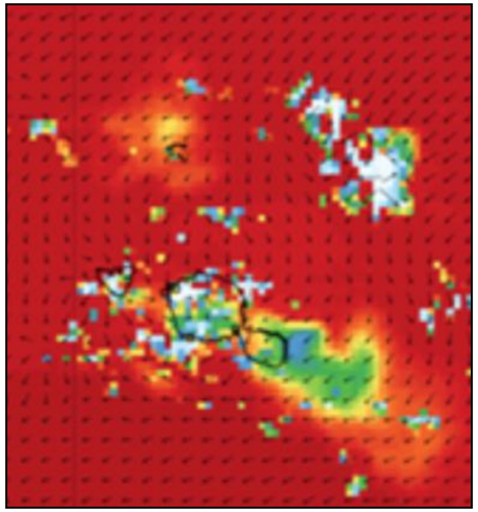


Control optimization and sizing of energy storage for PV systems using probabilistic forecasts

Pierre Besson

May 2020

Steadysun presentation

A range of professional products & services

- Fostering integration of solar energy into the grids
- Mitigating incurred cost of variability
- Turn state-of-the-art technologies into business solutions
- 2 main activities: forecasting services, and consultancy (solar ressource / forecast assessment, hybrid system optimization)

Solar forecasting products

	steadymet	steadysat	steadyeye
Forecast time-horizon	6 hours to 15 days	30 min to 6 hours	5 to 30 min
Update rate	4 times a day	10 to 15 min	1 minute
Spatial resolution	1 to 50 km	1 to 3 km	10 to 100 meters

Key Figures

Founded in April **2013**
Headcount: **22 p**

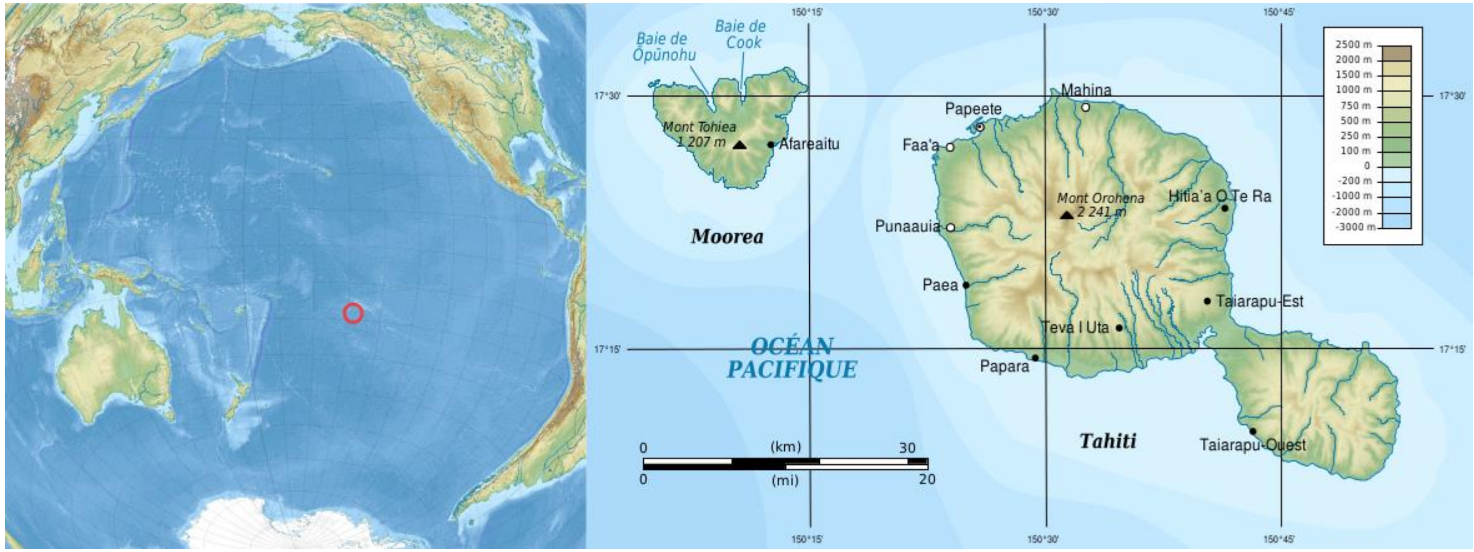
Our expertise

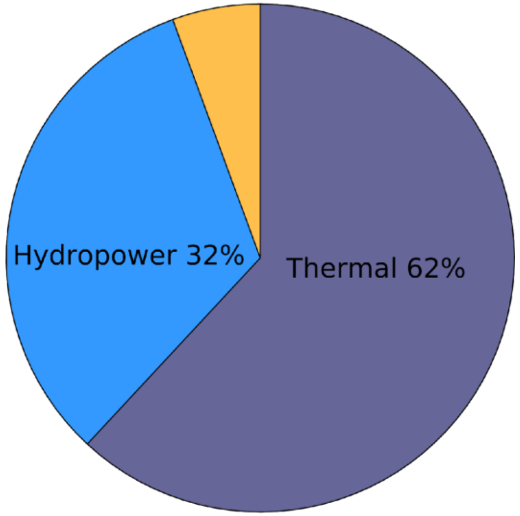
Solar Technologies,
Meteorology,
Image Processing,
Data Science,
IT & Web Services.

Agenda

- **Tahiti study case and objectives**
- **Grid code constraints**
- **Modeling platform and methodology**
- **Results**

Tahiti study case





Electricity generation share (2019)

- Reach 75% of renewable electricity by 2030
- Issues for mitigating PV variability risk for the system balance
- Near-future: Doubling of solar capacity (+ 30 MWp), combined to Energy Storage Systems
- New grid code with requirements for PV energy injection

=> How to satisfy this grid code, while limiting ESS size?

