APPLICATION OF NOWCASTING TO REDUCE THE IMPACT OF IRRADIANCE RAMPS ON PV POWER PLANTS

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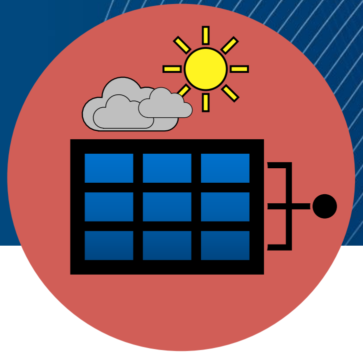


WHY POWER SMOOTHING?

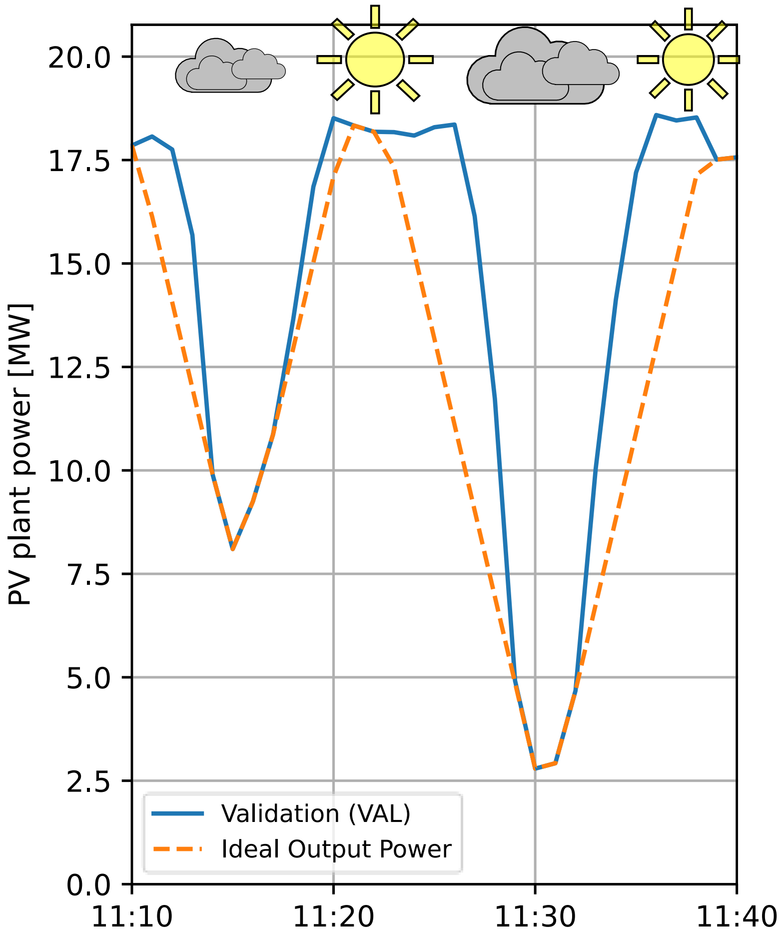
- **Solar energy challenges grid stability [1]**

  e.g. **grid frequency balance [2] [3]**

- **Irradiance fluctuations cause ramps**
- **Proposed solution: Power smoothing [4] [5]**

  (e.g. 10% power / min)

Example: Power Fluctuations



➢[1] Ottmar Edenhofer et al. IPCC, 2011: Summary for Policymakers.
➢[2] Esteban A. Soto et al. “Analysis of Grid Disturbances Caused by Massive Integration of Utility Level Solar Power Systems”.
➢[3] N. Mithulananthan, R. Bansal, and V. Ramachandaramurthy, “A review of key power system stability challenges for large-scale PV integration”.
➢[4] Remember Samu et al. “Applications for solar irradiance nowcasting in the control of microgrids: A review”.
➢[5] Qianwei Zheng et al. “Overivew of grid codes for photovoltaic integration”.

WHICH SOLUTIONS EXIST?

- **Current solution: energy storage**

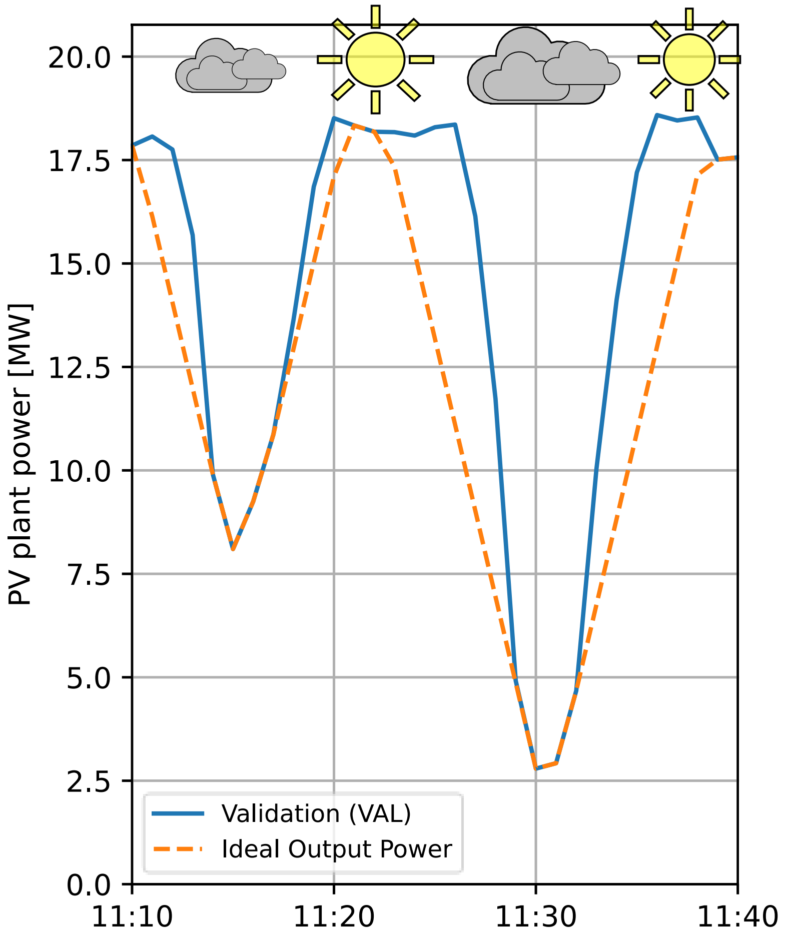
  (e.g. batteries, …)

- **Nowcasting: short-term solar irradiance forecasting**
- **Ideal nowcasts can substitute battery storage completely [6]**

  But: Nowcasts with high resolution required

  & uncertainties are decisive

Example: Power Fluctuations



➢[6] Mojtaba Saleh et al. "Battery-less short-term smoothing of photovoltaic generation using sky camera".

