Assessment of Control Strategies Performance in Stand-Alone PV-Diesel System: Simulation and Experimental Test

Thai Phuong DO[1], Gabin A. KOUCOI[1] , Franck BOURRY[1], Xavier LE PIVERT[2]

[1]National Institute of Solar Energy - France

[2]Steadysun - France

3rd International Hybrid Power Systems Workshop

Speaker : Pierre Besson

May 2018

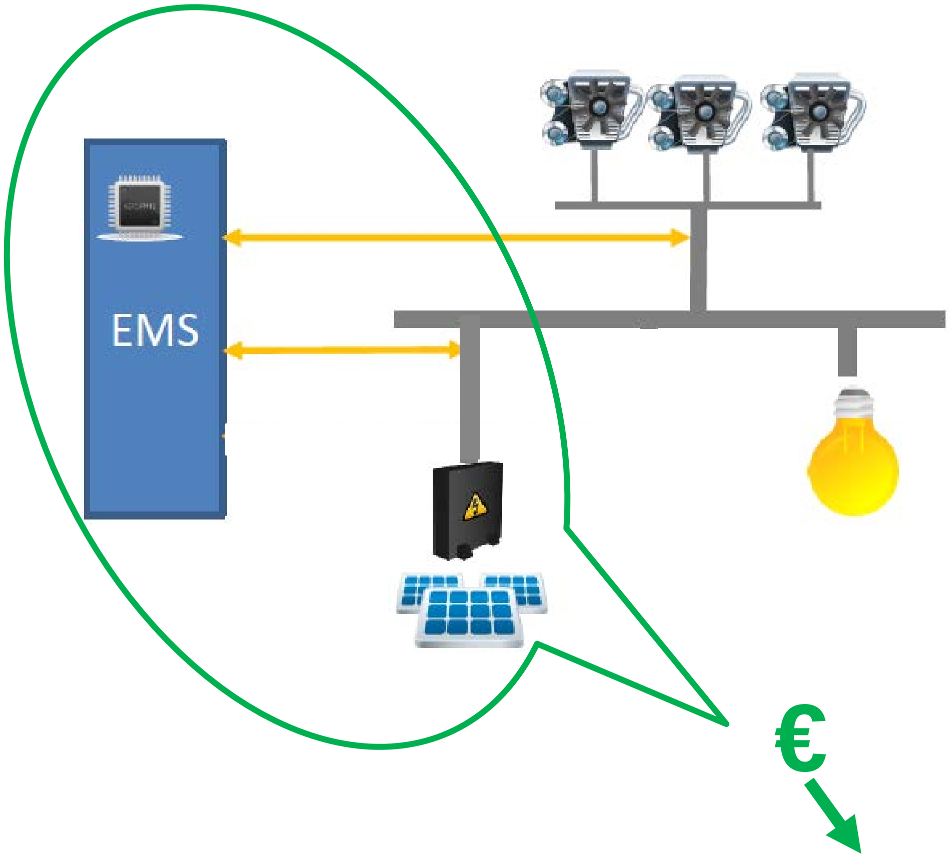
Agenda

I. Context and objectives
II. Simulation of control strategies
III. Results
IV. Validation on an experimental platform
V. Conclusions

Context

- Off-grid systems for industrial applications (# 100 kVA – # MVA): traditionally based on gensets
  - High OPEX costs
- Hybrid PV-diesel can lower cost
  - Lower OPEX
  - BUT issues linked to PV generation => instability
- Key point: efficient management of genset (Unit commitment)

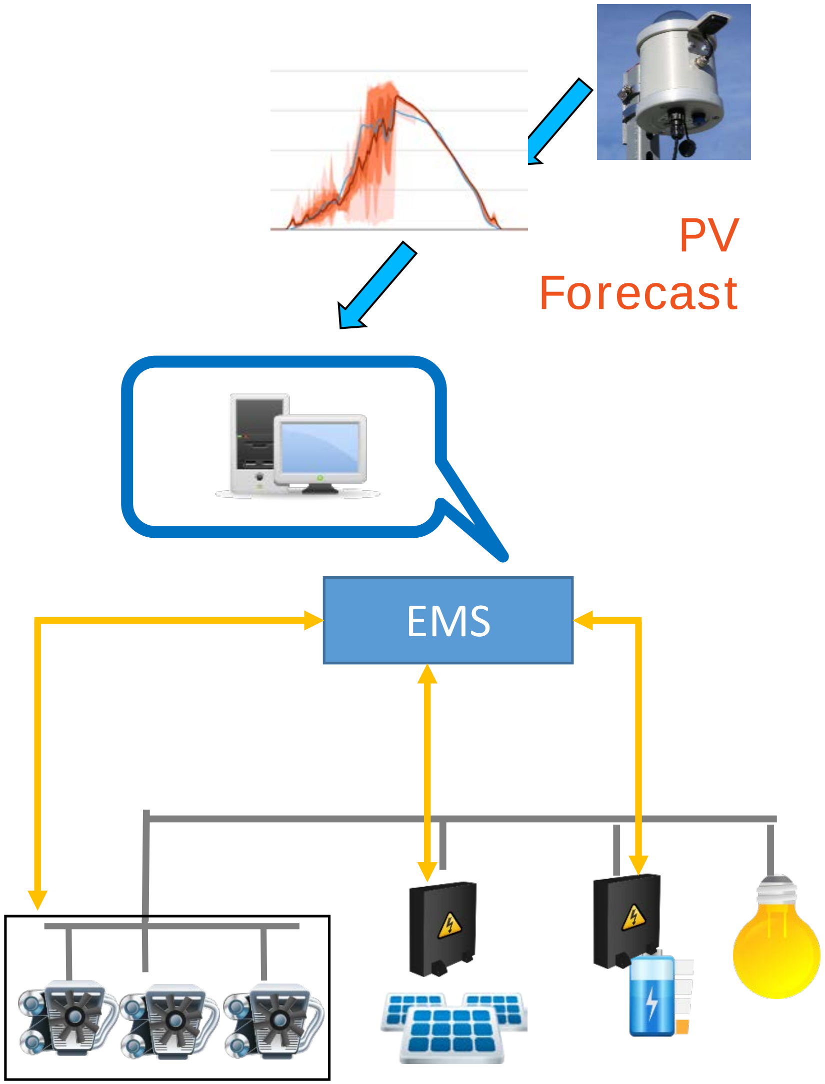
  => Control strategy (EMS) has to be adapted to PV integration