Objectives

Challenge:

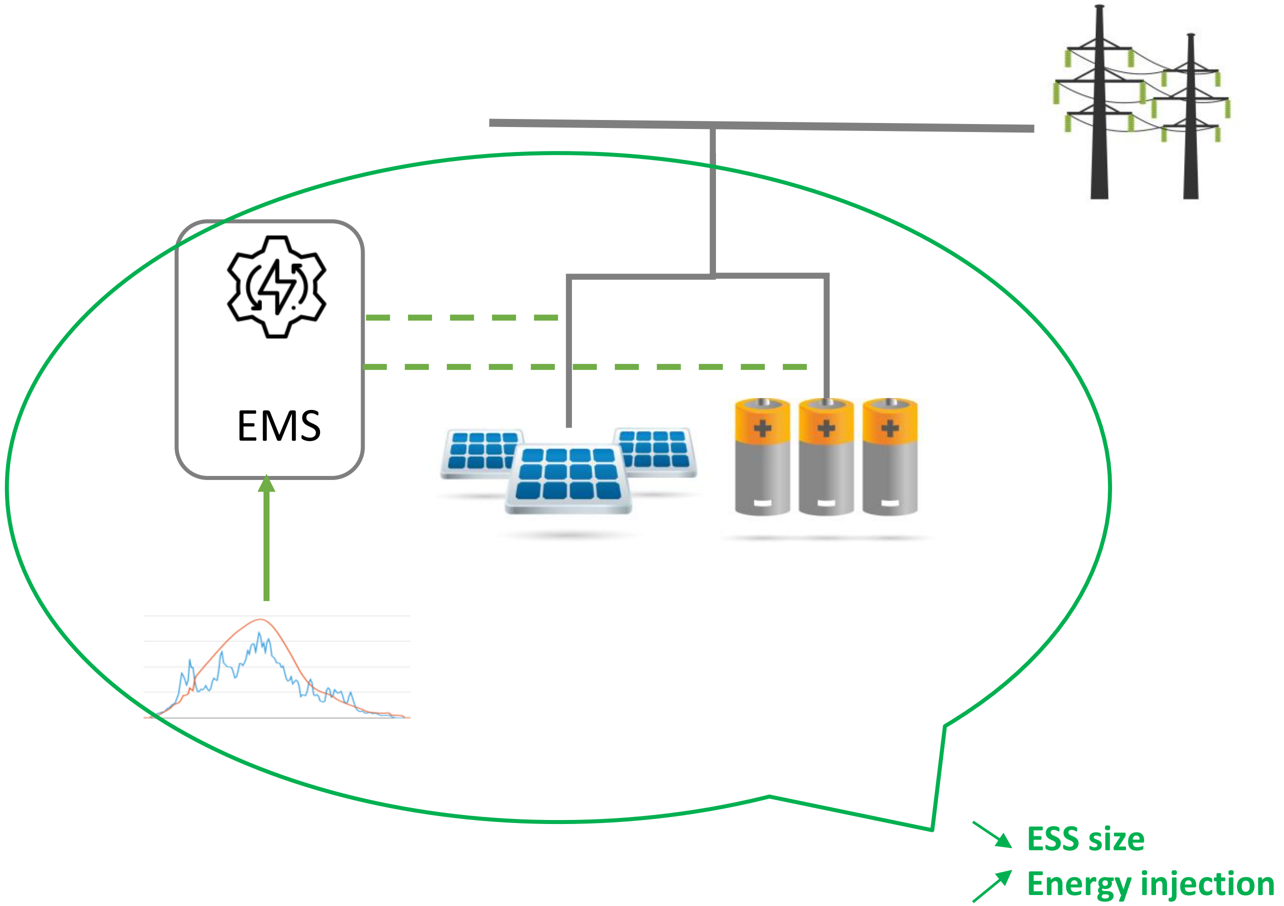
How can we maximize PV penetration, while limiting ESS size and respecting grid code constraints?

Hypothesis:

Probabilistic forecasts can help optimizing trade-off between ESS size and energy injection

Objectives:

- Development of PV-ESS model, with adapted control
- Integrate grid code requirements in control strategy
- Simulate system for different ESS sizes
- Quantify benefits in terms of battery size and energy injection



Tahiti grid code constraints

Injection plan constraints:

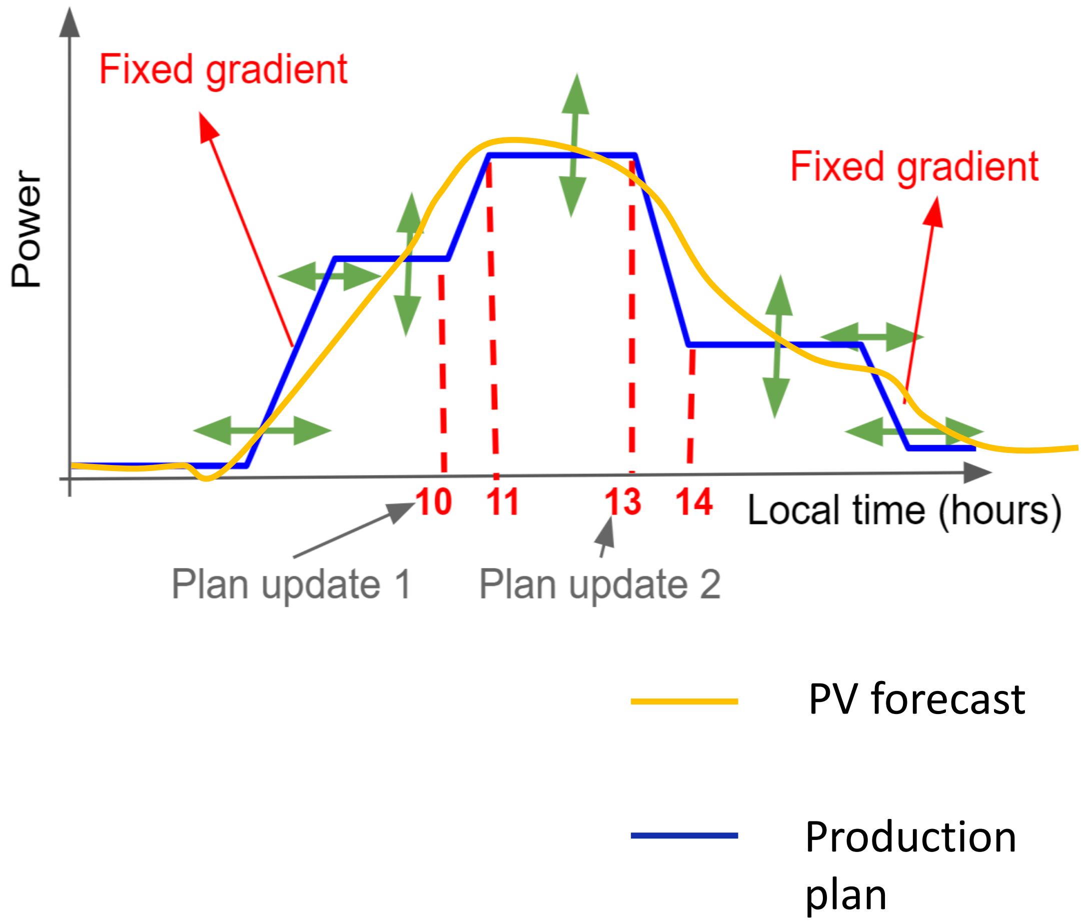
- 3 plateau
- Hours between plateau transitions are fixed, others are flexible (± 30 minutes)
- Fixed gradients at start and end of the day
- Maximum power of plateau cannot exceed 75% of PV peak power

