Sky-imager forecasting for improved management of a hybrid photovoltaic-diesel system

Louis-Étienne Boudreault*
Olivier Liandrat*, Antonin Braun*
Étienne Buessler*, Marion Lafuma*
Sylvain Cros*, André Gomez†

Reuniwatt SAS*
JA Delmas Caterpillar†

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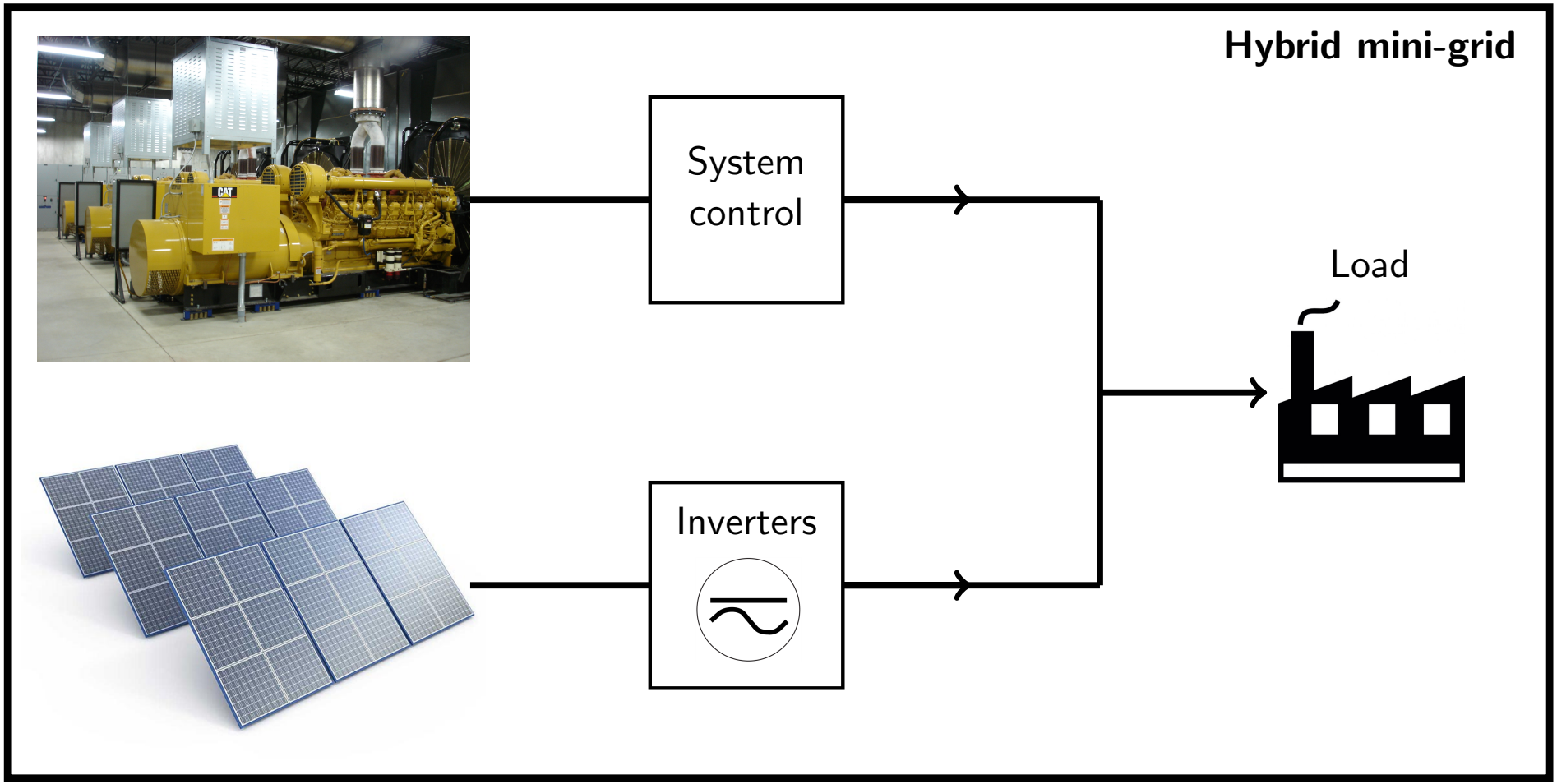
About Reuniwatt

- French startup founded in 2010 in Reunion Island
- Cloud cover forecasting + solar resource assessments
- We specialize mainly in photovoltaics
- Products covering various time-scales: intra-hour (0-30 mins, sky-imaging), intra-day (0-6 hours, CMV), day-ahead (0-7 days, NWP)

Motivation

Use case: *Can sky-imager forecasts help integrate more PV into a hybrid PV-diesel mini-grid?*