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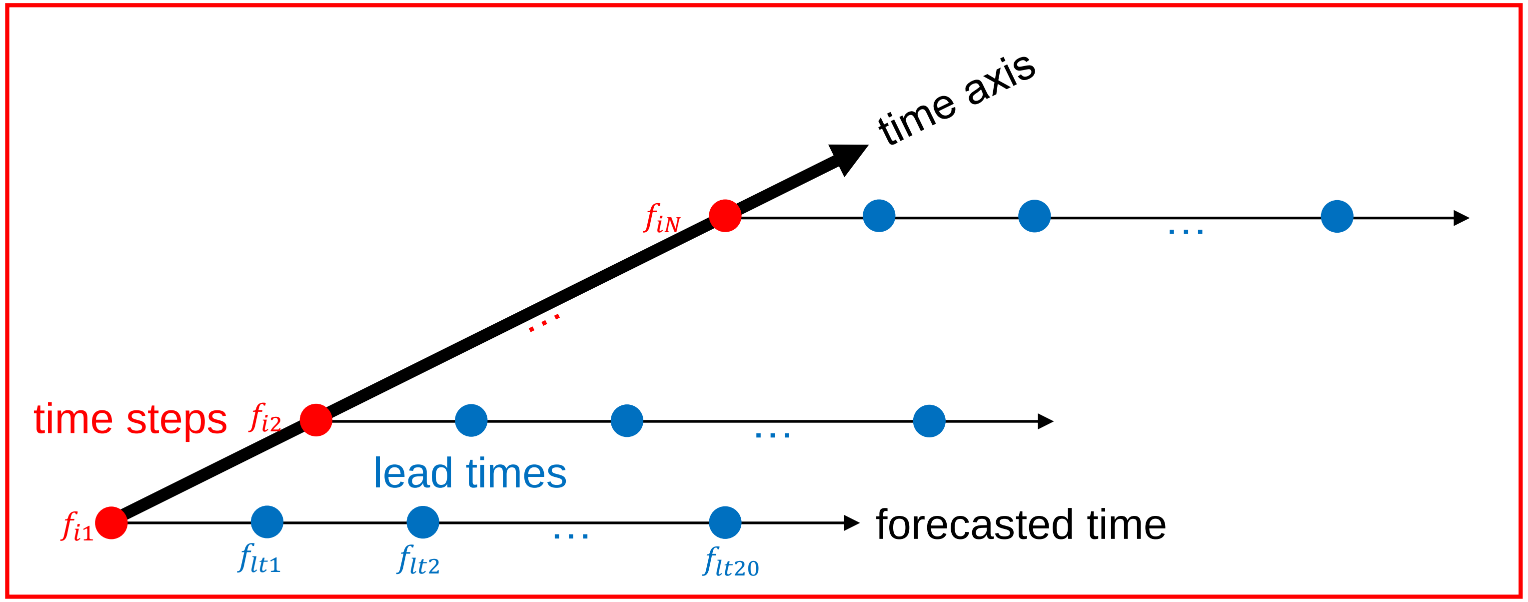
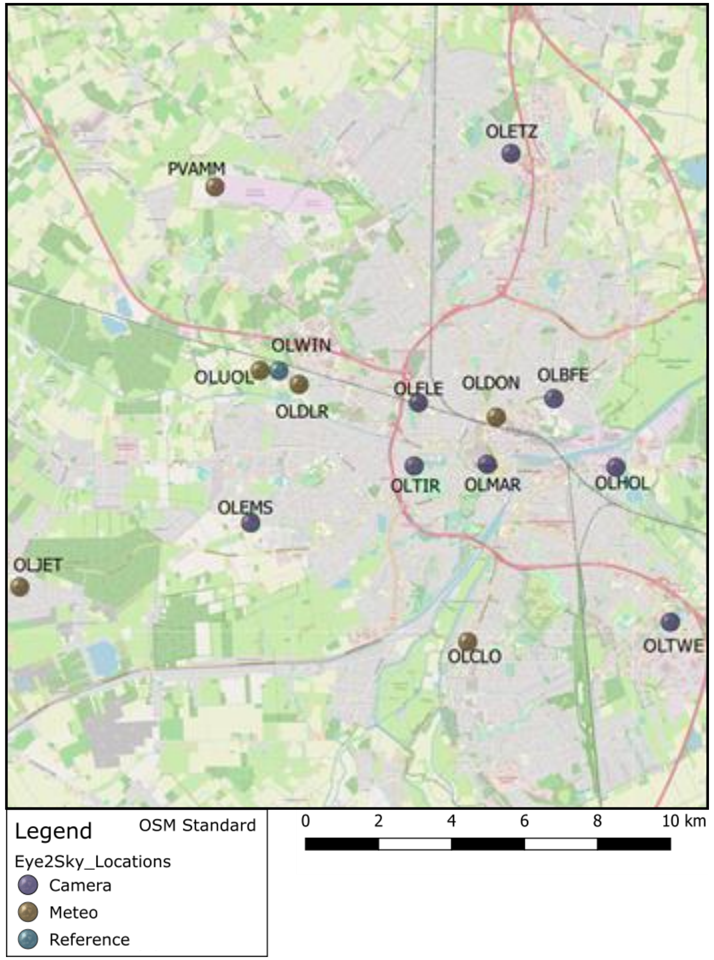
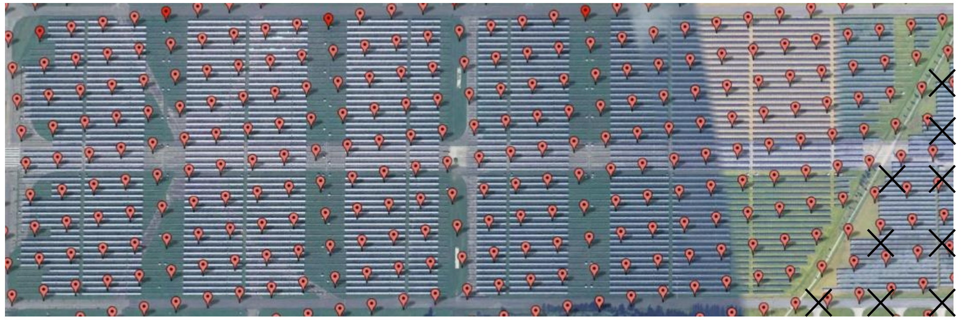
PROBABILISTIC NOWCASTS







