Simulation of Grid-Tied PV Systems with Battery Storage in PVsyst

36th European PV Solar Energy Conference and Exhibition - Marseille, France - 09th to 13th of September 2019

André Mermoud, Adrien Villoz, Bruno Wittmer
PVSYST SA, route du Bois-de-Bay 107, CH 1242 Satigny - Switzerland

Abstract

Grid-tied PV systems with battery storage are becoming ever more common as battery prices keep falling. The battery storage in a PV system allows to displace the usage of the solar generated power to times where consumption or injection is needed or possible. The correct sizing of the PV and storage capacity is challenging, and depends on climatic factors, geographical location, power dispatch strategy and energy pricing. The PVsyst simulation software, that allows to model PV systems from small residential size up to large utilities, has implemented the possibility to model grid-tied PV systems with battery storage. Three different dispatch strategies have been foreseen, namely peak-shaving , maximizing self-consumption and weak grid support. In this work we show how the sizing of the PV array and of the battery impact on the system performance and profitability.

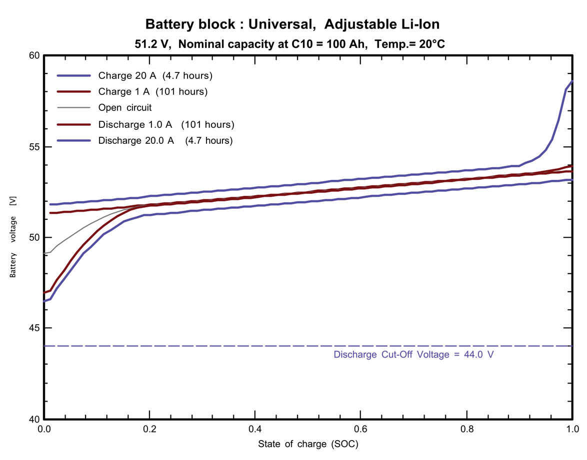
Simulation models

Battery Models

Li-Ion and Lead-acid battery models

Battery behavior is simulated as function of:
- Charge/Discharge rate
- Temperature
- Depth of discharge (DoD)

Model determines:
- State of Charge (SOC)
- Battery Voltage
- Battery Losses
- Ageing (State of Wear SOW)



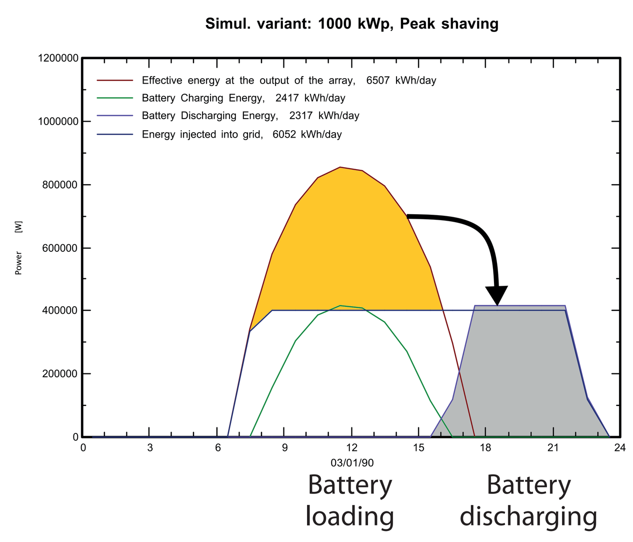
Battery control algorithms based on State of Charge (SOC)