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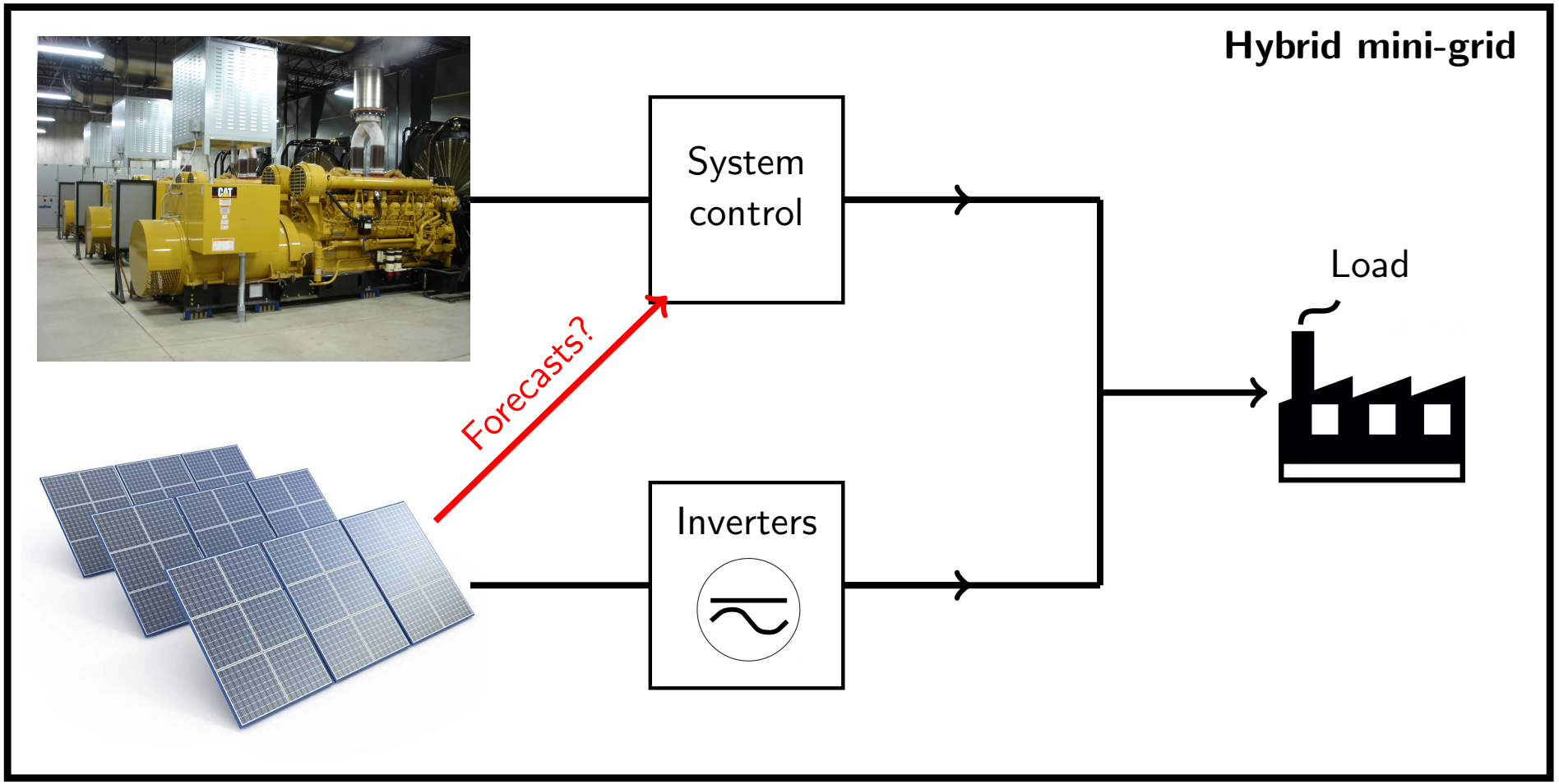
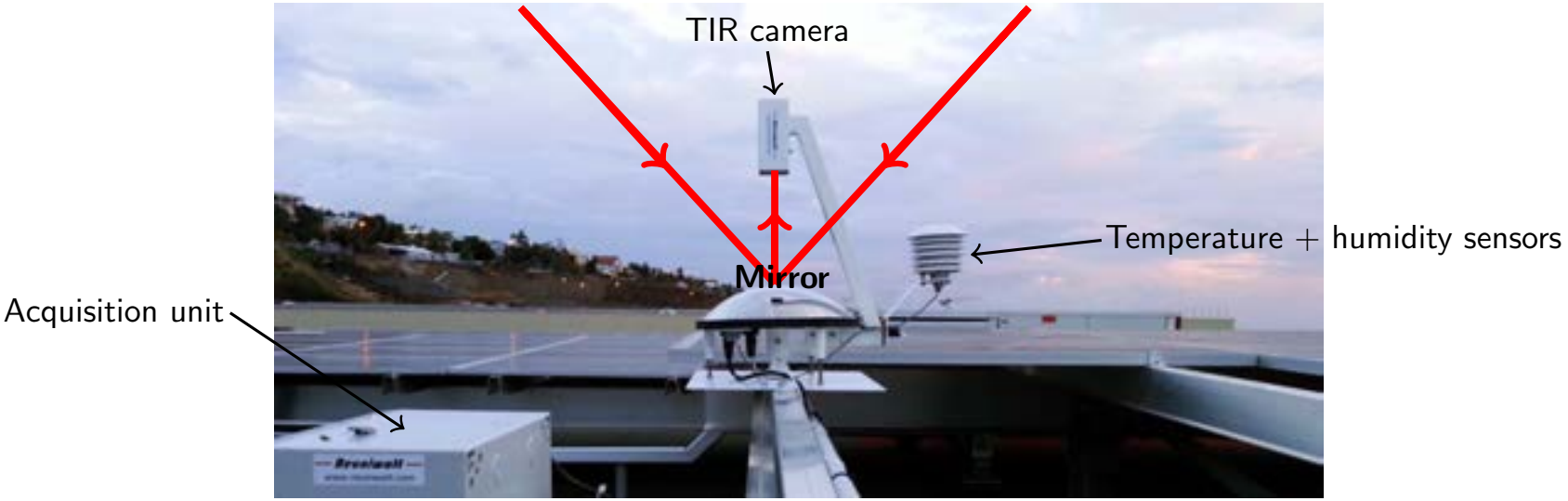
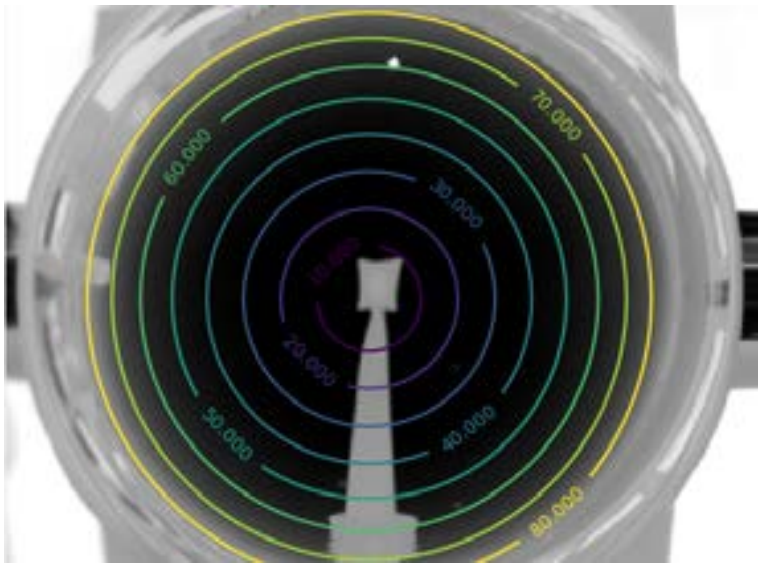