Parameter	ASI network
Spatial resolution	50 m
Extent	up to 156 km²
Forecasts update	30 s
Forecast step	1 min
Forecast horizon	20 min

[13]

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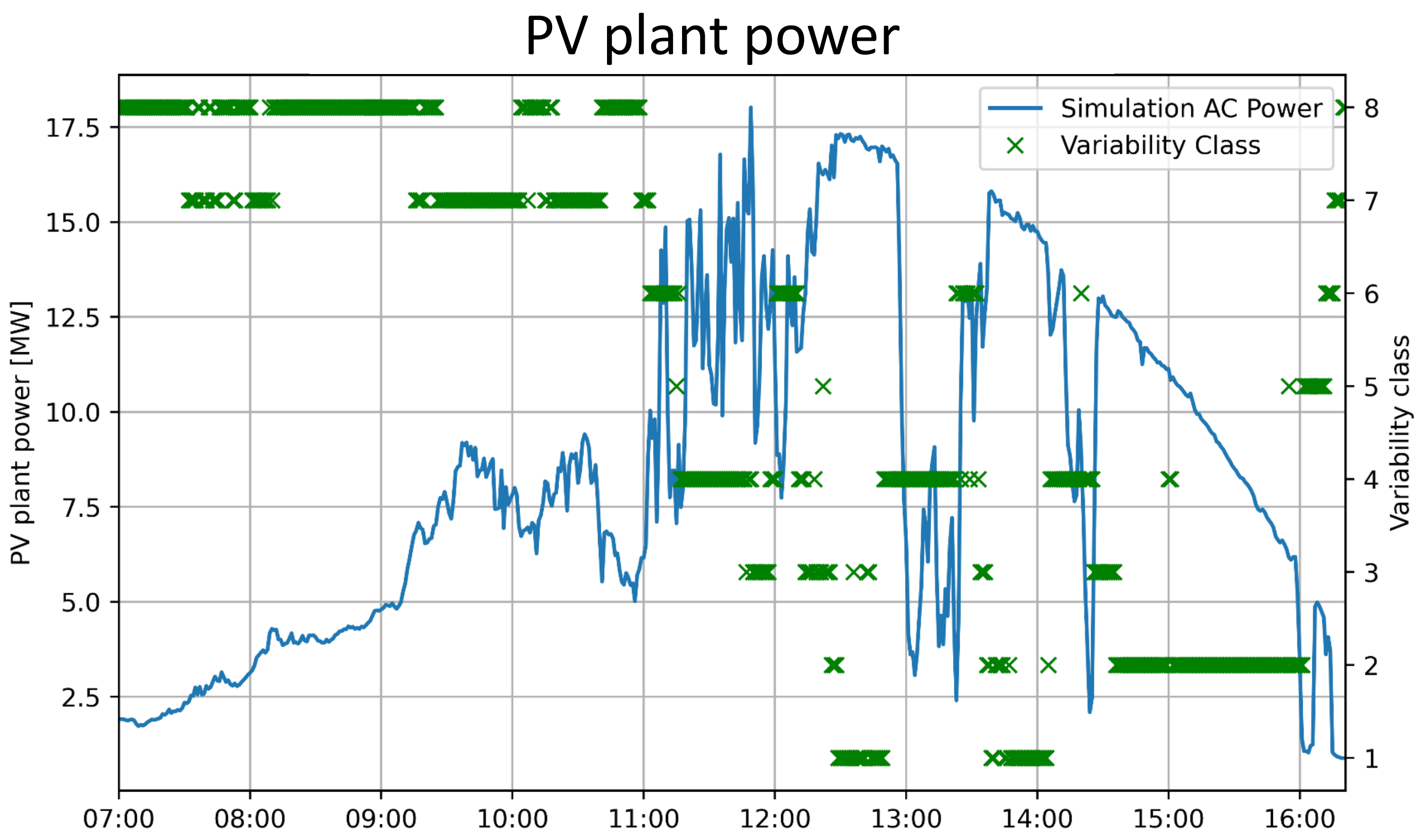
CLASSIFICATION