Objectives

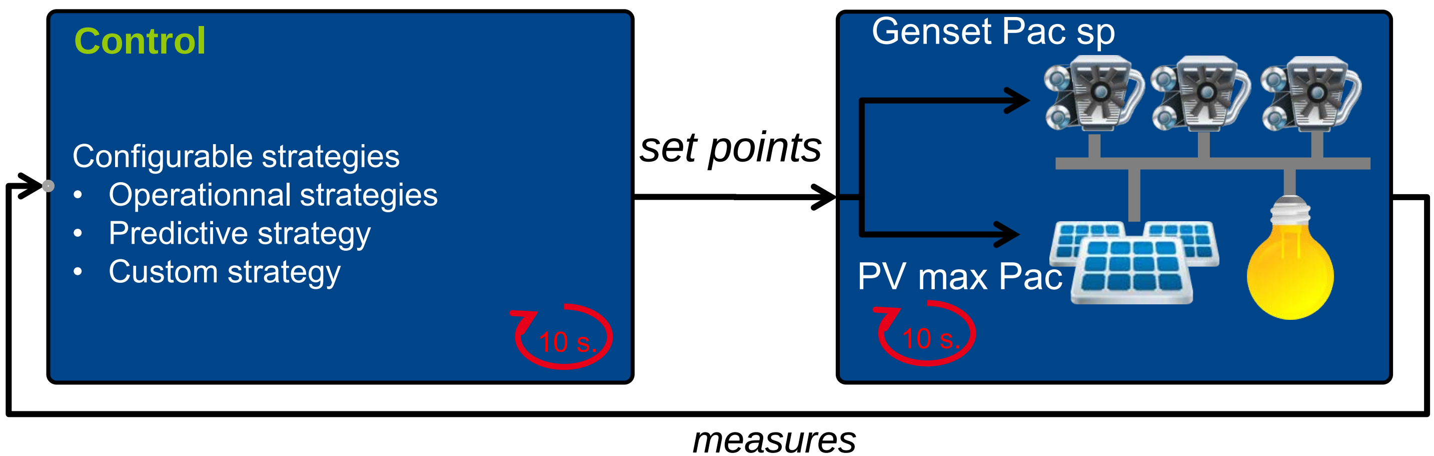
- Hypothesis
  - **Unit Comitment of gensets facilitated by better knowledge of PV production (forecast)**

- Work plan
  - Development of an **adapted modeling tool** for testing control strategies
  - Evaluation of benefits of short-term PV forecast through **simulation**
  - **Application on a real system** for validation



Modeling system operation

- Based on a **simulation platform from CEA-INES : SPIDER**
  - Model-based design applied to power systems for Energy Management System (EMS) development
  - Simulink model libraries

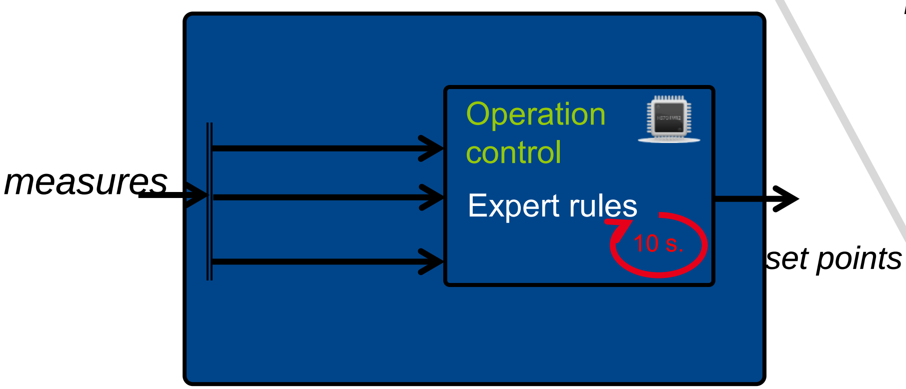


  - Possibility to model off-grid and on-grid system behavior, at second time step
    - ⇒ Adapted to transient phenomenon in genset and PV
    - ⇒ Tested EMS can be implemented in real solutions