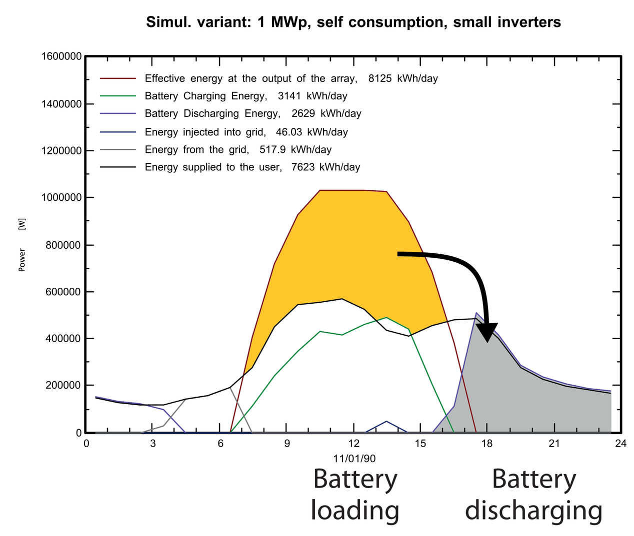
Dispatch strategies

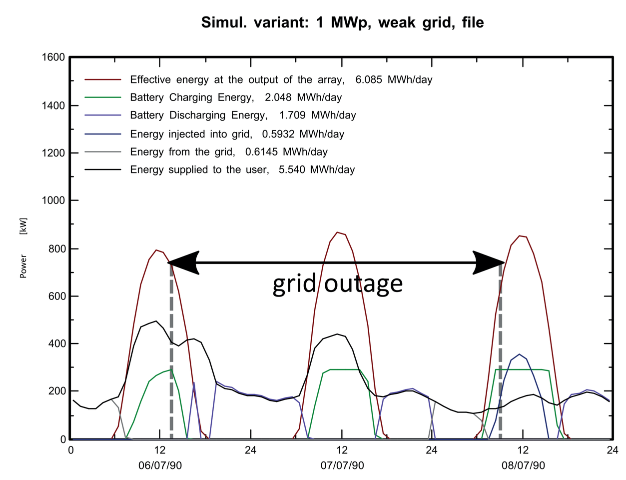
Peak shaving
Injection limitation leads to curtailment in absence of storage
Battery effectively extends PV generation into evening

Self-consumption
Used with a given load profile
Battery effectively extends PV generation into evening

Weak grid islanding
Like self-consumption
Battery discharging is limited in order to cover the load during possible grid outages

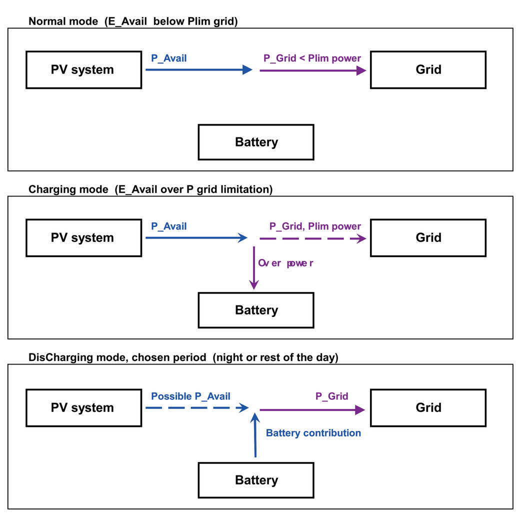






Peak Shaving

Simulation details

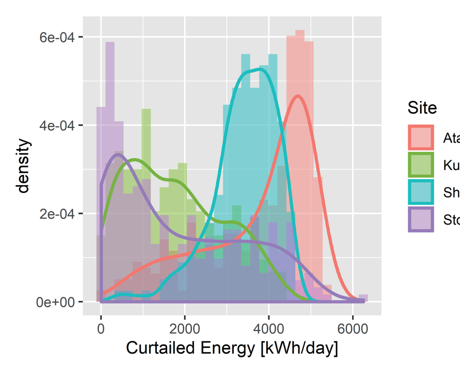


Oversizing Factor OF = PV capacity / Injection Limitation

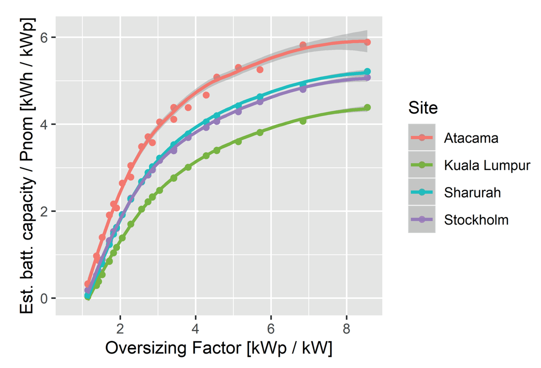
Daily curtailed energy

Battery is used in daily cycles
Daily curtailed energy depends on climate and oversizing factor
Quantiles can be used for battery sizing

