Ramp-rate control in large PV plants: Battery vs. Short-Term forecast

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ABSTRACT

- Energy storage systems (ESS) and batteries in particular, have positioned as the most evident solution in order to smooth power fluctuations below the maximum allowable by new grid codes.
- Recent short-term forecast sources open the door to do a ramp-rate control without batteries, using only inverter limitation. This option entails some energy curtailment losses that has not been yet addressed.
- We compare the Levelized Cost of Energy (LCOE) of installing a lithium-ion battery vs. perfect short-term forecast solution for ramp-rate control.
- The results obtained indicate that battery-less strategies must not be neglected for ramp-rate control, since they can be more cost-effective using perfect forecast for any ramp value.

OBJECTIVES

- **Quantify energy curtailment losses** for battery-less strategy using short-term forecast.
- **Compare the Levelized Cost of Energy** of installing a lithium-ion battery vs. the short-term forecast for ramp-rate control.

CASE ANALYZED

AMARELEJA PV PLANT (45 MWp / 38,5MW)

- Synchronized PV power output every 5s in the course of 2 years at the 38.5 MW PV power plant of AMARELEJA (Portugal).
- This plant, owned by Acciona Energía, occupies an area of 250 Ha and includes 2520 vertical axis-trackers (18 kWp, tilted 45º), up to a total peak power of 45.6 MWp.

ECONOMIC SCENARIO

- LCOE of a PV plant without restrictions has been estimated ($LCOE_{basecase}$) → 0.045 $/kWh

$$LCoE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

It	Investment costs	600 $/kWp
Mt	Maintance costs	3%
Ft	Fuel costs	0
r	discount rate	4%
n	Expected lifetime	20 years
Et	Annual energy produced	Company data

- Now LCOE has been modified for both strategies

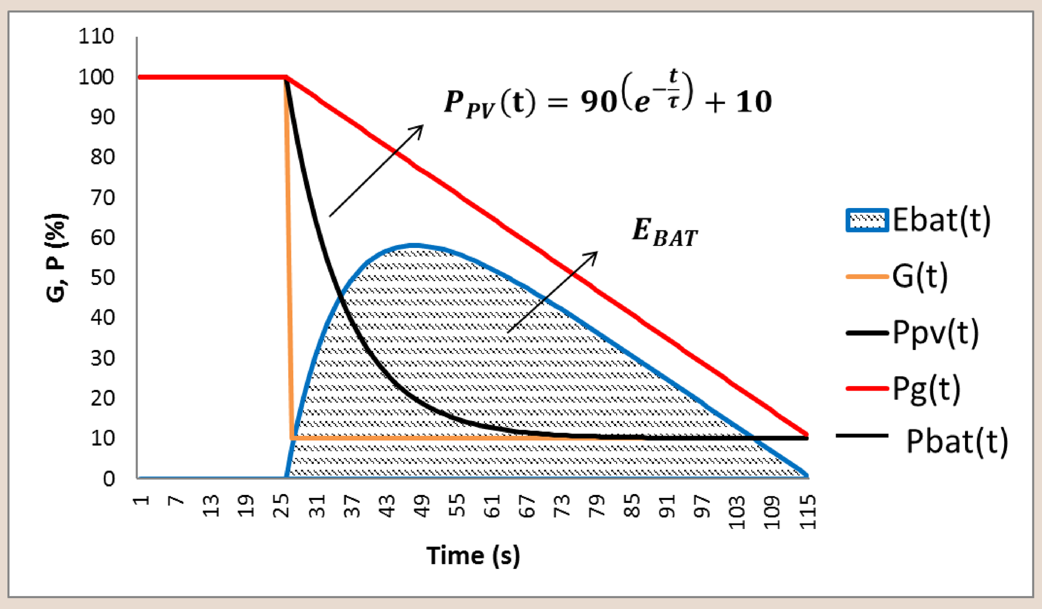
Strategy based on battery	
It	600 $/kWh
n	10 years

Strategy based on short-term forecast	
Et	Annual energy is modified according to energy curtailment due to inverter limitation

CONTROL STRATEGIES PERFORMANCE

RAMP-RATE CONTROL WITH BATTERY

- Minimum energy requirements C_{bat} granted with strategy proposed in [1].



$$C_{BAT} = \frac{0.9 P_N}{3600}\left[\frac{90}{2 \cdot r_{MAX}} - \tau\right]$$

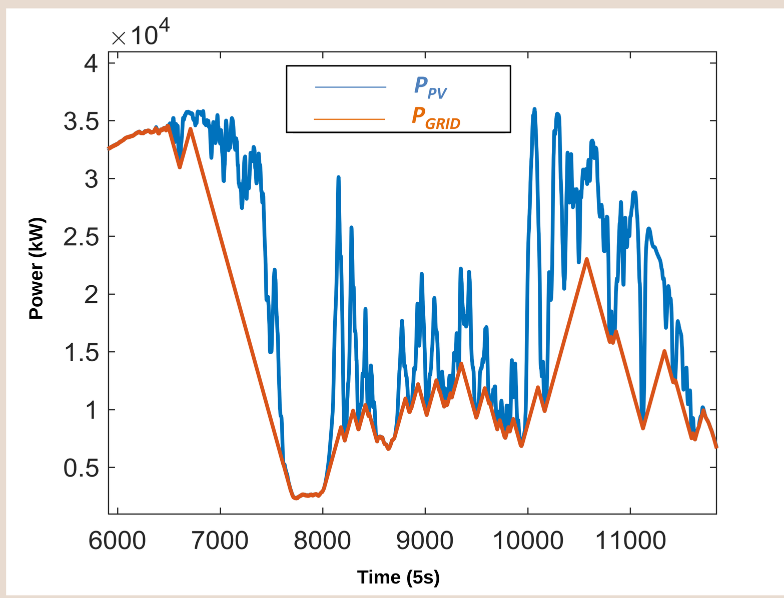
- P_N: nominal power (38,5 MW).
- τ: empirically correlated with the shortest dimension of the PV plant perimeter