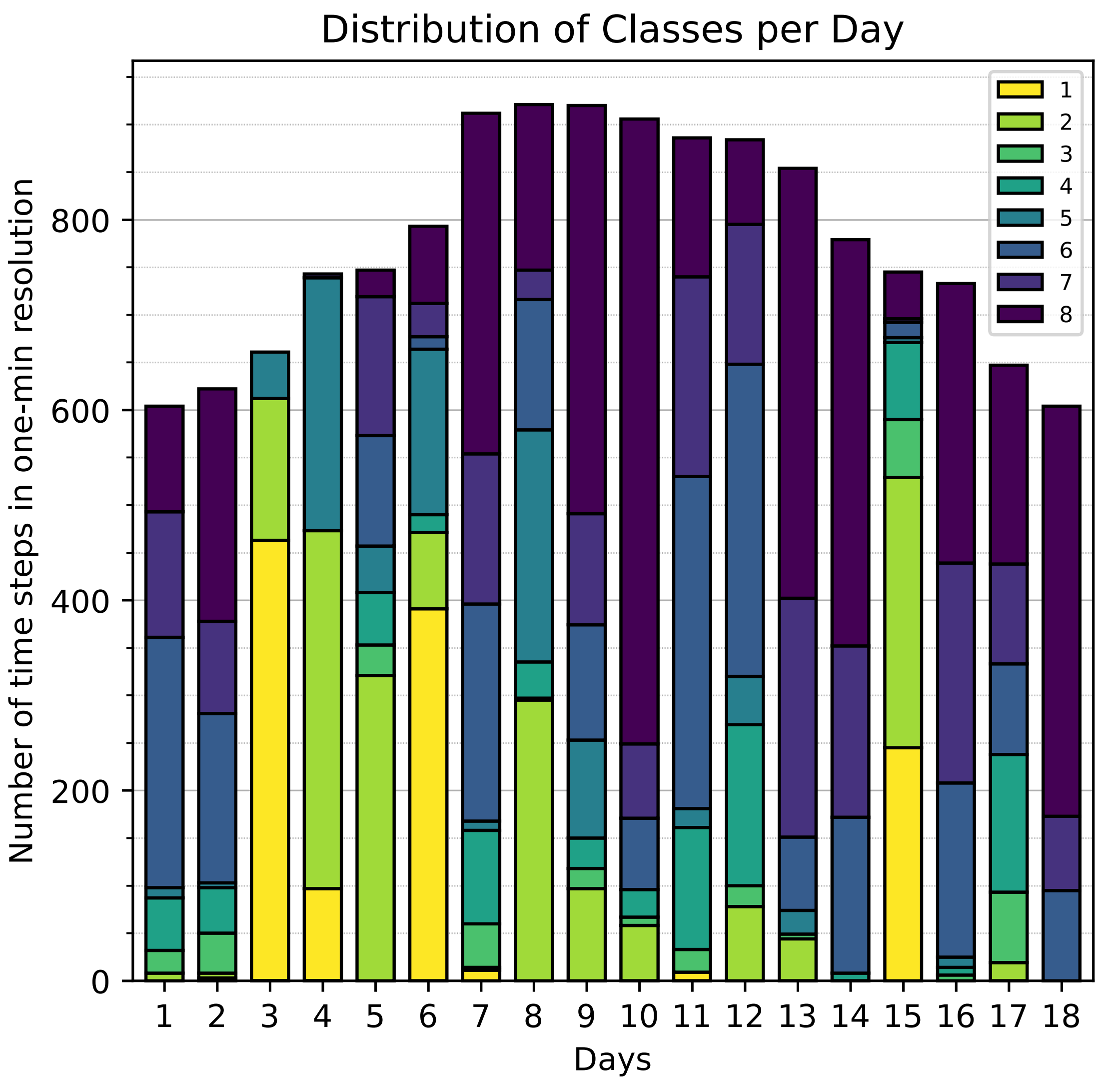
Class	Sky conditions	Variability
1	Mostly clear sky	Low variability
2	Almost clear sky	Low variability
3	Almost clear sky	Medium variability
4	Partly cloudy	High variability
5	Partly cloudy	Medium variability
6	Partly cloudy	High variability
7	Almost overcast	Medium variability
8	Mostly overcast	Low variability

DATASET

- **nowcasts for 18 test days with high variability conditions**

  Days have large range of classes and vary from each other

- **PV power plant production data (Validation)**



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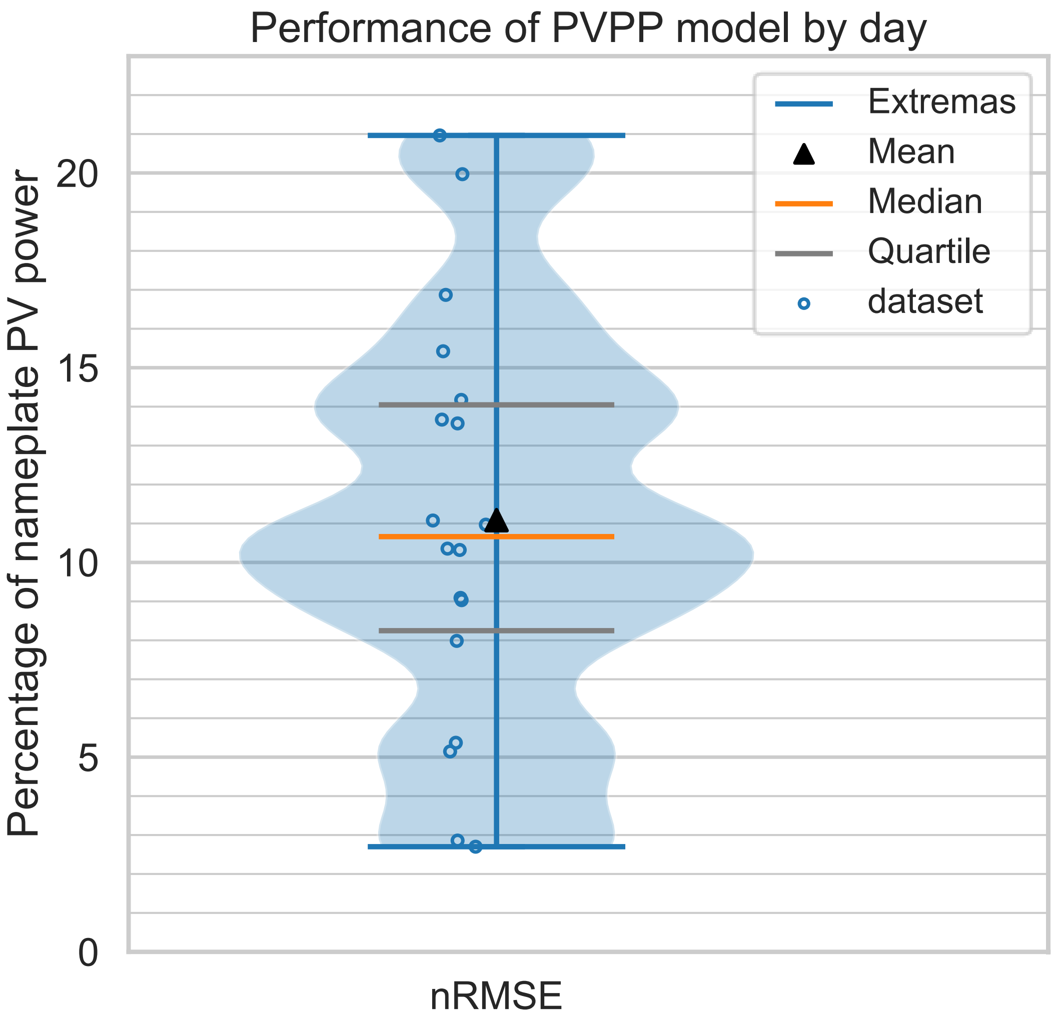
MODEL PERFORMANCE