Plan annoncement and updates:

- 1st annoncement at 4 a.m.
- 2 updates: 10 a.m. and 1 p.m.

Penalties system:

- Disconnection of the system from the grid for the rest of the day if:
  - Difference between planned and delivered energy exceeds ± 10% over 15 minutes
  - Difference between planned and delivered power exceeds ± 20% (instantaneous)



SteadyMet forecast

Combination of day-ahead forecasts:

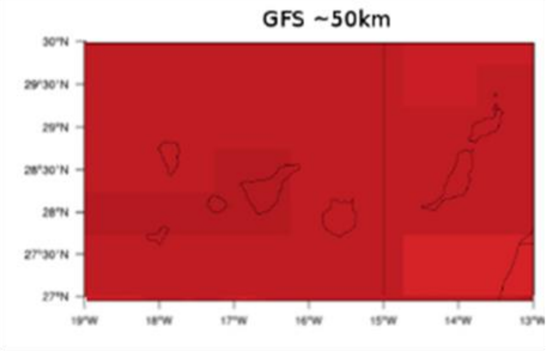
- the GFS model (50 km resolution) and its ensemblist version GEFS (50 km)
- IFS-HRES model from the ECMWF (10 km)
- AROME model from Météo-France (2.5km)
- WRF model (until 1 km), which is setup and operated by Steadysun

⇒**Probabilistic irradiance forecasts**

- Physical PV model to estimate PV production
- Statistical corrections using machine learning and real-time solar production measurements

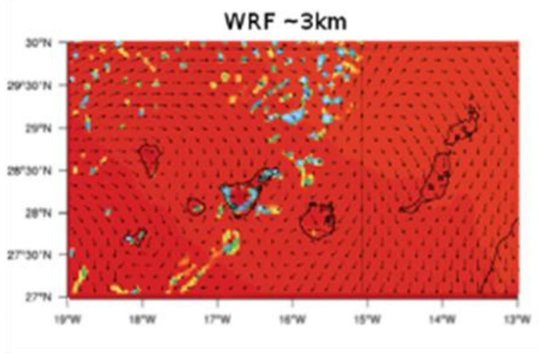
Global models

- **Coarse spatial resolution**
- **Empirical decomposition of GHI**
- **No cloud-aerosol-radiation interactions**
- **Limited local data assimilation**