Daily curtailment for Oversizing Factor OF = 3.8



90% - quantile of curtailing distribution

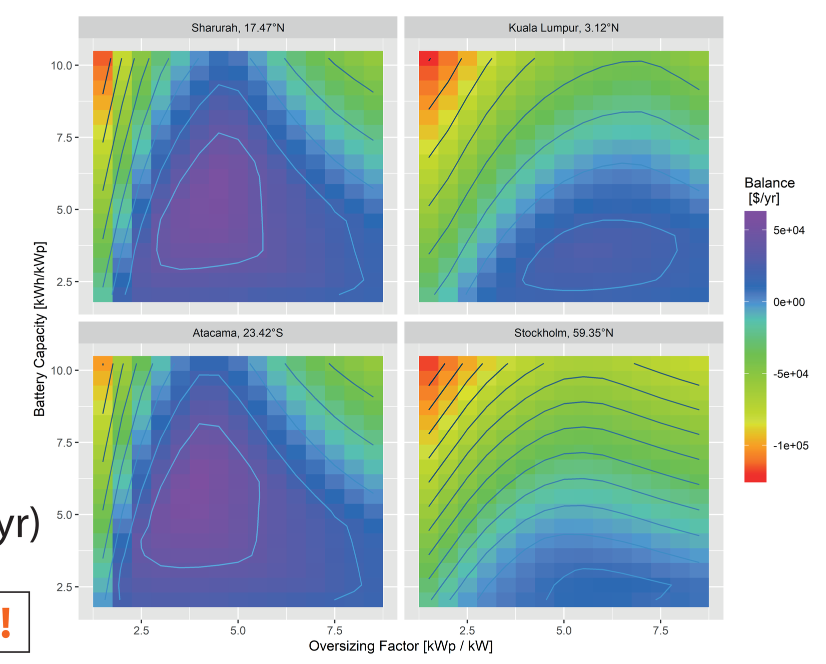


Economic Balance

- Electricity to grid: 0.15 $/kWh
- Battery costs: 120 $/kWh
- Battery lifetime: 6-10 years
- PV costs: 0.4 $/Wp
- System lifetime: 25 years

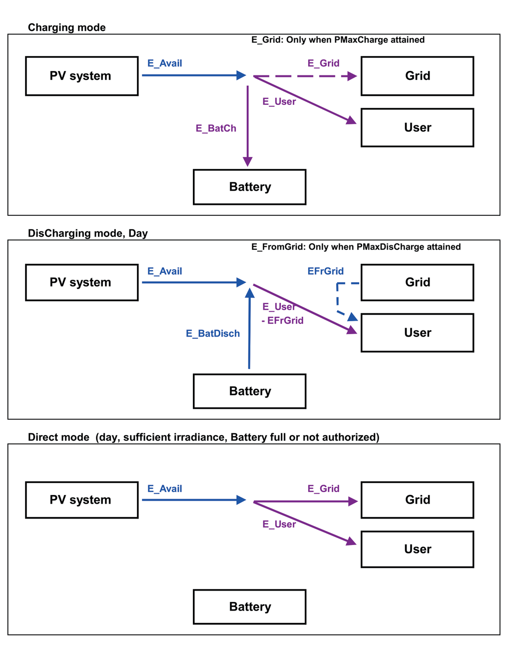
Yearly cost/benefits balance = Elect. sold from storage - (Battery cost / yr + add. PV costs/ yr)

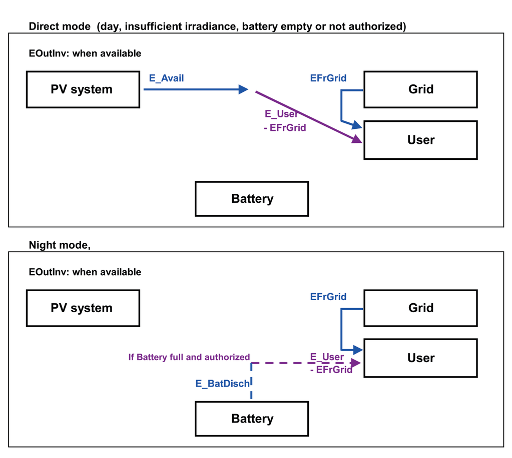
Strongly dependent on tariffs!