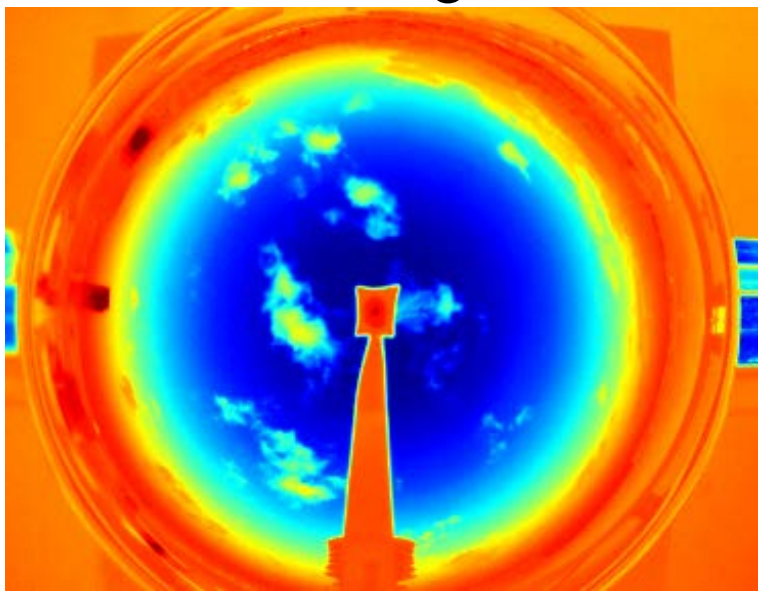
Forecasting system: the *Sky InSight*



Geometric calibration



Raw images



Forecasting algorithm

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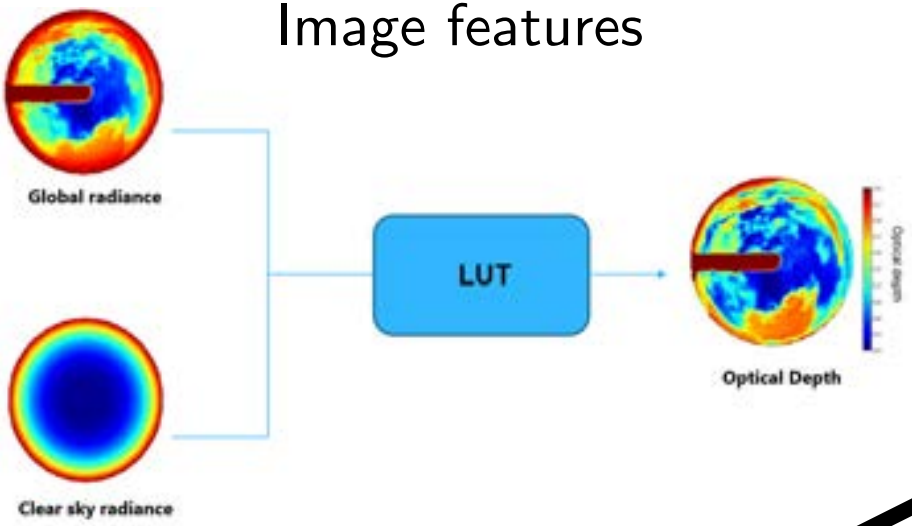
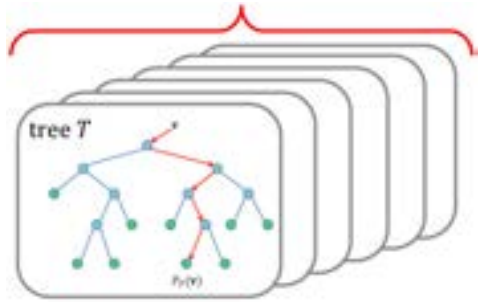
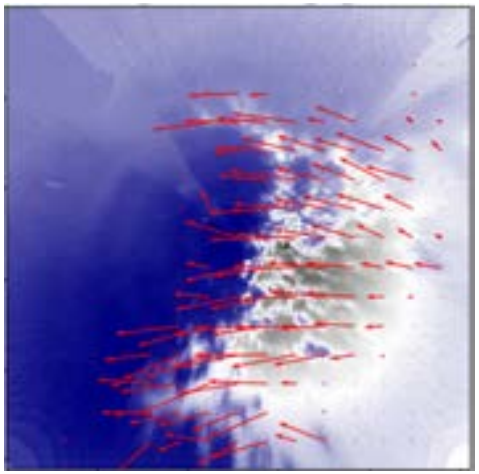
Image features