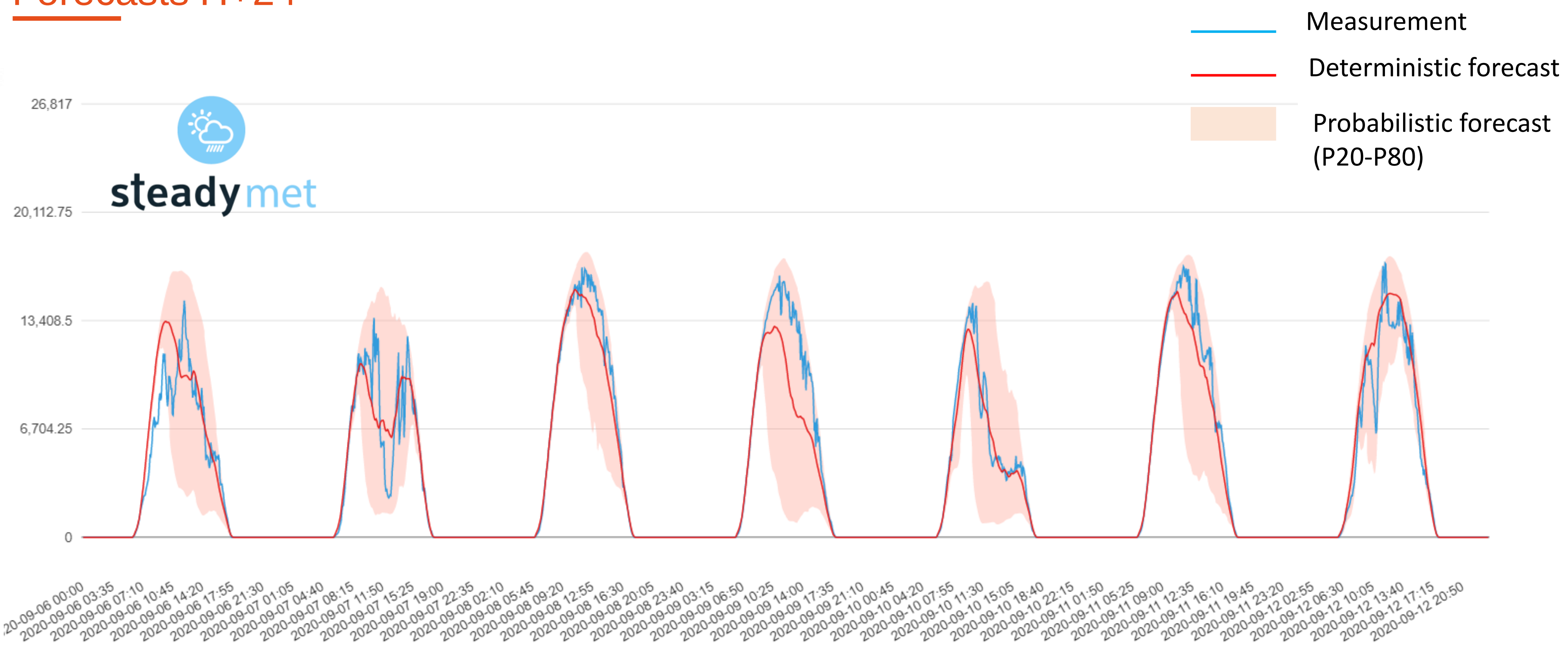
WRF model

- **High Spatial Resolution**
- **Physical Decomposition of GHI**
- **Advanced cloud-aerosol-radiation interactions**
- **Enhanced Initial Conditions**



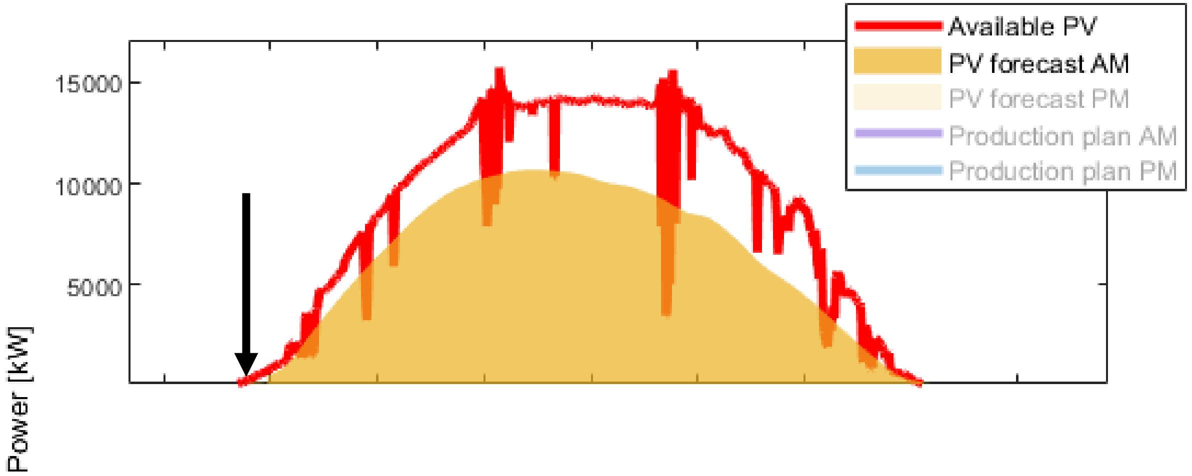
SteadyMet forecast example

Forecasts H+24



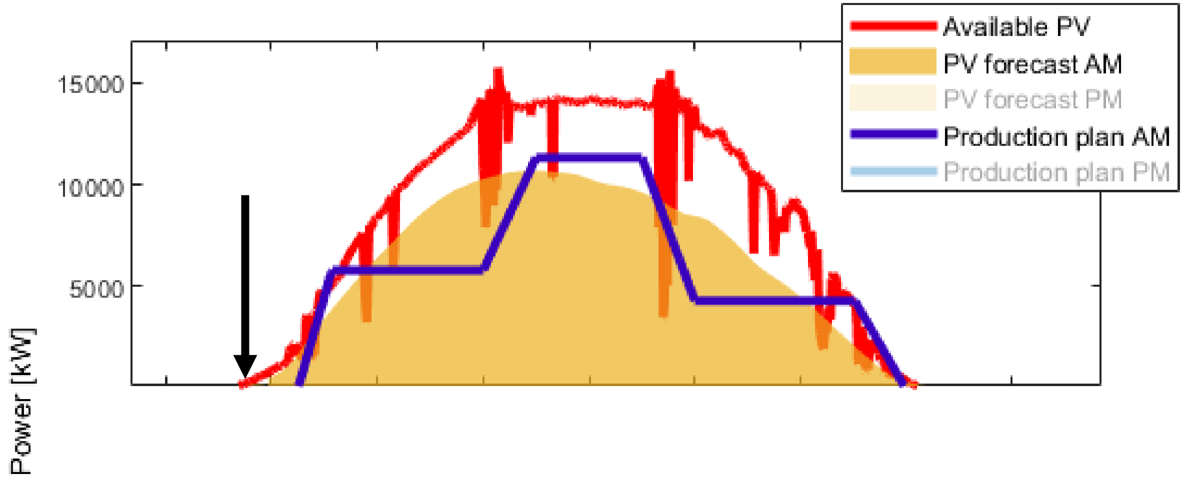
- Probabilistic forecast
- nMAE (insular conditions): <3% on aggregated power plants ; ~4% on single power plant