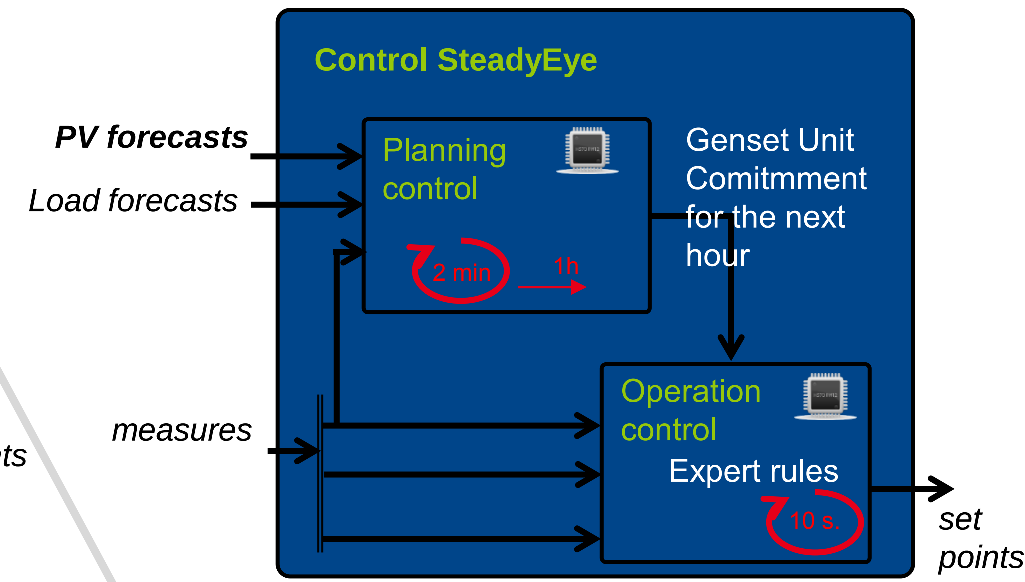
Control strategies

- Different control strategies tested:
  - Strategy S1 : « Netload »: Simple strategy, based on net load power
  - Strategy S1b: « Curtailment strategy », PV power can be limited to respect genset power restriction (known as ‘fuel saving’)
  - Strategy S2: « steadyEye », anticipation of genset dispatching with PV forecast

S1 & S1b



S2



PV production forecast

- **Steadysun** solution : Photovoltaic power forecast from few minutes to several days

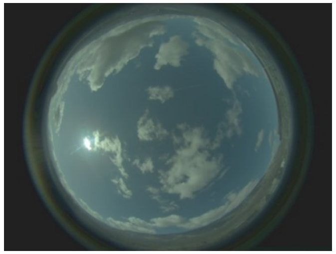
➔ **"steadyEye"** : analyzes on-site sky images to forecast PV power up to 1 hour in advance

Key points

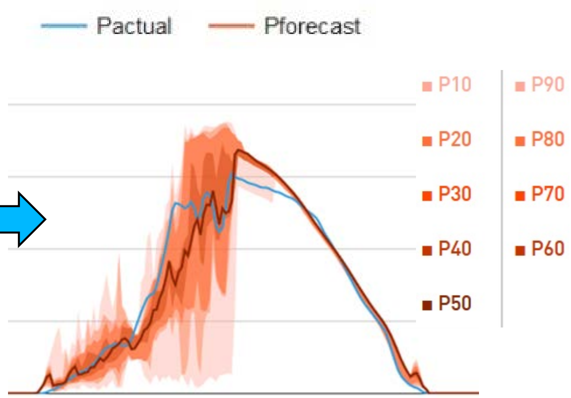
- Image quality
- 15'' updates
- Percentiles
- Confidence interval

