Compensation of forecast error in large PV plants with battery storage: associated strategies

Javier Marcos*, Iñigo de la Parra, Mikel Muñoz, Miguel García, Luis Marroyo
Dept. of Electrical and Electronic Engineering
& Institute of Smart Cities
Public University of Navarre, Campus Arrosadía, 31006, Pamplona (Spain).
(javier.marcos@unavarra.es)

ABSTRACT

- As penetration rates of utility-scale photovoltaics (PV) increases, large PV plants will participate in the daily wholesale electricity market in the same way that wind farms.
- Then, PV plant owner can receive some kind of economic penalty depending on the forecast deviation. This opens the way to use a battery energy storage system (BESS) to compensate the prediction errors.
- Taking advance of the several 1-hour intra-diary market sessions, the PV plant owner can correct the prediction for the next hours. Hence, a 1-hour BESS SOC control can be implemented to avoid large energy requirements.
- Here we present two novel strategies which allow a large PV-BESS plant to fulfil the programme referred.

OBJECTIVES

- Development of control strategies which allow to **completely compensate the forecast errors** in large PV plant with BESS.
- Optimize these strategies in order to **minimize the storage** requirements and the cycling **degradation**, using **forecast** and **1 hour intra-diary market sessions**.

EXPERIMENTAL SET-UP

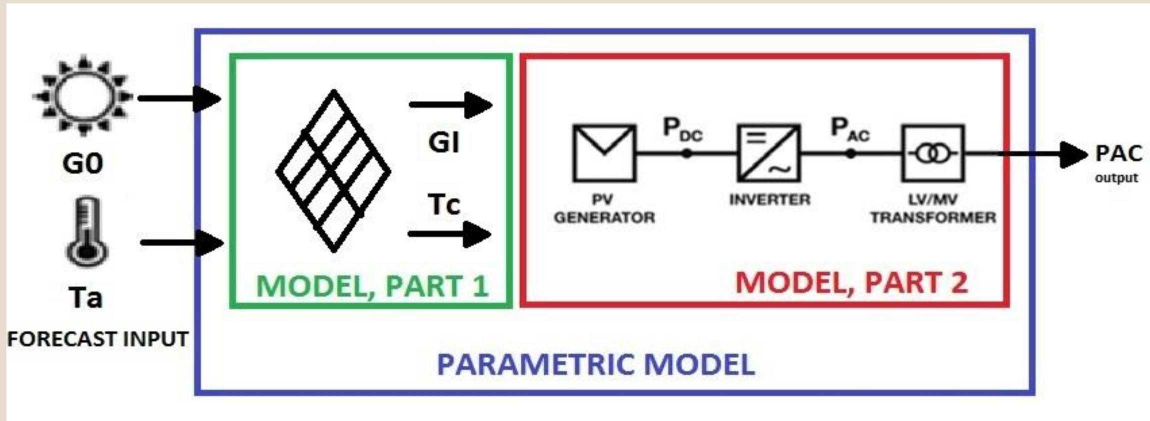
AMARELEJA PV PLANT (45 MWp)

- 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.

FORECAST WITH PARAMETRIC PV PLANT MODEL

- Output AC power of Almaraleja PV plant using two forecast input variables: Ambient temperature (T_a) and Global horizontal irradiance (G_0) from METEOGALICIA (Open source one day in advance) [1].



Model Accuracy	
Part 2 (From Tc & GI measure): ±1%	±1%
Model Part 2 + Part 1 (From Tc & GI measure):	±4%
Complete model (From Ta & G0 forecast)	±18%

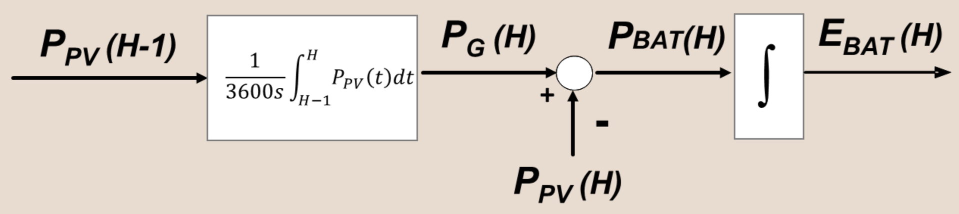
[1] M. P. Almeida, M. Muñoz, I. de la Parra, & O. Perpiñán (2017). Comparative study of PV power forecast using parametric and nonparametric PV models. Solar Energy, 155, 854-866.