Production plan calculation using forecast



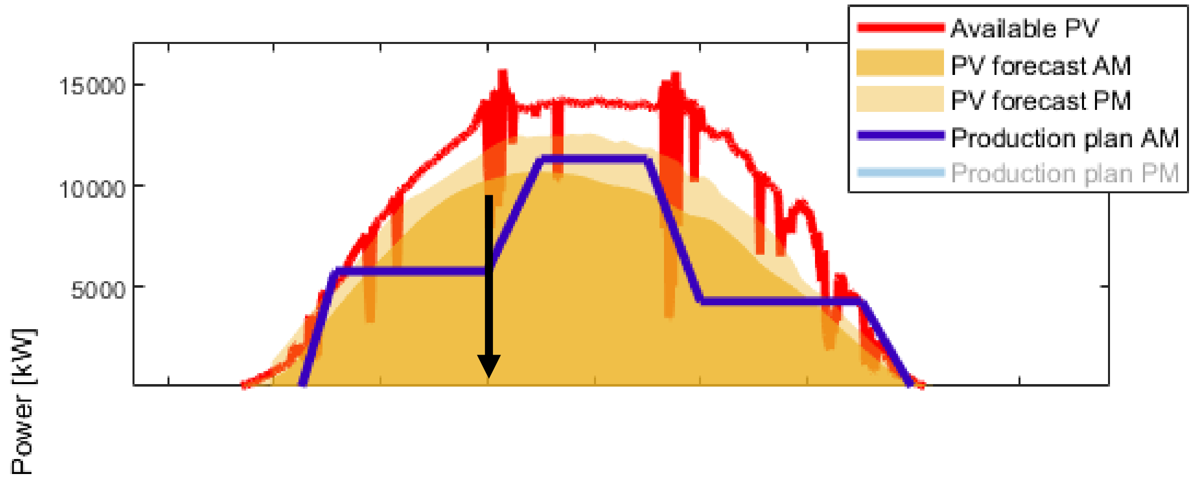
1. Morning forecast is available

Production plan calculation using forecast



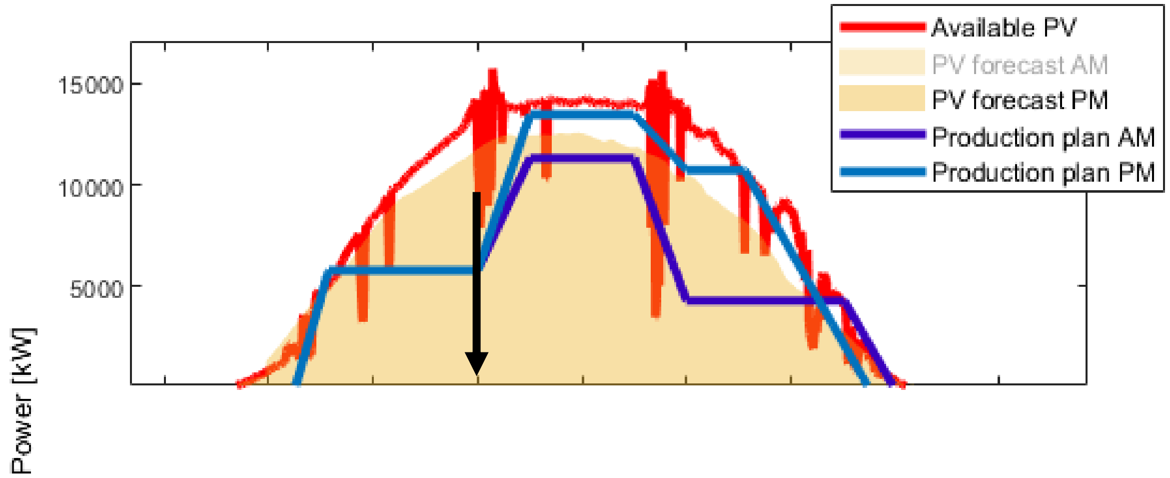
1. **Morning forecast is available**
2. **Calculation of production plan at 4 AM**

Production plan calculation using forecast



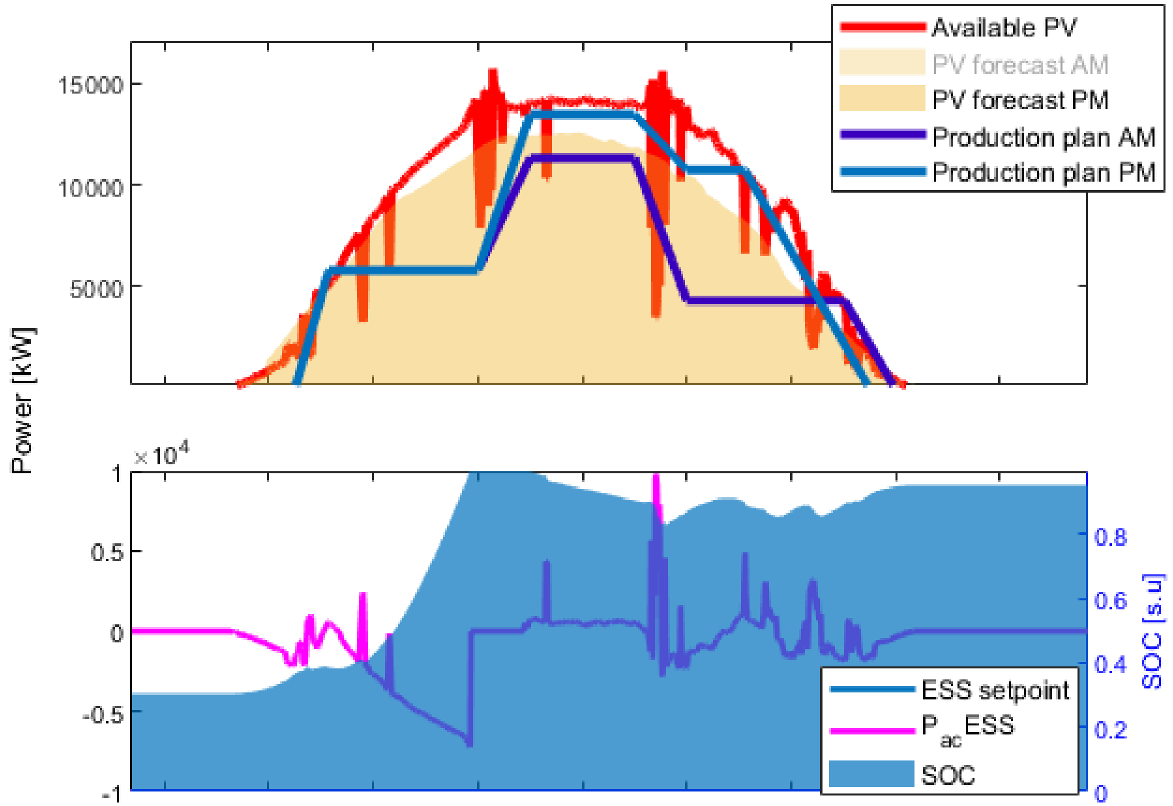
1. **Morning forecast is available**
2. **Calculation of production plan at 4 AM**
3. **New forecast is available**