- Steadysun expertise
  - ✓ Image processing
  - ✓ Algorithms
  - ✓ Real-time system

steadyEye sky imager



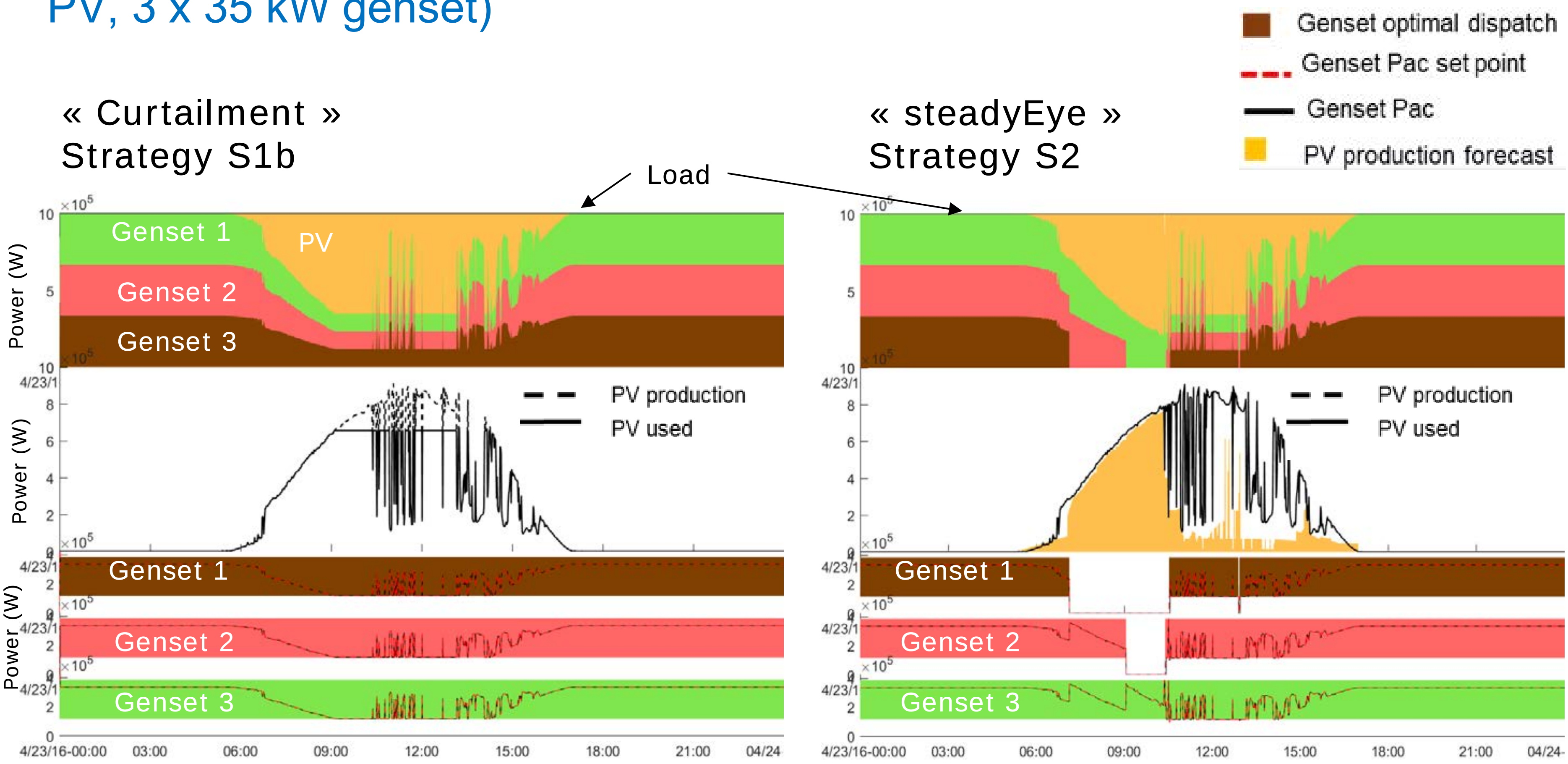
sky images processing



PV power forecast and its percentiles

Results example

- Zoom on 1 day results for a small system (100 kW load, 100 kW PV, 3 x 35 kW genset)



⇨ Saving: 55 l for this day with SteadyEye strategy (100 kW system)

Simulation for large scale system

- Simulation case:
  - Large scale system (industry, micro-grid, etc.) => 25 MW

System characteristics

System	Gensets (SDMO)	PV	Charge
Large scale	3 X 9.8 MW	12.5 MWc to 37.5 MWc	25 MW