Self-Consumption

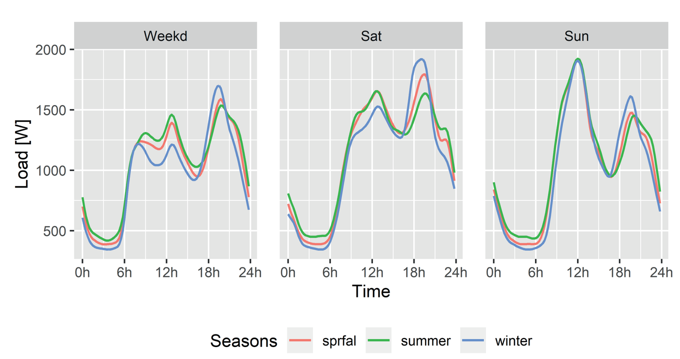
Simulation details





No injection from battery
No charging of battery from grid

Typical household profile (Germany)*



* From BDEW, German Federal Association of Energy and Water

In this study:
Normalized to yearly consumptions between 3000 kWh and 15000 kWh

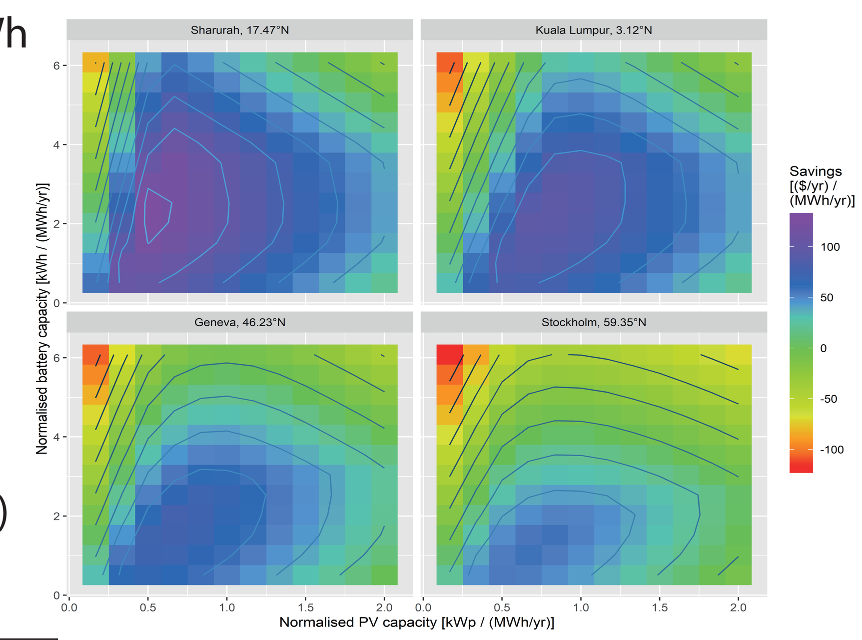
Economic Balance

- Electricity from grid: 0.25 $/kWh
- Battery costs: 250 $/kWh
- Battery lifetime: 5-10 years
- PV costs: 1.5 $/Wp
- System lifetime: 25 years

Yearly cost/savings = Elect. used from storage - (Battery cost / yr + PV costs/ yr)

(Injected energy neglected hear)

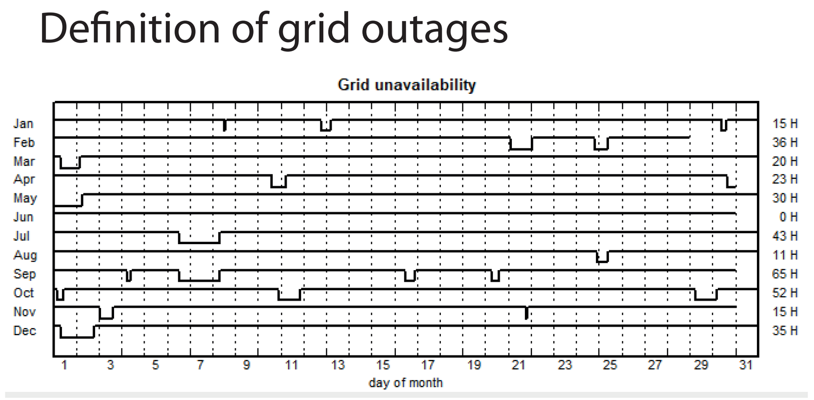
Strongly dependent on tariffs!