- **Simulated power vs. validation data**
- **18 day test dataset**

  with various weather conditions
- **nRMSE between 2.7 and 21.7% (mean 12.0%)**

  (normalized to max power of day)
- **nBIAS of +0.5%**

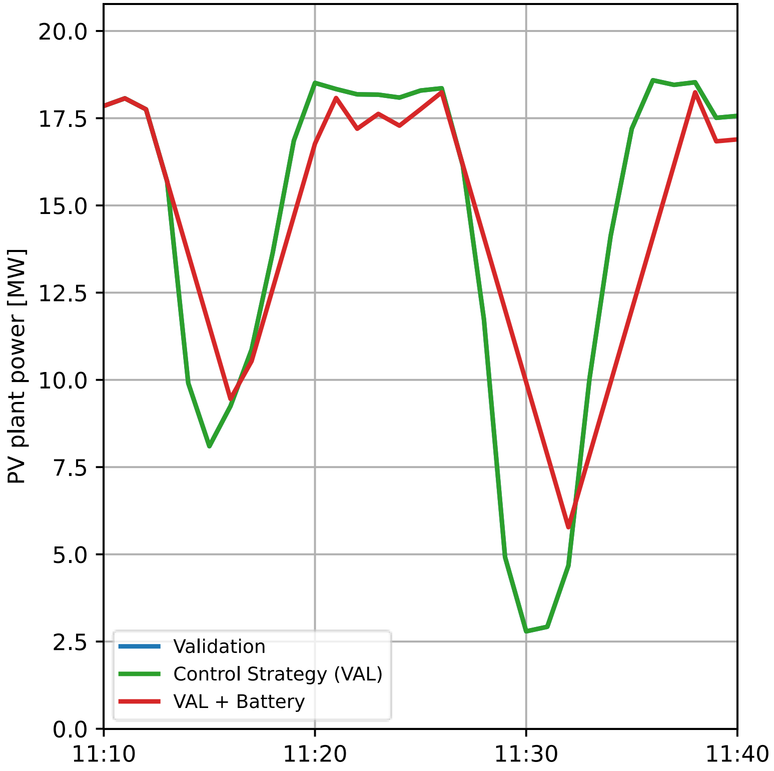


3 STRATEGIES: VAL, IDV & MIX

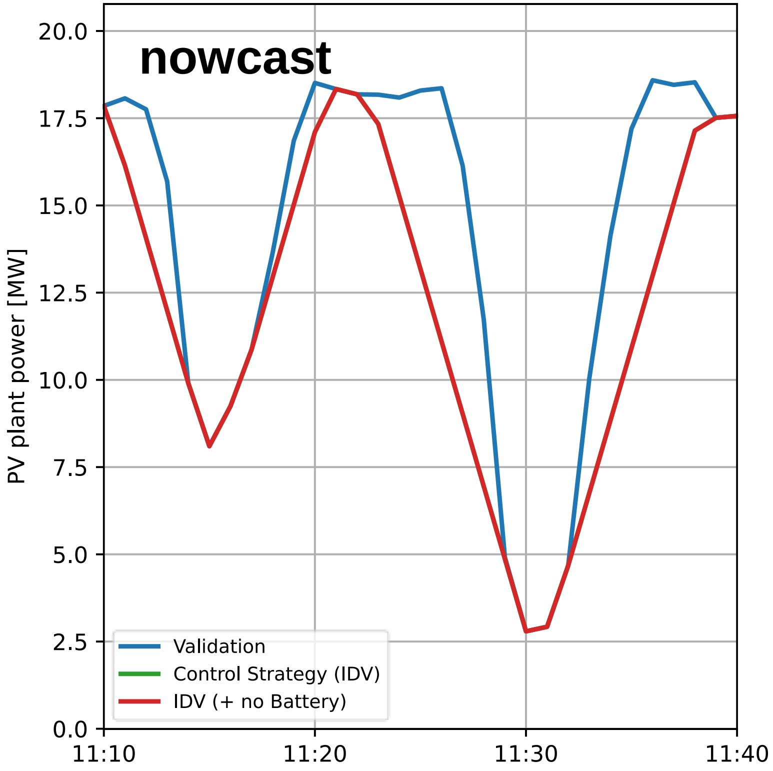
- **Battery works as a fail-save: only interferes in case of control strategy failure**