Machine learning

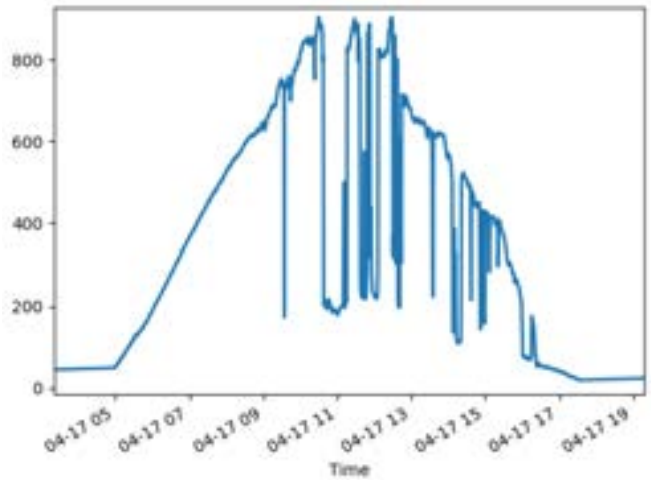


Cloud motion features



GHI measurements

GHI prediction



Hybrid system example

Grid balance:

$$B(t) = P_{PV}(t) + \sum_{i=1}^{k} P_{gen,i}(t) - L,$$

PV system:

- 1MW (30% of the load)

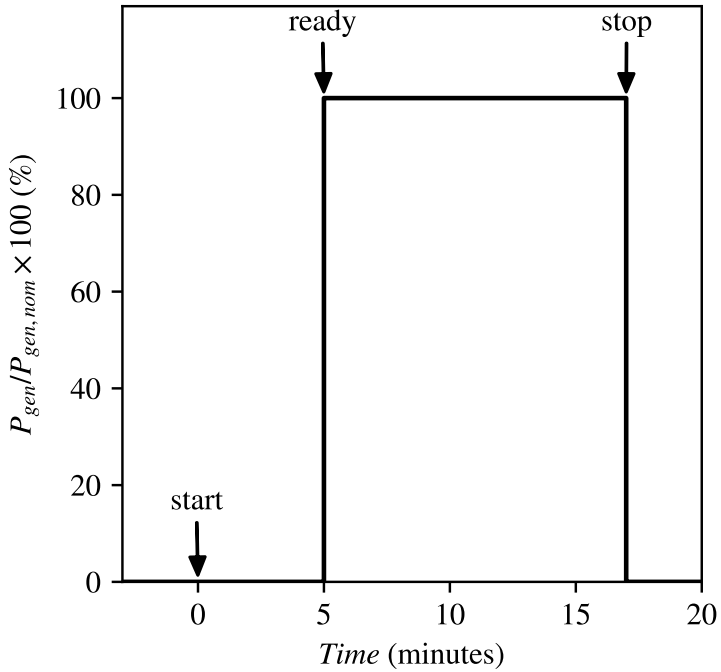
Load:

- Constant 3MW load

$\rightarrow$ study 1 month of operation

Gensets system:

- 15×0.2 MW units = 3 MW



Assumptions

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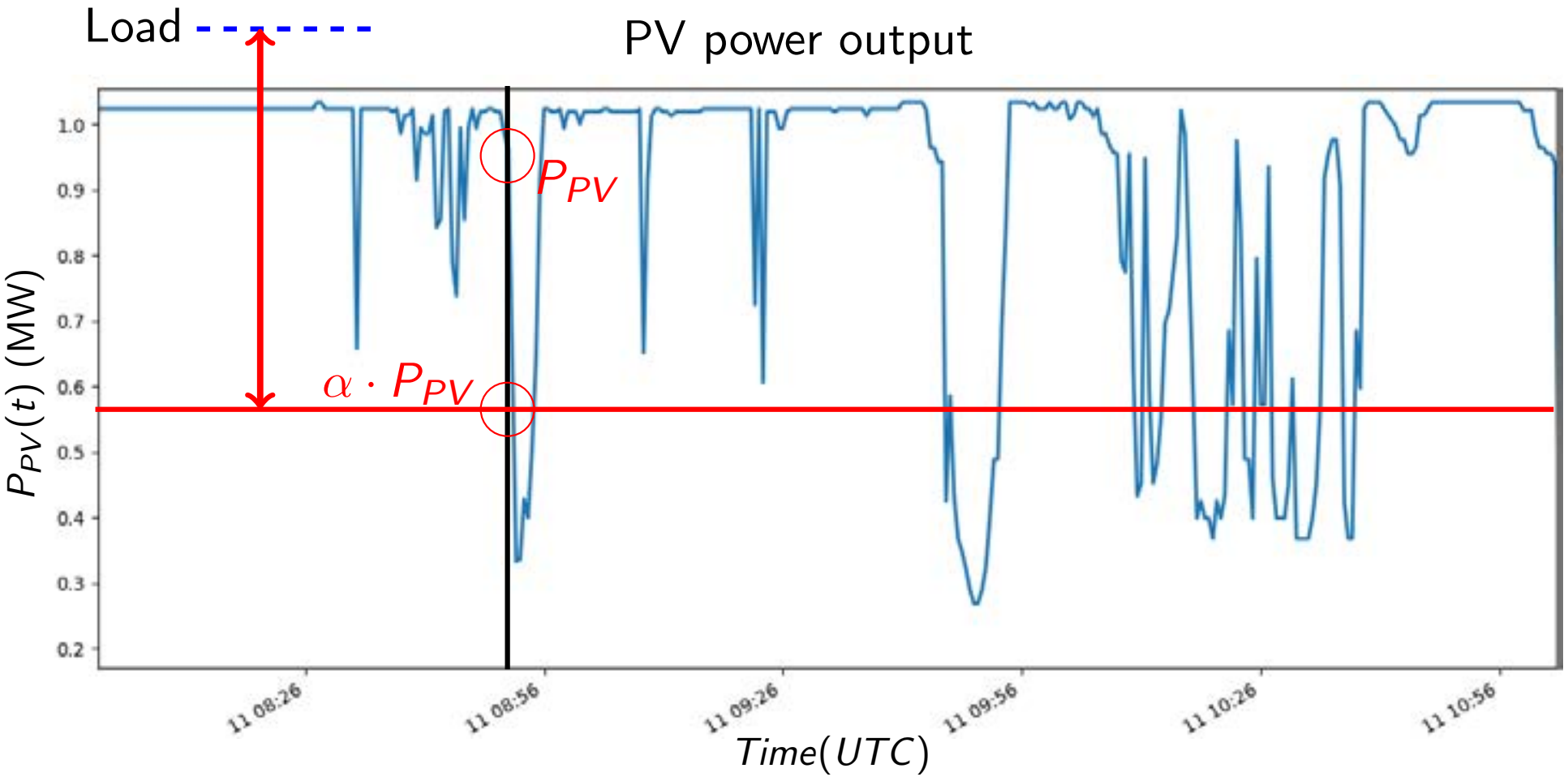
- The PV and gensets systems have perfect efficiencies $\eta_{PV} = \eta_{gen} = 1$
- The demand load is assumed constant $L = cst$
- The gensets always operate at their nominal output $P_{gen} = P_{gen,nom}$

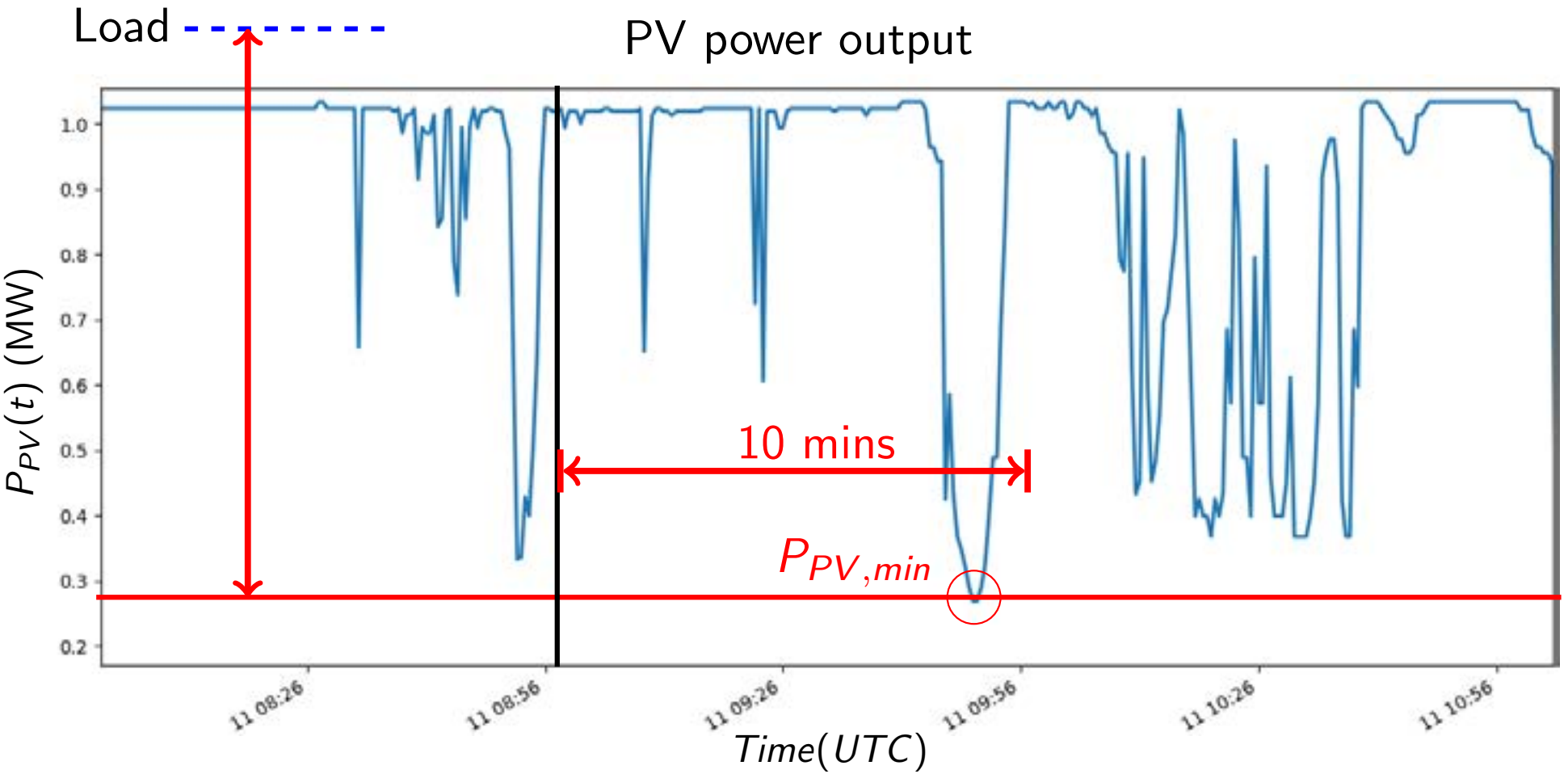
Hybrid system control



- Control scheme 1 (no forecast)