Ramp-rate control with battery	r_{MAX}					
	1%/min	2%/min	5%/min	10%/min	20%/min	30%/min
Storage time requirements (h)	0.7	0.32	0.12	0.05	0.02	0.01

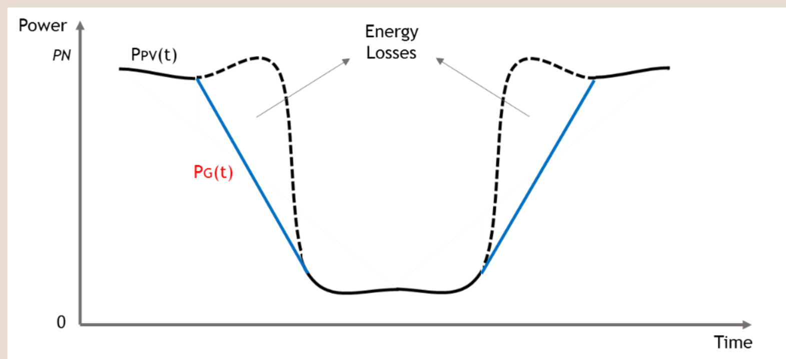
[1] e la Parra, I., Marcos, J., García, M., Marroyo, L., 2015. Control strategies to use the minimum energy storage requirement for PV power ramp-rate control. Sol. Energy 111, 332–343.

BATTERY-LESS WITH PERFECT FORECAST

- Perfect short-term forecast is assumed.



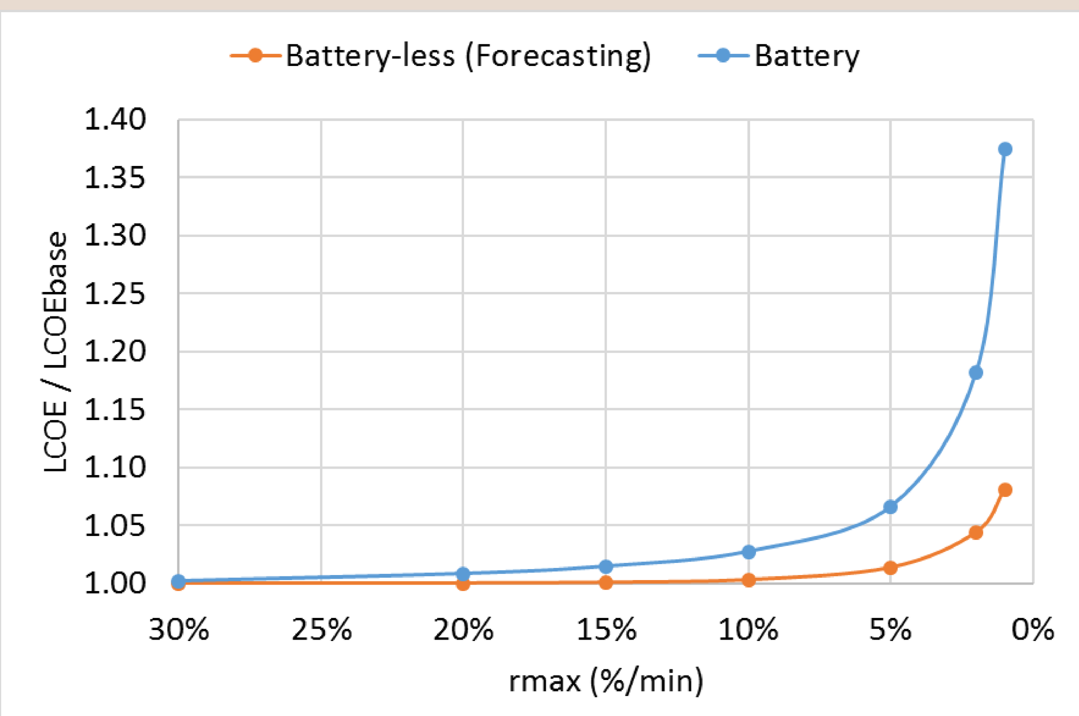
- However, this entails some energy losses in the inverter limitation that has not been yet properly addressed



Ramp-rate control without battery	r_{MAX}					
	1%/min	2%/min	5%/min	10%/min	20%/min	30%/min
Inverter Losses (% total production)	7.96	4.37	1.38	0.33	0.09	0.03

RESULTS

- LCOE increment of the battery-less solution is lower at any case.



- For a maximum allowable ramp-rate of 10%/min, battery-less option is around 14 times cheaper than battery option (4.5% vs. 0.3%)

CONCLUSIONS

- Two possible solutions for ramp-rate control strategy to smooth PV power fluctuations have been addressed: based on the use of a battery and perfect short-term forecasting (with inverter limitation).
- Extensive simulations based on observed high resolution power measurements have been performed at 45 MWp PV plant.
- Energy curtailment has proved to be really low, hence, **short-term forecasting strategy is the best option from a economic perspective**.

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