System power = output power + battery

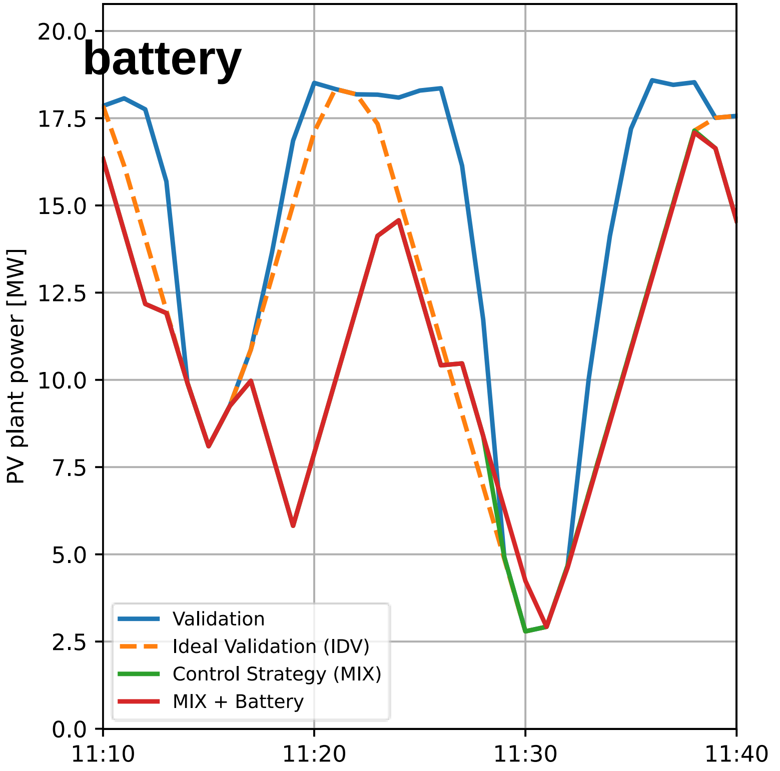
Strategy VAL: battery only



Strategy IDV: ideal nowcast



Strategy MIX: nowcast + battery



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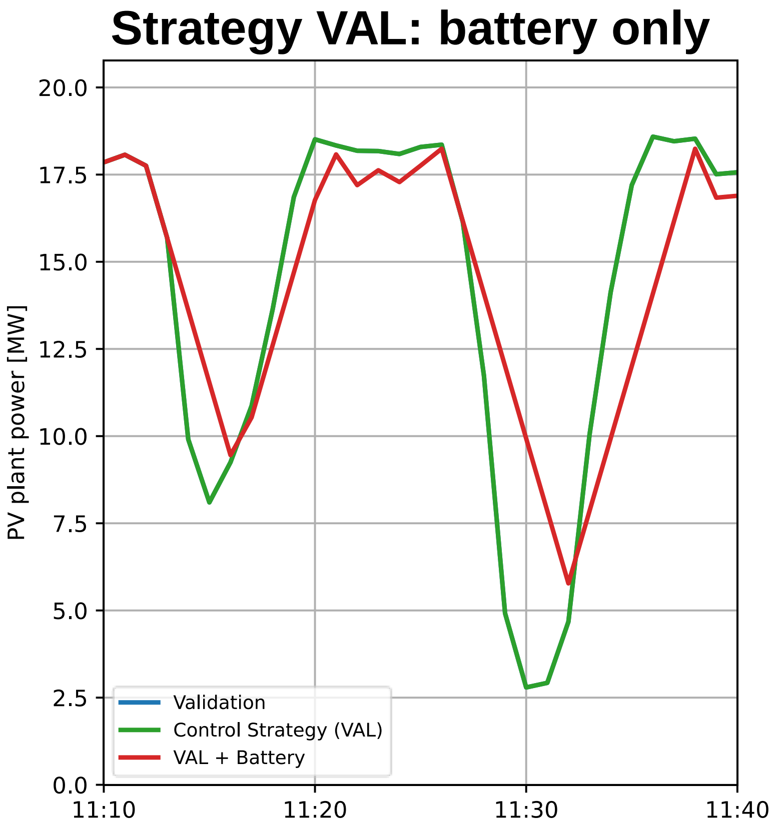
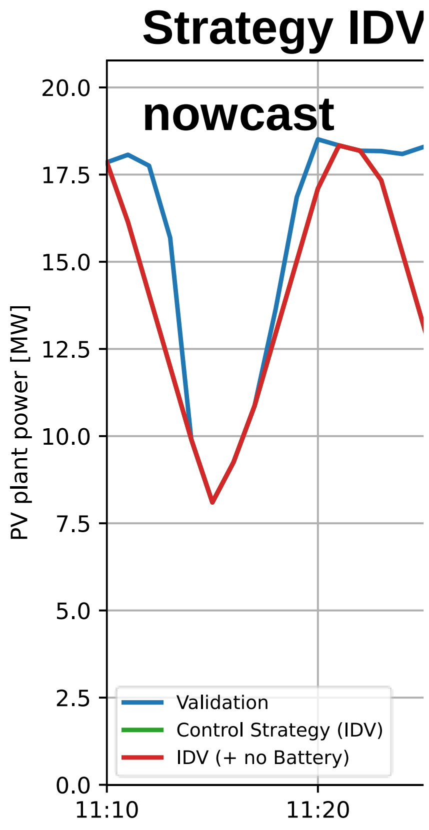
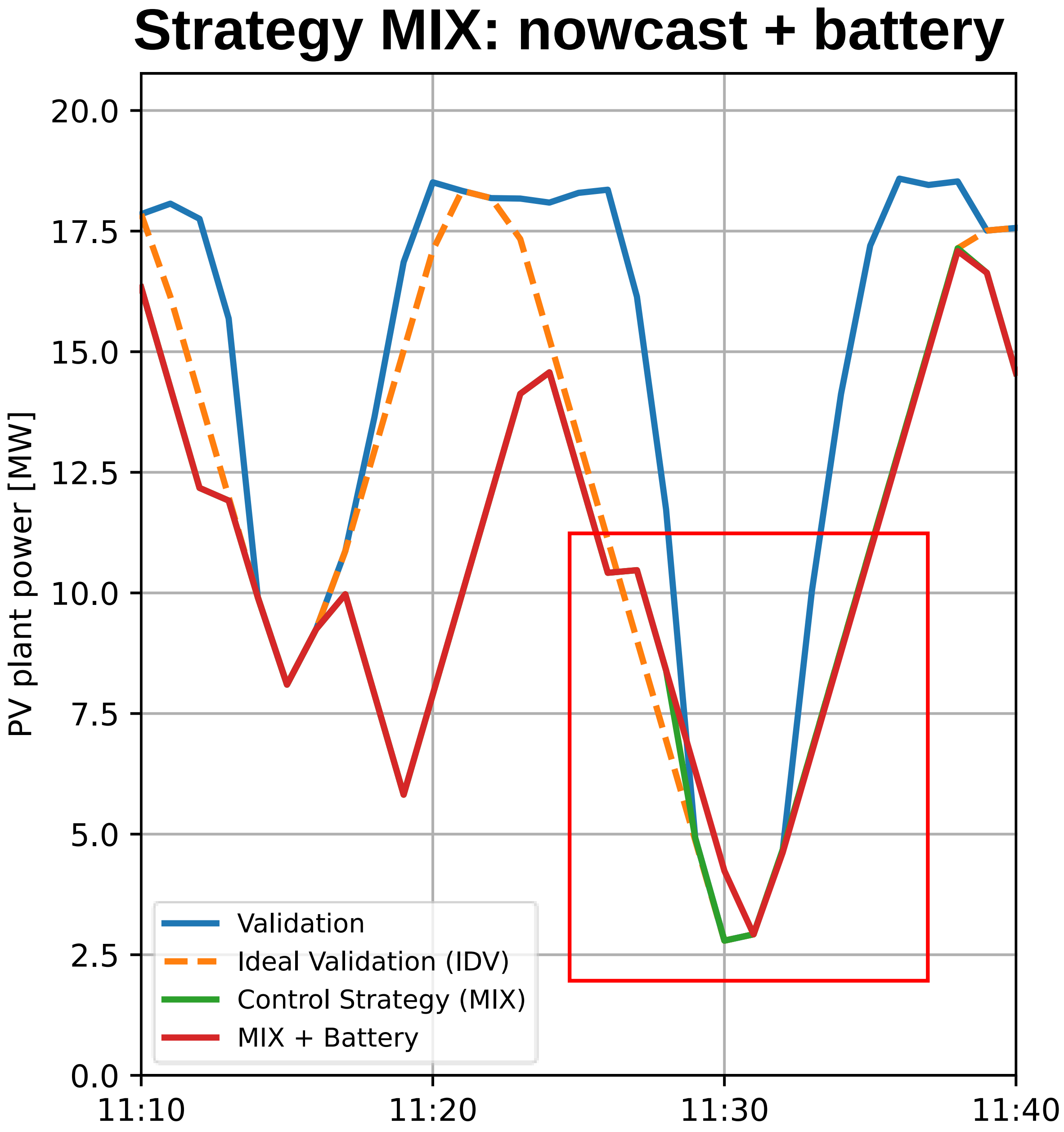