$$P_{target}(t) = L - \alpha \cdot P_{PV}(t)$$

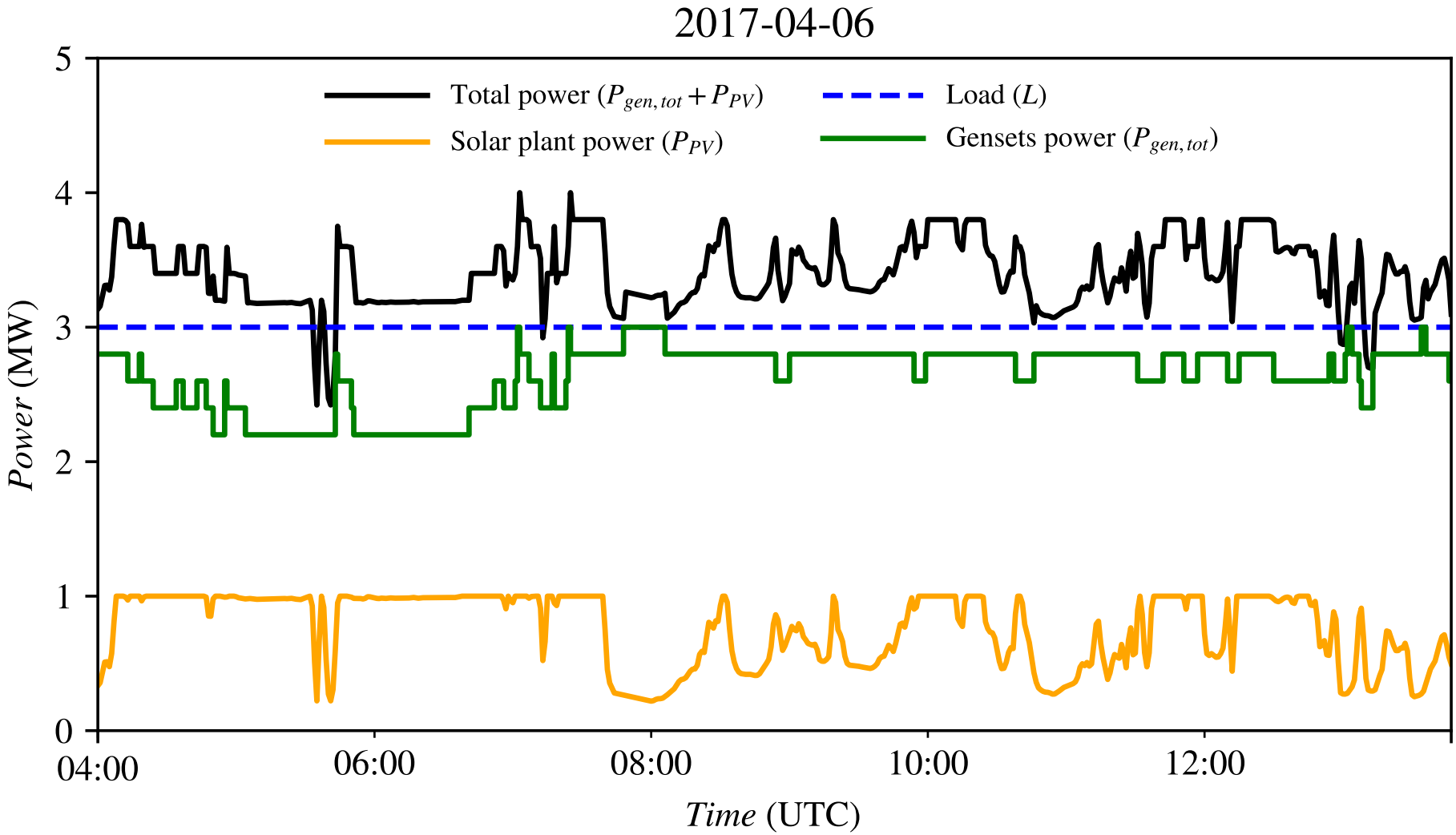
Hybrid system control



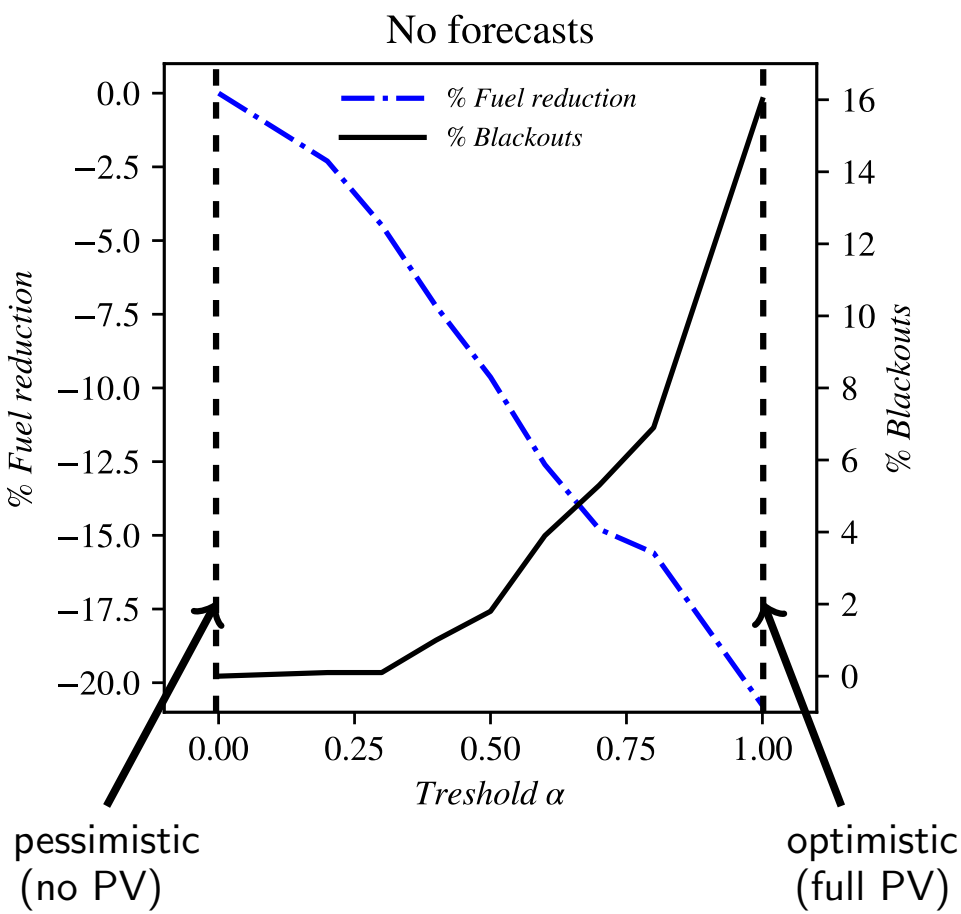