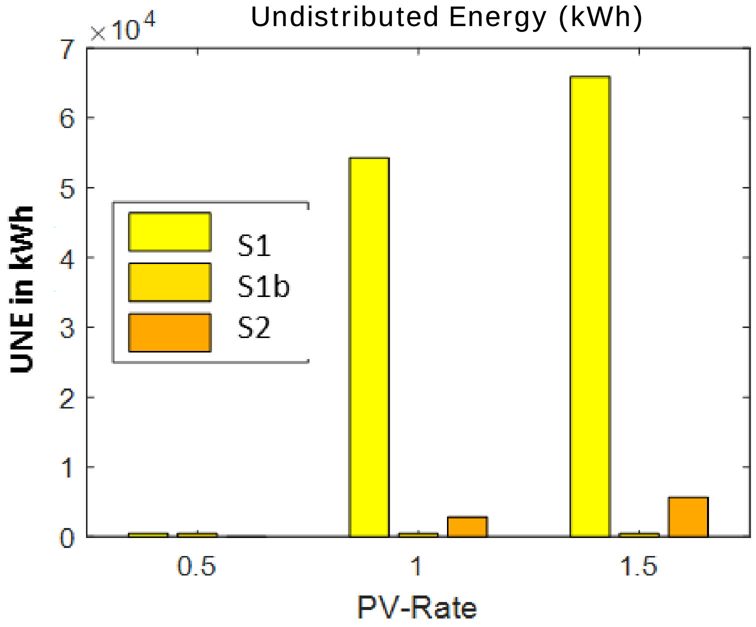
Genset time characteristics

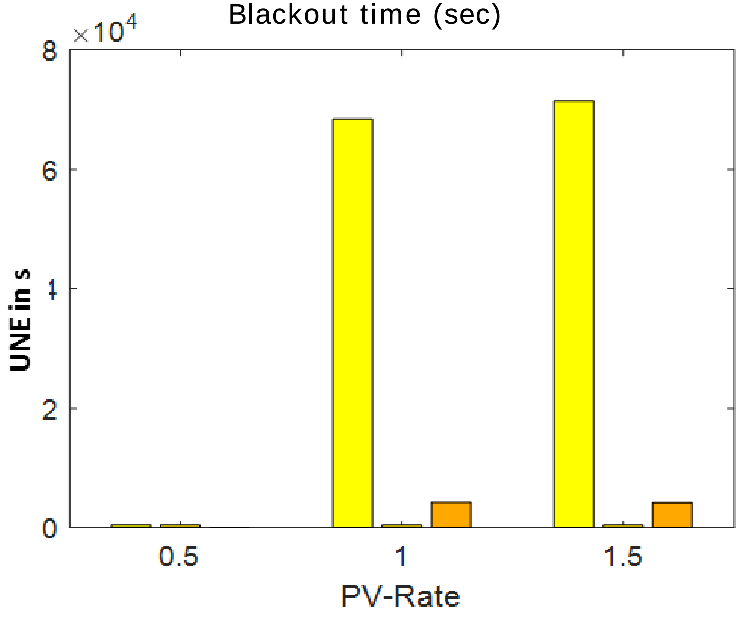
Tstart	T_min_ON
6 mn	60 mn

- More than 40 days simulated with various and representative PV profiles
- Different indicators analyzed: energy unavailability, fuel consumption, genset operating time

Results

- Undistributed energy for different PV-rates (load 25 MW)



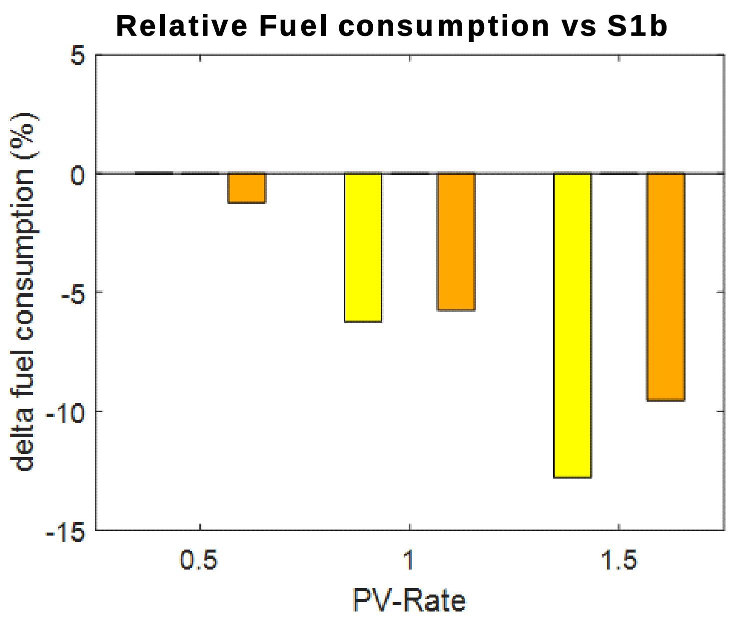


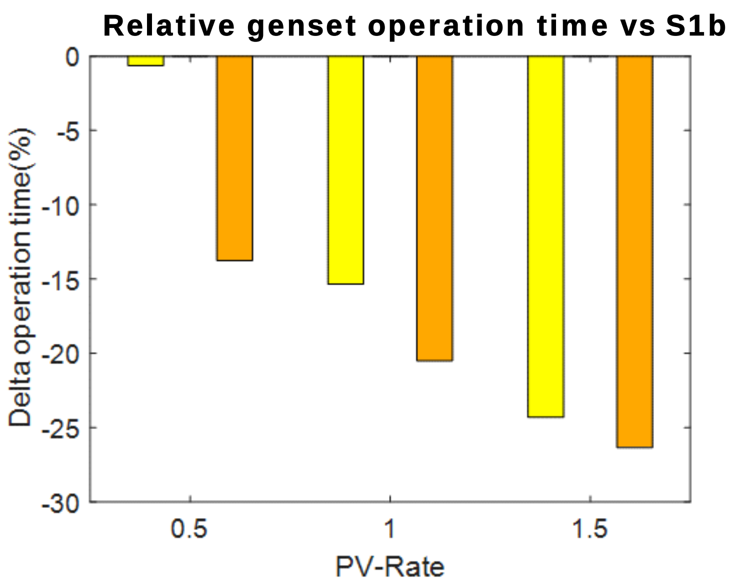
- ✓ Instability in creases with PV-rate
- ✓ S1b and S2 strategy are efficient strategies for decreasing energy shortage

NB:Ref strategy = S1b

Results

- Fuel consumption and operation time for different PV-rates (25 MW load): comparison of S1 and S2 vs S1b (reference)





✓ S1 and S2 allows saving ~6% of fuel, and ~20% of operation time for PV-rate of 1. This can be increased when PV-rate increases!