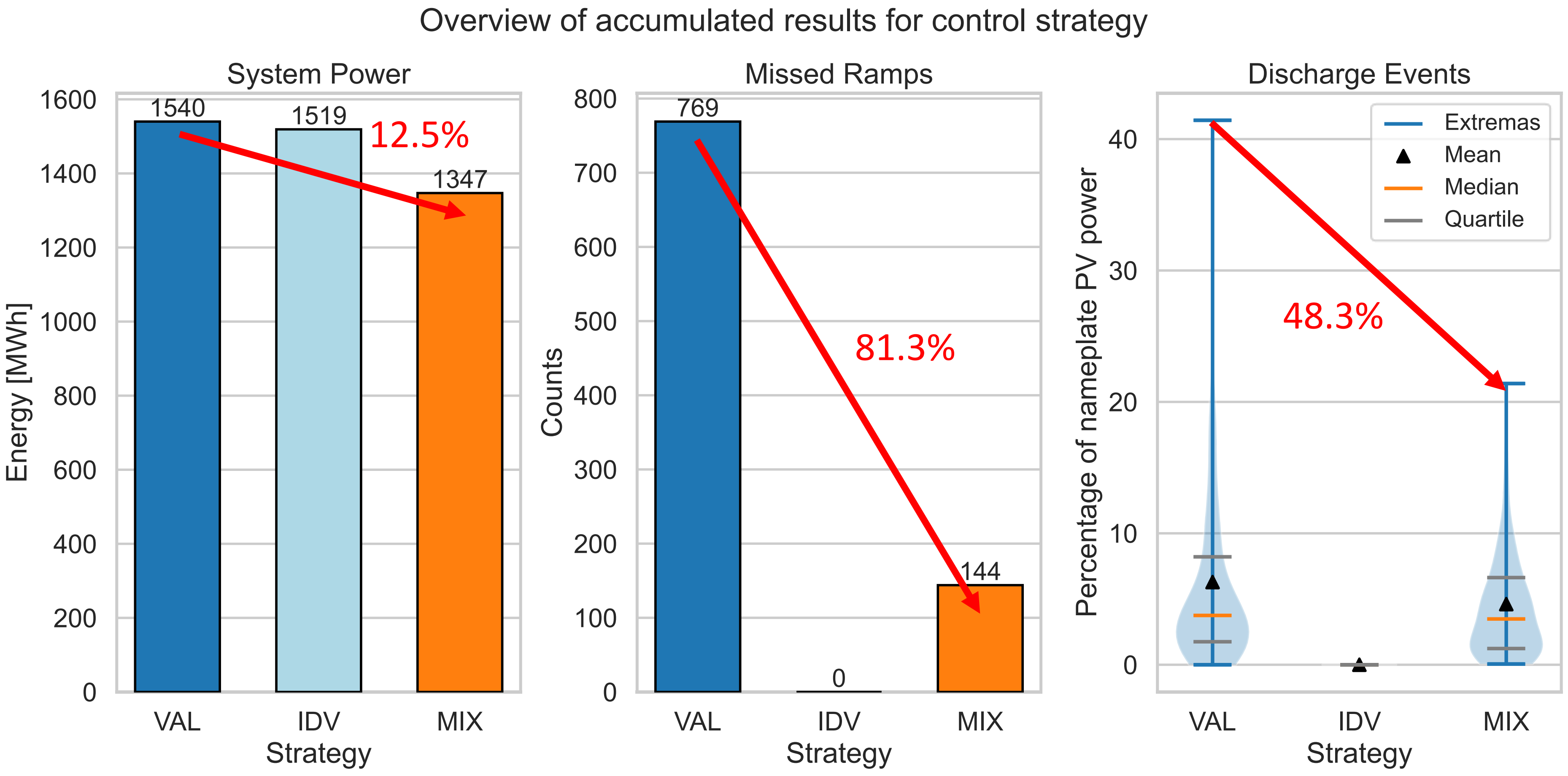




18 TEST DAYS – ACCUMULATED

Three cases for comparison:

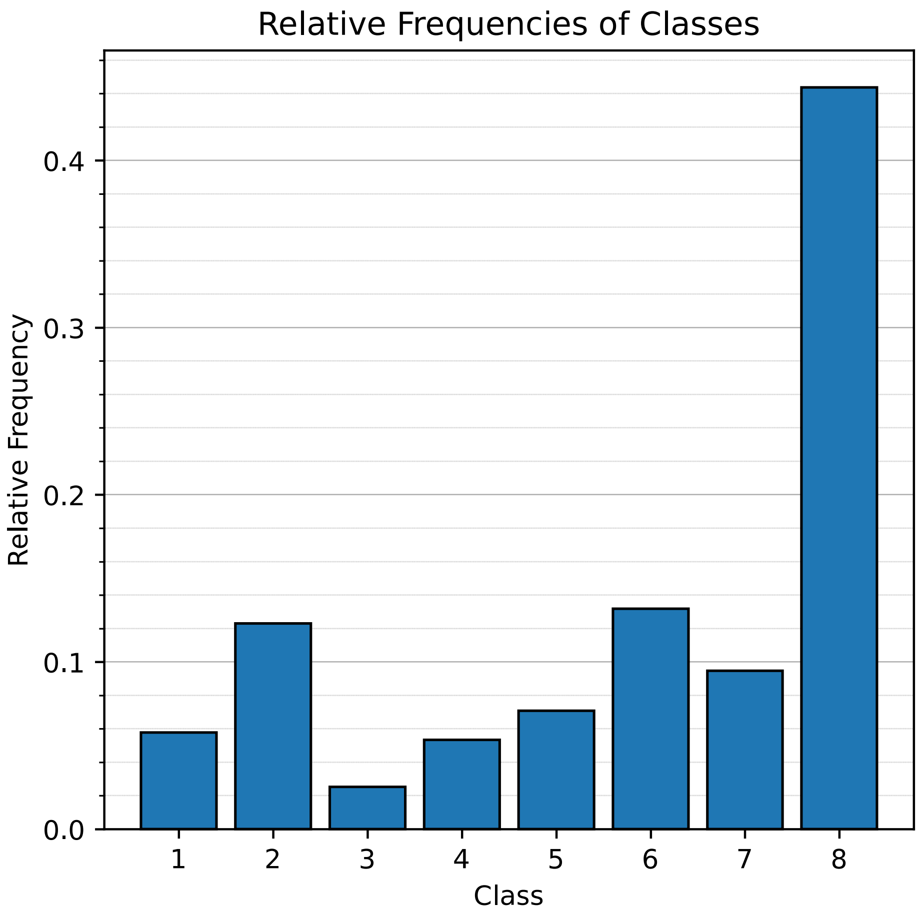
- **Strategy VAL: battery only**
- **Strategy IDV: ideal nowcast**
- **Strategy MIX: nowcast + battery**