- Control scheme 2 (with forecast)

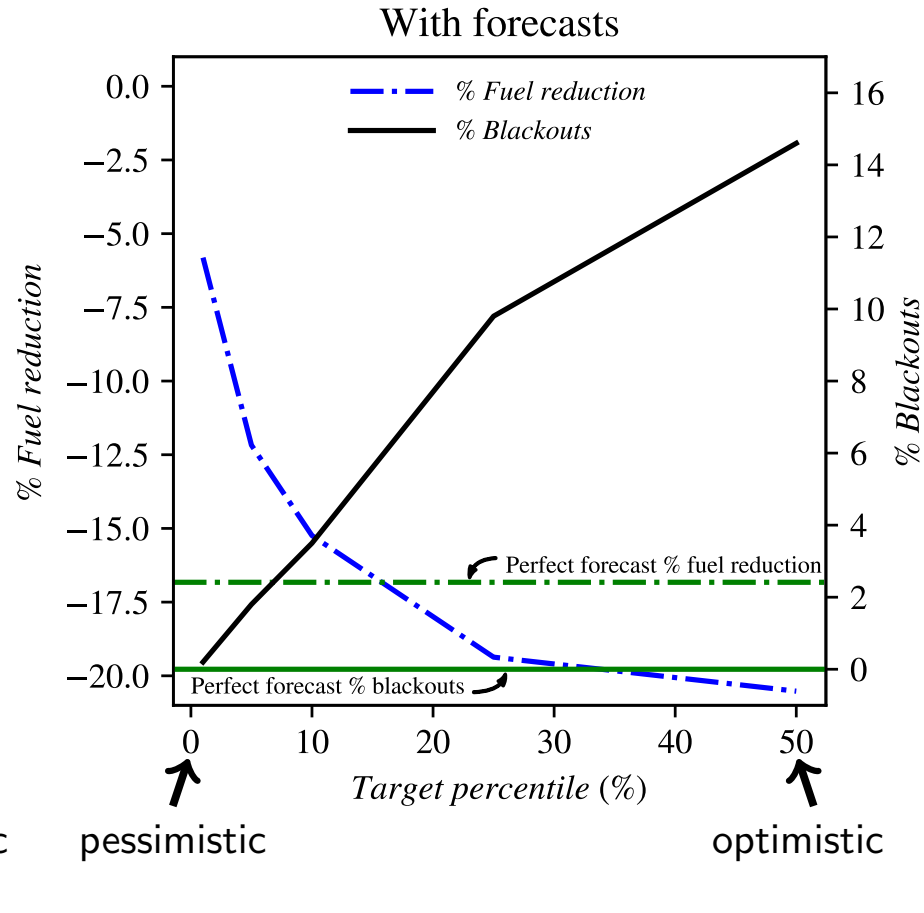
$$P_{target}(t) = L - P_{PV,min}(t \rightarrow t + 10 \text{ mins})$$