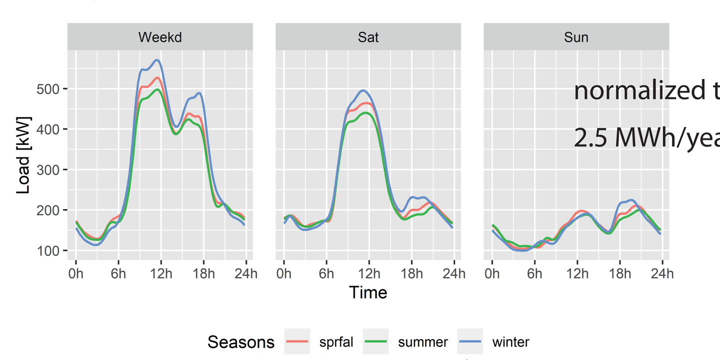
Weak Grid Islanding

Simulation details

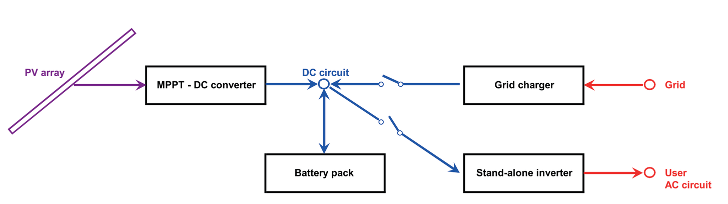
Definition of grid outages

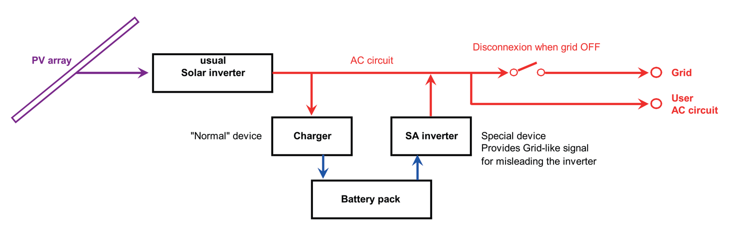


Load profile for commercial consumer (Germany)*

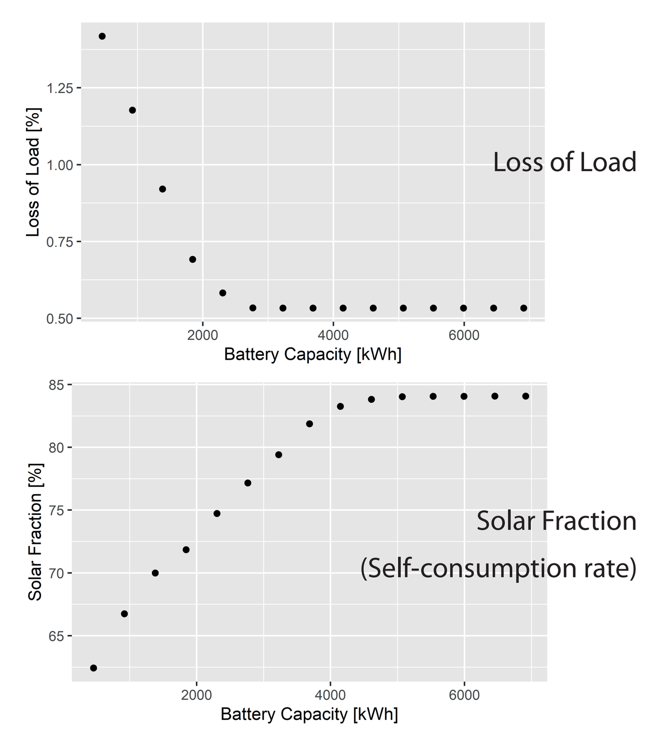


* From BDEW, German Federal Association of Energy and Water





Simulation results



Sites for examples

Site	Climate	Latitude
Atacama	Desert sunny, cool	23.42°S
Sharurah	Desert sunny, hot	17.47°N
Kuala Lumpur	Tropical cloudy, warm	3.12°N
Geneva	Temperate	46.23°N
Stockholm	High Latitude	59.35°N

Summary: The PVsyst software allows the simulation of three different dispatch strategies for grid-connected systems with battery storage. The PV and Battery capacity sizing can be optimized in parametric studies. A fourth strategy called 'Load Shifting' will be implemented. The tools for financial analysis will be integrated into parametric scans to allow economic optimizations.