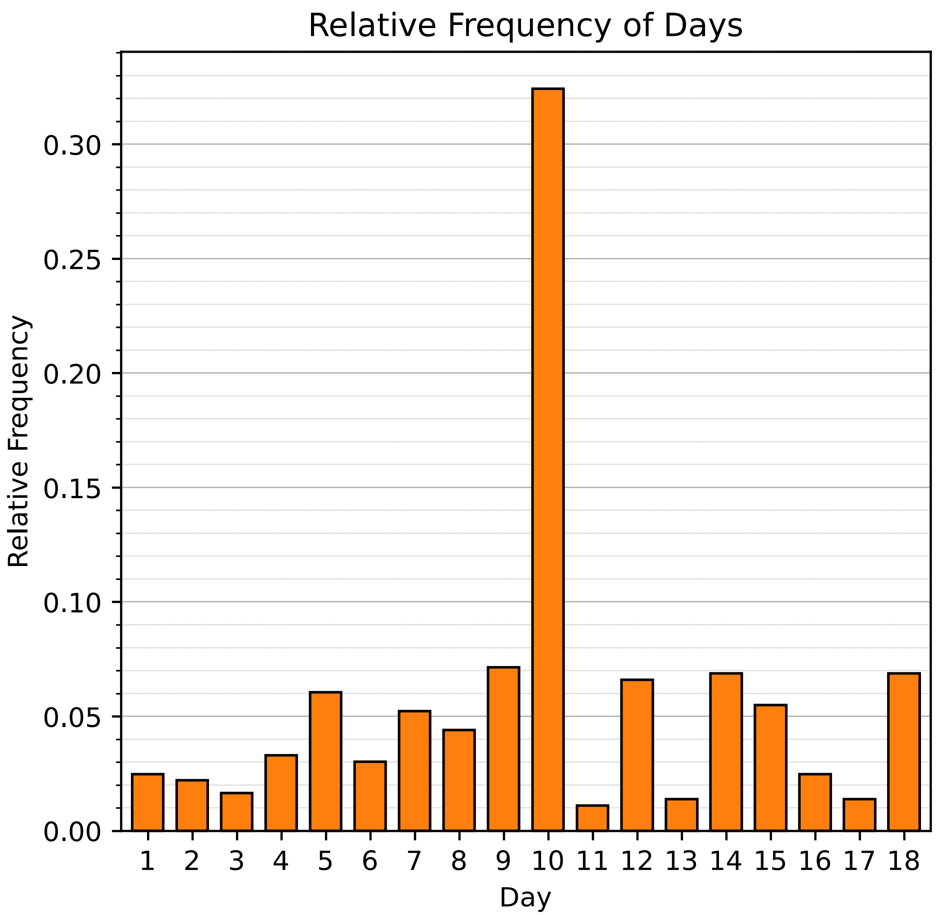


UPSCALING TO ONE YEAR

Based on:

- **18 test days**
- **Class frequency**

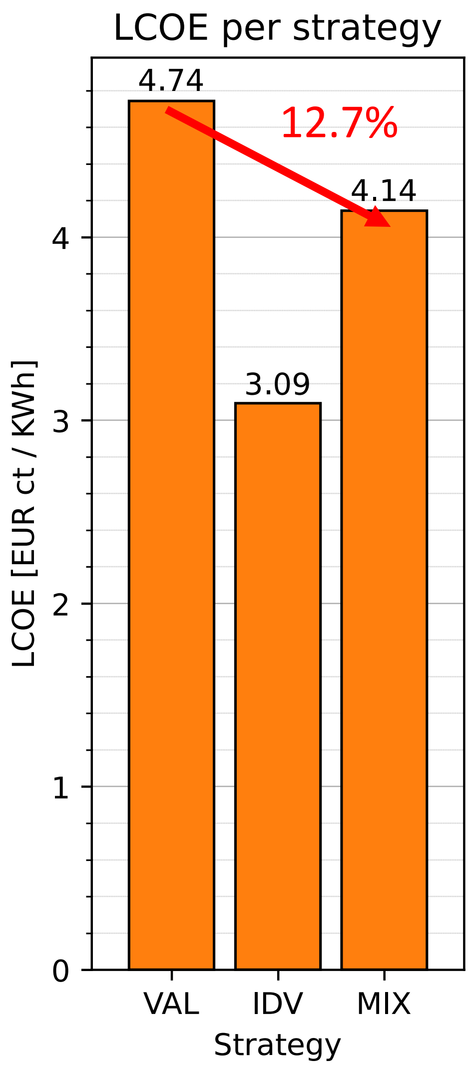




ECONOMIC EVALUATION

Key findings:

- **Energy loss reduced to 8.7% for one year**
- **Levelized-cost-of-energy (LCOE) reduced by 12.7% (MIX)**
- **Reduction potential of 34.8% (IDV)**



CONCLUSION

- **Simulation study of nowcasts in power smoothing for Germany**
- **18 test days with variety of irradiance conditions**

  Mean model performance of 12.0% nRMSE (max)

  4 out of 5 ramps avoided by control strategy alone

  Fail-save battery with smaller capacity (-71.1%) and power (-48.3%)
- **Full year (scaled-up)**

  8.7% curtailment losses

  LCOE reduction of 12.7% with potential to 34.8%

THANK YOU FOR YOUR ATTENTION!

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