Results: power-grid profiles

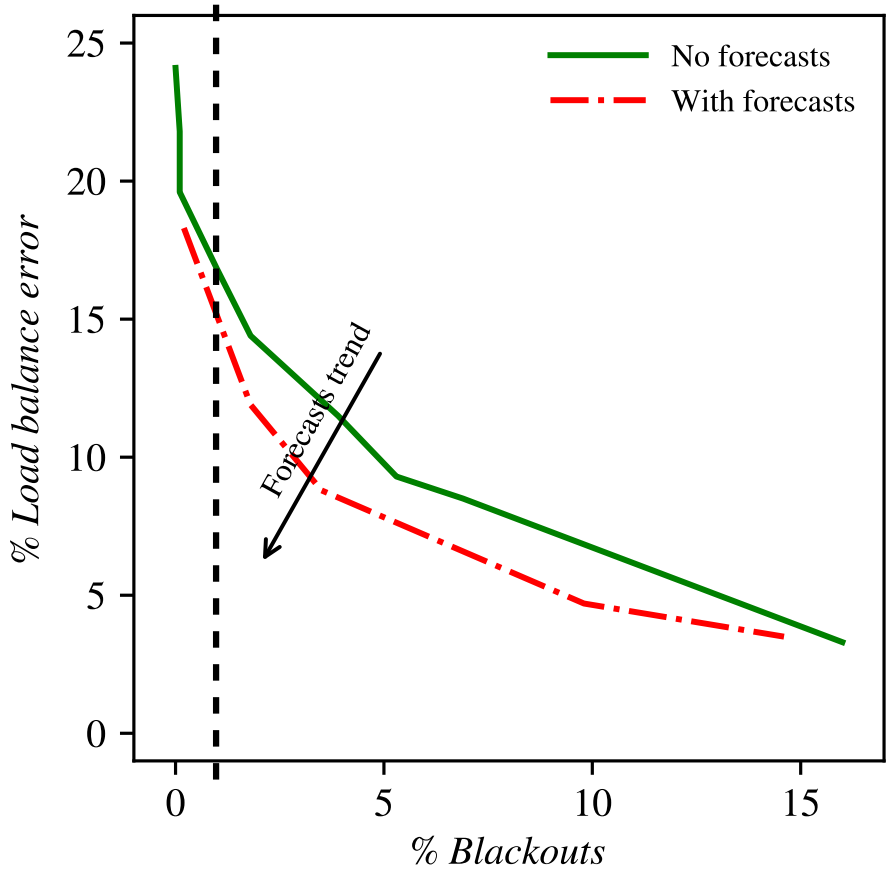


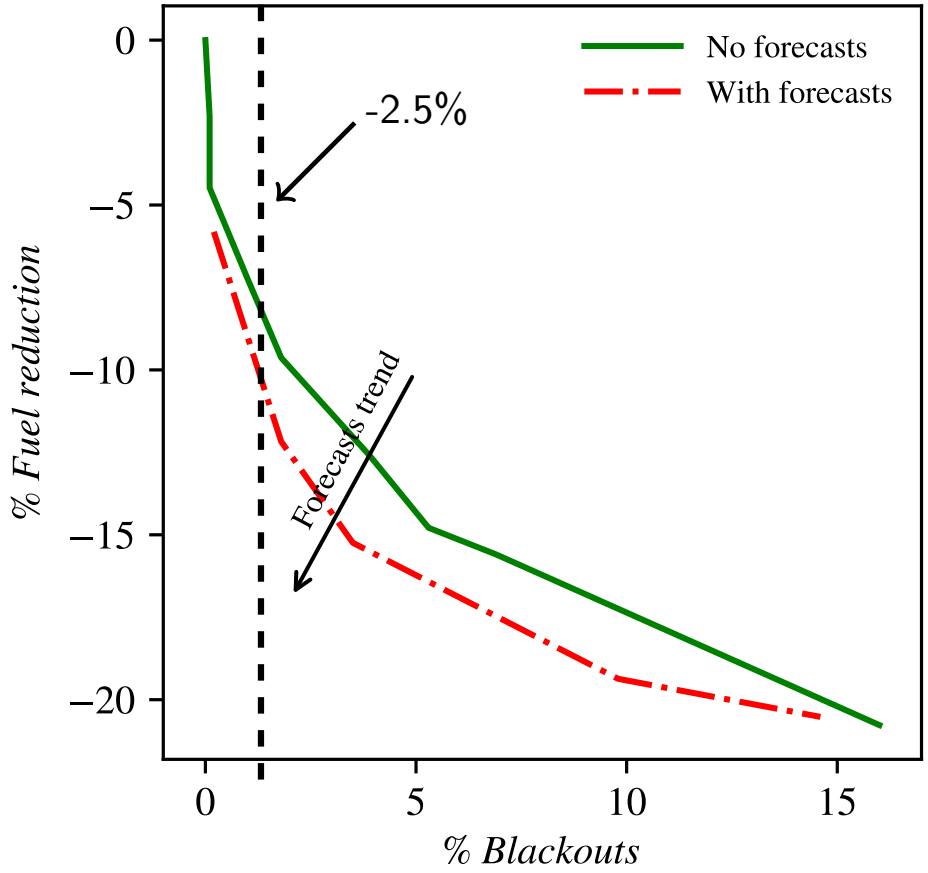
Results: forecast dependence





Results: forecast effect





Lessons learned

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- Forecasts should be tailored for one's specific needs (e.g. rural electrification, mines, agriculture)
- Granularity of gensets gives more flexibility to the system (thus more solar penetration)
- Risky situations occurs when clouds are preceded by long sunny periods
- Forecasts can help managing the spinning reserve better (altough not removing grid-failures)

Conclusion

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- A 4 MW hybrid PV-diesel system was modelled
- The system integrated short time-scale (10 mins) forecasts from a TIR sky-imager to control the start-stop cycle of the gensets
- The cases with forecasts were compared with cases without forecasts
- The results indicated that forecasts can reduce overall fuel consumption while reducing the number of blackouts

For this system:

We estimate a
$97 000/year cost reduction by using sky-imager forecasts