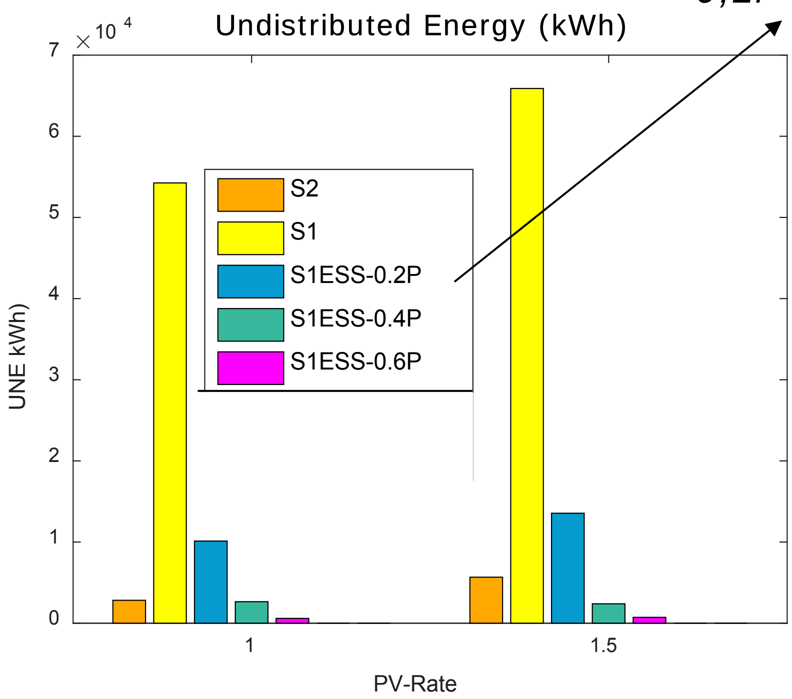
➔ **S2 allows both saving fuel and improving system stability**

NB:Ref strategy = S1b

Results

- Comparison steadyEye strategy S2 vs S1+Battery storage solution: different storage size compared