Production plan calculation using forecast



1. **Morning forecast is available**
2. **Calculation of production plan at 4 AM**
3. **New forecast is available**
4. **Production plan is updated, according to new forecast and SOC**

Production plan calculation using forecast

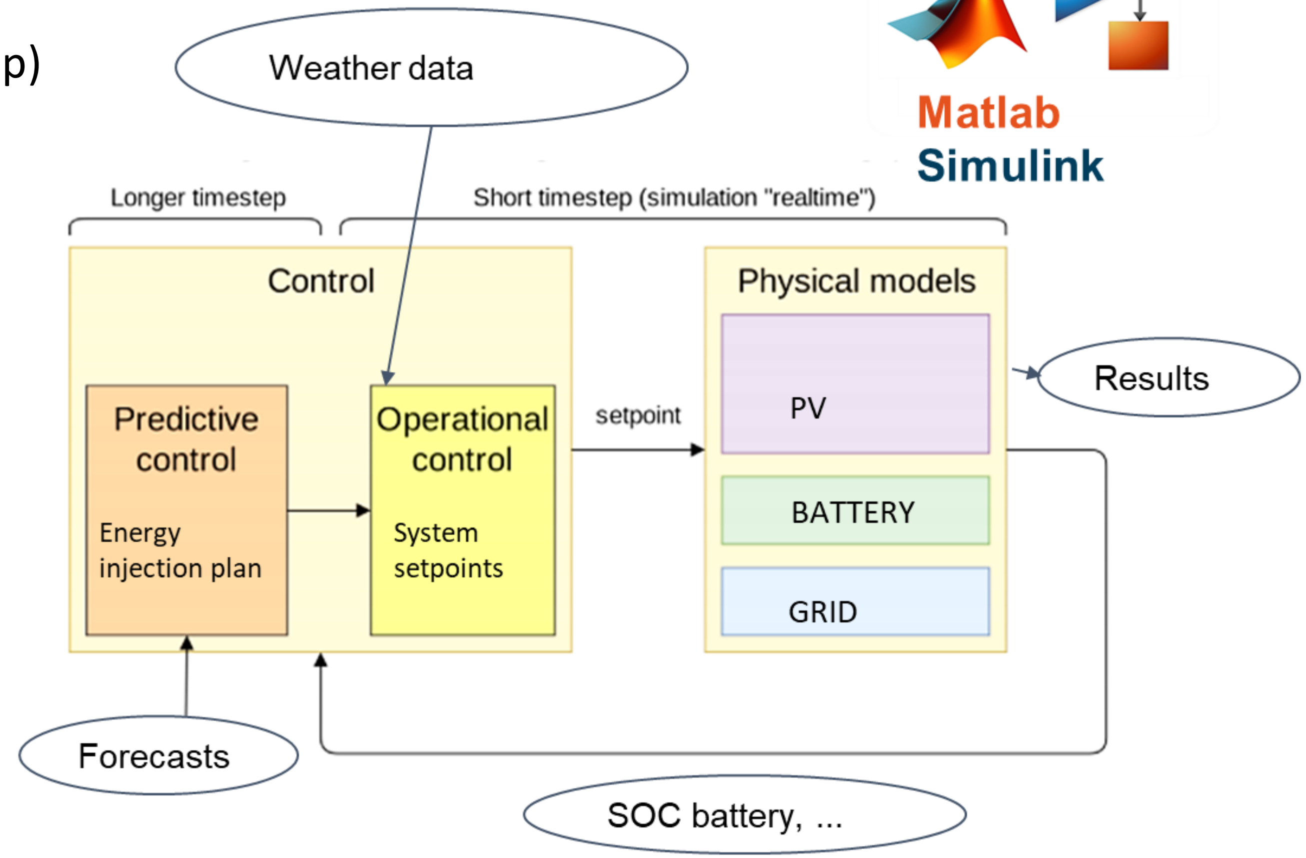


1. **Morning forecast is available**
2. **Calculation of production plan at 4 AM**
3. **New forecast is available**
4. **Production plan is updated, according to new forecast and SOC**
5. **Better usage of ESS thanks to the plan update**

Simulation and control

Simulation platform « Spider »:

- Model-based design applied to power systems for Energy Management System (EMS) development
- Simulink model libraries
- On-grid and off-grid capabilities (10 sec time step)
- EMS ready-to-be implemented in operational systems



Control strategy:

- 2 level control strategy:
  - 1 planning phase => calculates injection plan at specific horizon
  - 1 operational phase => at each timestep, tries following plan by defining adapted setpoints

Study case and hypothesis

Fixed PV plant size: 18 MWp, with production at 1 minute timestep estimated

ESS study:

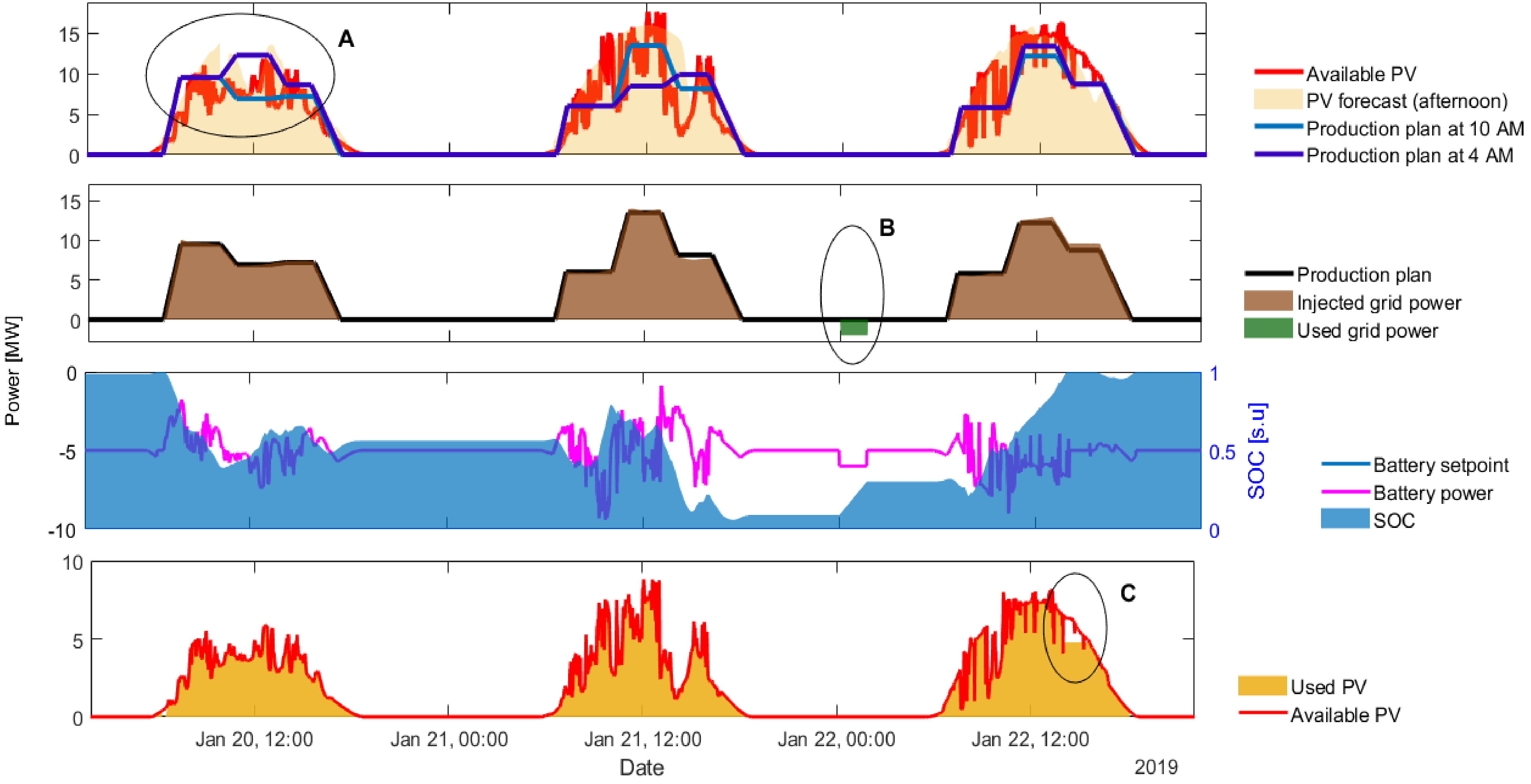
- ESS size sensitivity analysis: from 12 to 22 MWh, with 2 MWh step
- No upper and lower limit for SOC : "Useful" energy capacity is considered
- Maximum charge/discharge power = 18 MW
- Fixed efficiency: 95%

3 types of forecasts:

- Perfect forecast: forecast = actual production
- Persistence: forecast = actual production from previous day
- Steadysun: SteadyMet probabilistic forecast => Forecast adapted to SOC

