
- **Load Factor (LF)**: can be improved with peak shaving leading to reduced kWh tariffs
- **Future work**: Need to optimize the PV and Battery size (power and energy)
- **Other future battery uses**: dispatchable load, power quality, frequency control
- **UCY**: will become a carbon neutral institution

Thank you! Questions?

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