0,2P=20% of load = 5 MW/1,5MWh



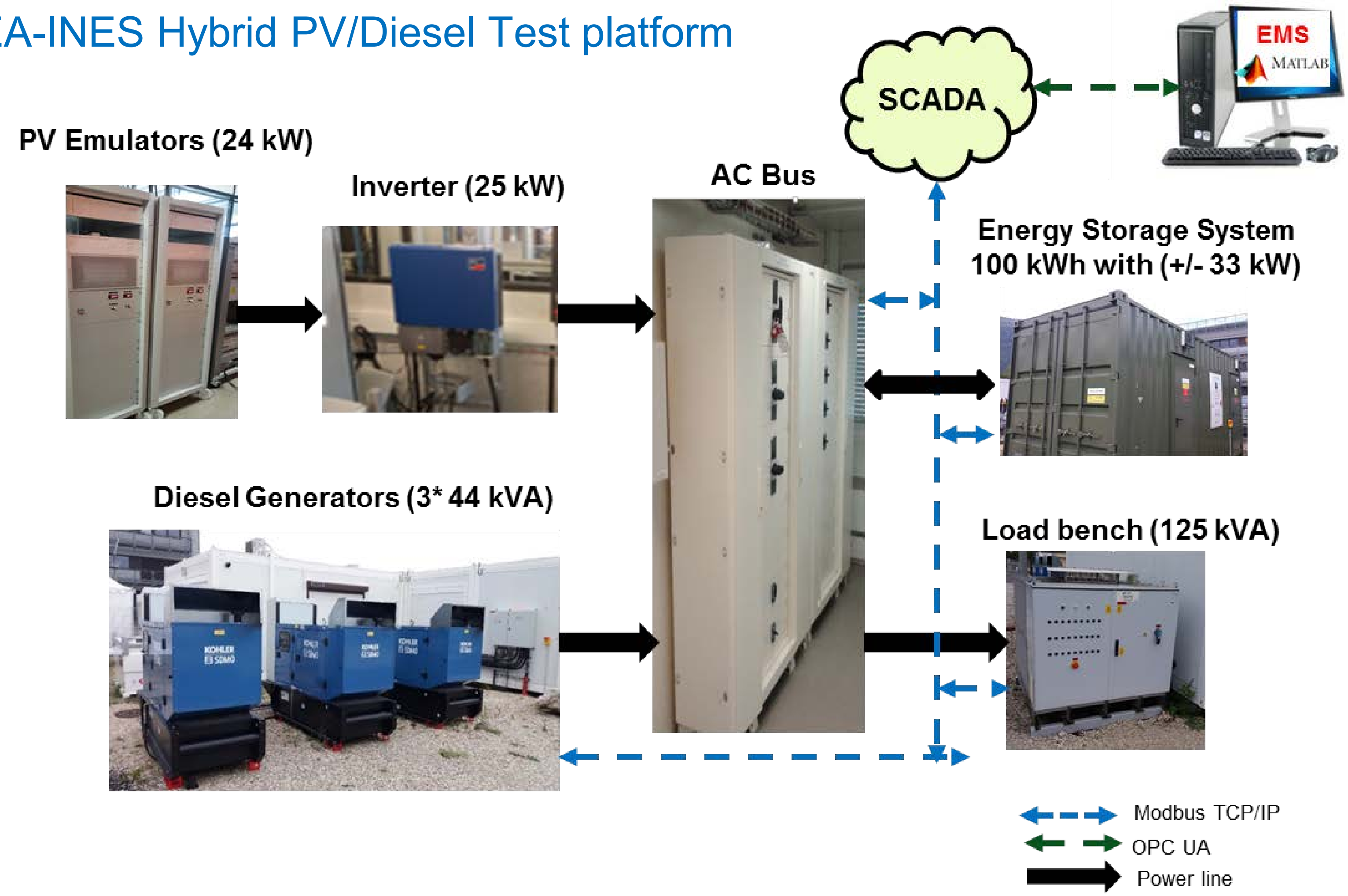
✓ Stability increases with storage size

✓ **steadyEye strategy S2 corresponds to a 40% storage size (10MW/3MWh for PV-rate = 1)**
NB: Storage of 3 MWh ~= 1 M€ with 300 €/kWh

✓ steadyEye strategy S2 can also be combined with battery storage to reduce battery size for obtaining END = 0 kWh

Experimental validation: set-up

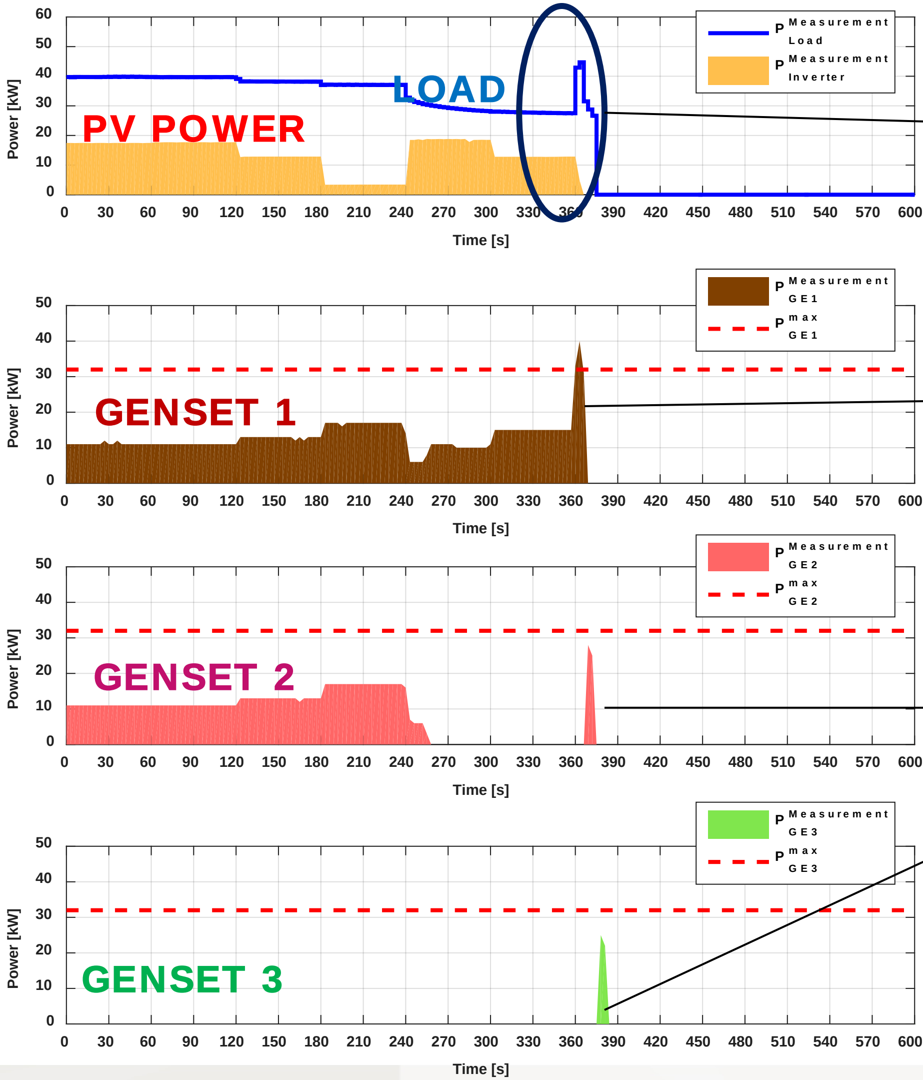
- CEA-INES Hybrid PV/Diesel Test platform