Simulations are performed for **1 year at 1 minute timestep**

Results example



Different situations are shown

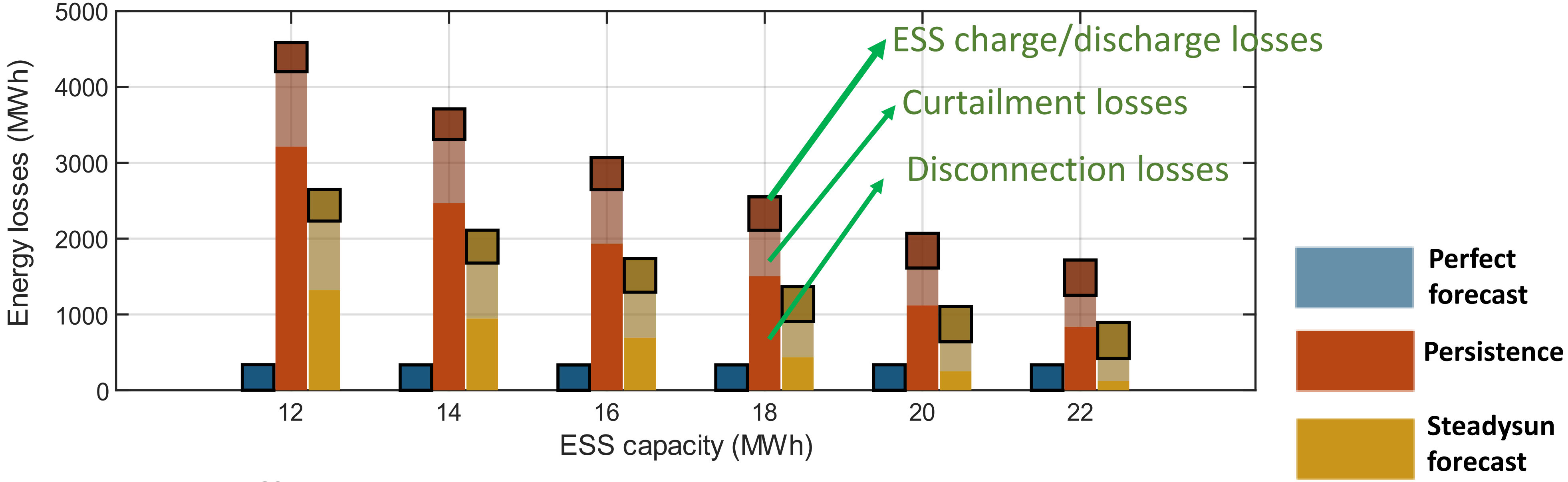
A : effective update of production plan

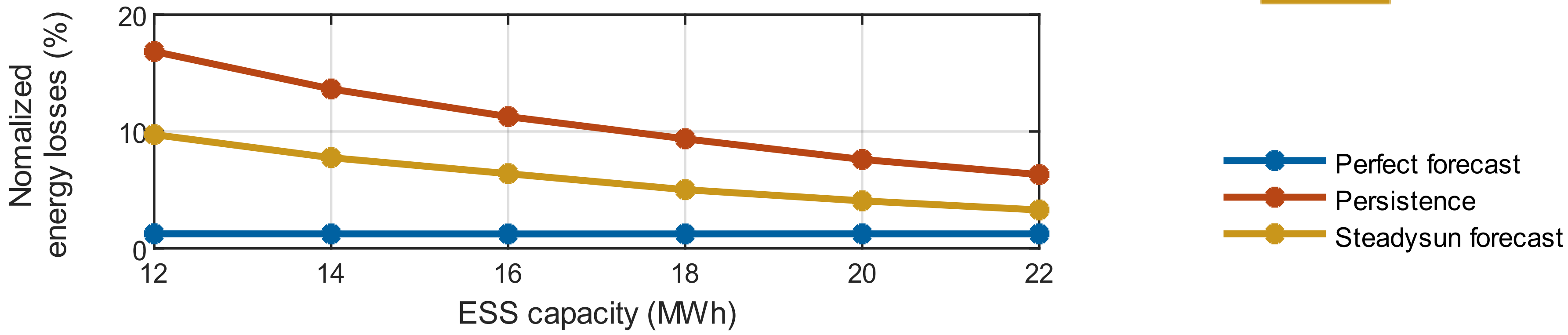
B : Night charge due to low SOC at end of the day

C : Curtailment (pessimistic forecast)

steadysun

Result example: energy losses analysis

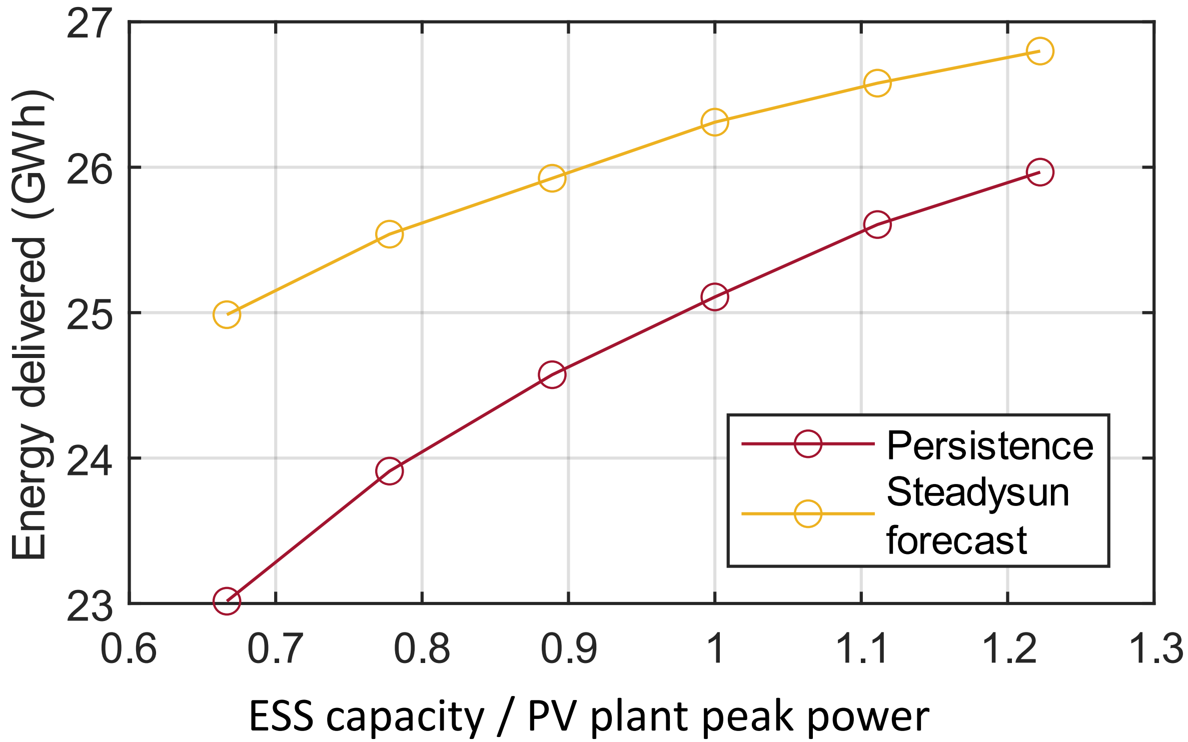




- Losses = available PV energy lost
- Higher losses with persistence: more important disconnections from the grid
- At 12 MWh:
  - 17% losses with persistence
  - 10% losses with Steadysun forecast
- At 18 MWh:
  - 9.5% losses with persistence
  - 4% losses with Steadysun forecast

=> More than 40% reduction of losses with Steadysun forecast compared to persistence

Results: energy delivered



- Higher amount of energy delivered with Steadysun forecast:
  - For a ESS capacity ratio of 1, increase of ~5 %
- To deliver same amount of energy with persistence:
  - Increase of ESS capacity ratio by 0.3 ! (6 MWh in our case)

Conclusions

- **Spider is an efficient modeling tool to evaluate EMS strategy designed for a specific grid code**
- **Day ahead and intraday forecasts are relevant for control strategy with a planning layer**
- **When compared with persistence, probabilistic forecasts allow:**
  - **Limiting energy losses in PV-ESS systems**
  - **Optimize the trade-off between battery size and energy injection**
- **Simulation results at 1 minute timestep can be used for estimating accurate ESS charge/discharge profile, and SOC variations**

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POUR MIEUX L'EXPLOITER

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