- Test on specific events (6 hours)

Experimental result

- Zoom on an event with load increasing and PV production decreasing
  - Strategy S1: Netload



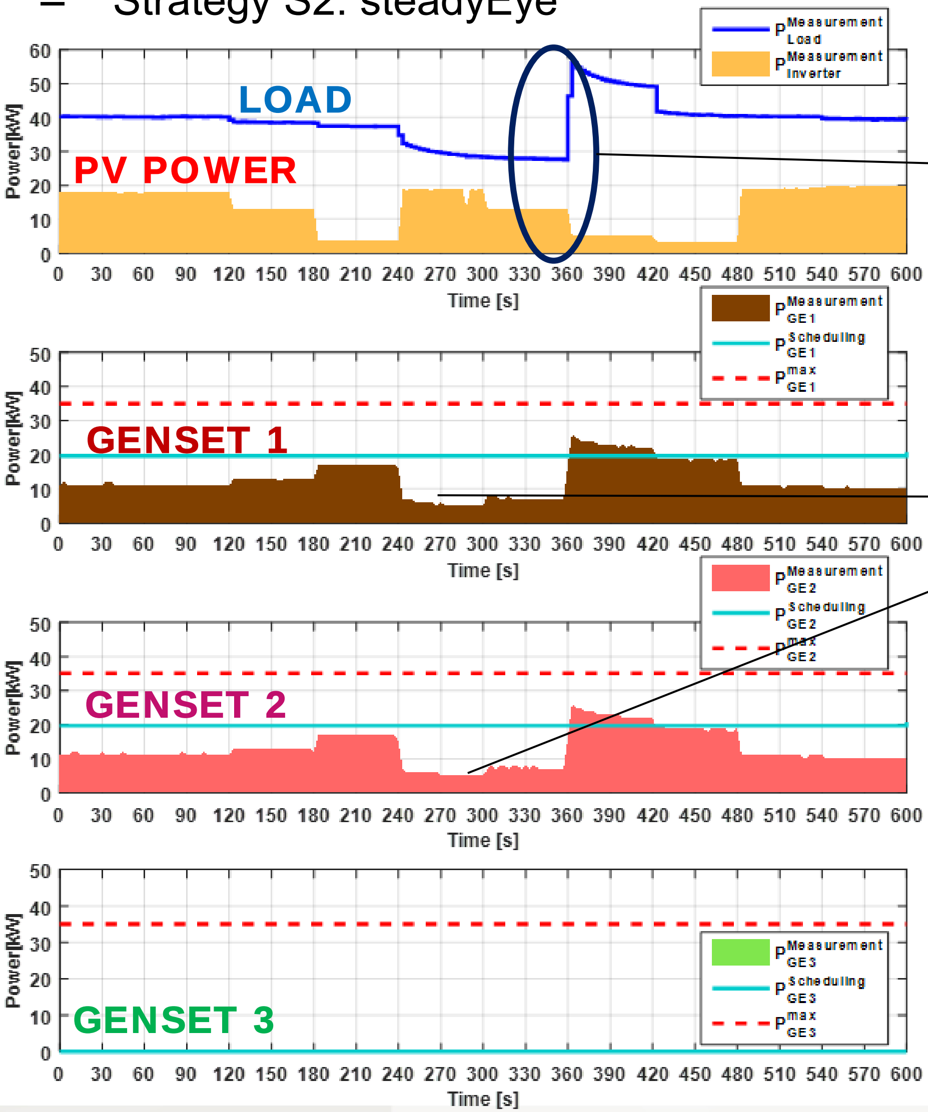
Load increases, with PV power decreases

Genset 1 tries to follow, but exceeds its limit and shuts down

Start order was given, but too late!

Experimental result

- Zoom on an event with load increasing and PV production decreasing
  - Strategy S2: steadyEye



Load increase, with PV power decrease

S2 anticipates power drop : Genset 1 and genset 2 are 'on' when event occures
=> System keeps working

Conclusions

- Conclusions
  - Control strategy = key role for optimizing the benefits of PV integration into hybrid systems
  - Operational simulation tool SPIDER for evaluating technic and economic benefits of control strategy
  - Validation of results with experiment: Integration of advanced control strategy on real system validated
  - Short-term PV forecast allows:
    - **10% saving on fuel consumption (PV-rate of 1.5)**
    - **Corresponds to a storage of 10 MW / 3 MWh for a 25 MW system**

- Perspectives
  - Better results expected with recent developments in steadyEye solution

Questions

Thanks for your attention!

Contact:

Pierre.besson@steady-sun.com