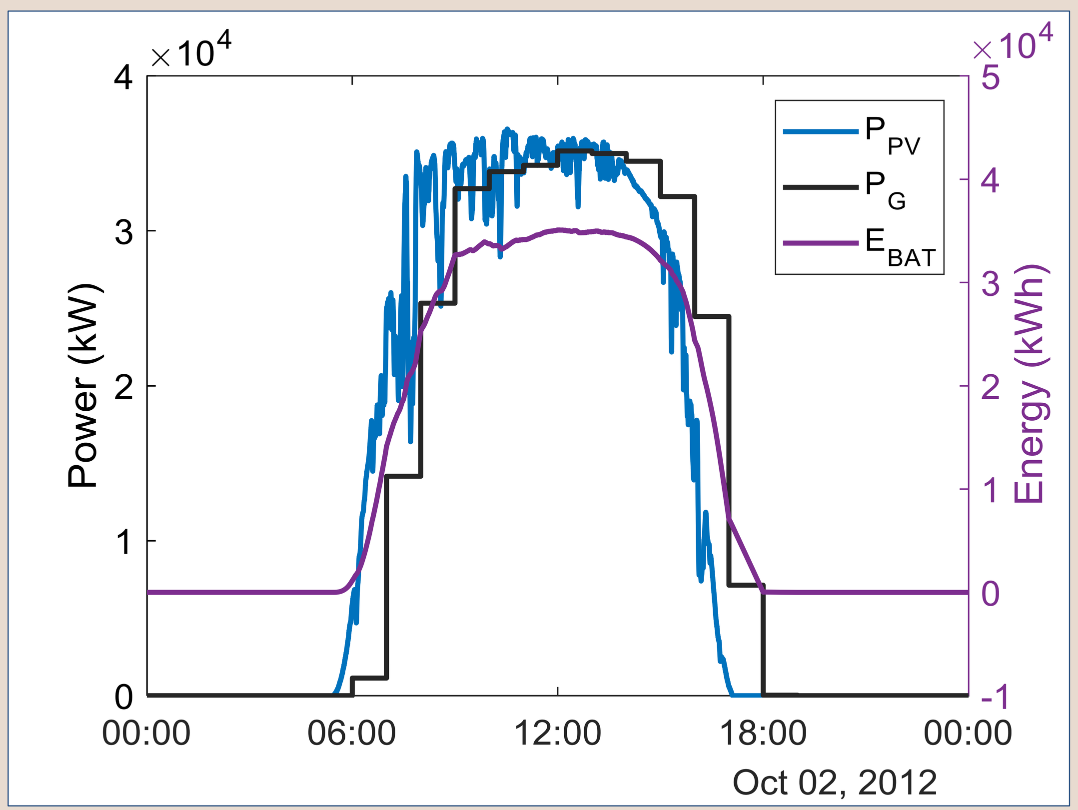
CONTROL STRATEGIES

STRATEGY 1: HOURLY MOVING AVERAGE

Algorithm

- $P_G(H+1) = \text{mean}(P_{PV}(H))$





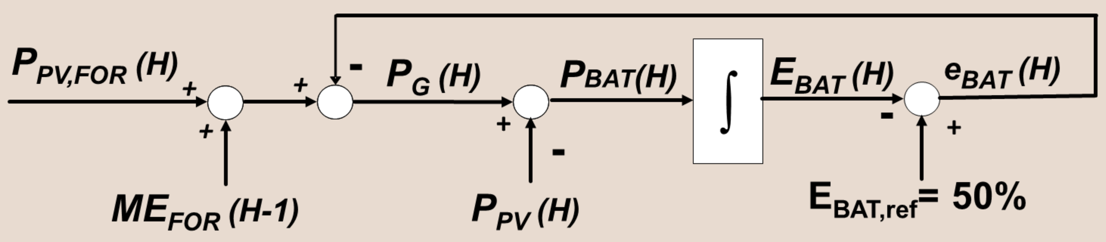
- Due to moving average, there is no need for any type of SOC control to prevent the battery charge /discharge.
- However, the strategy does not take advantage of forecast data.

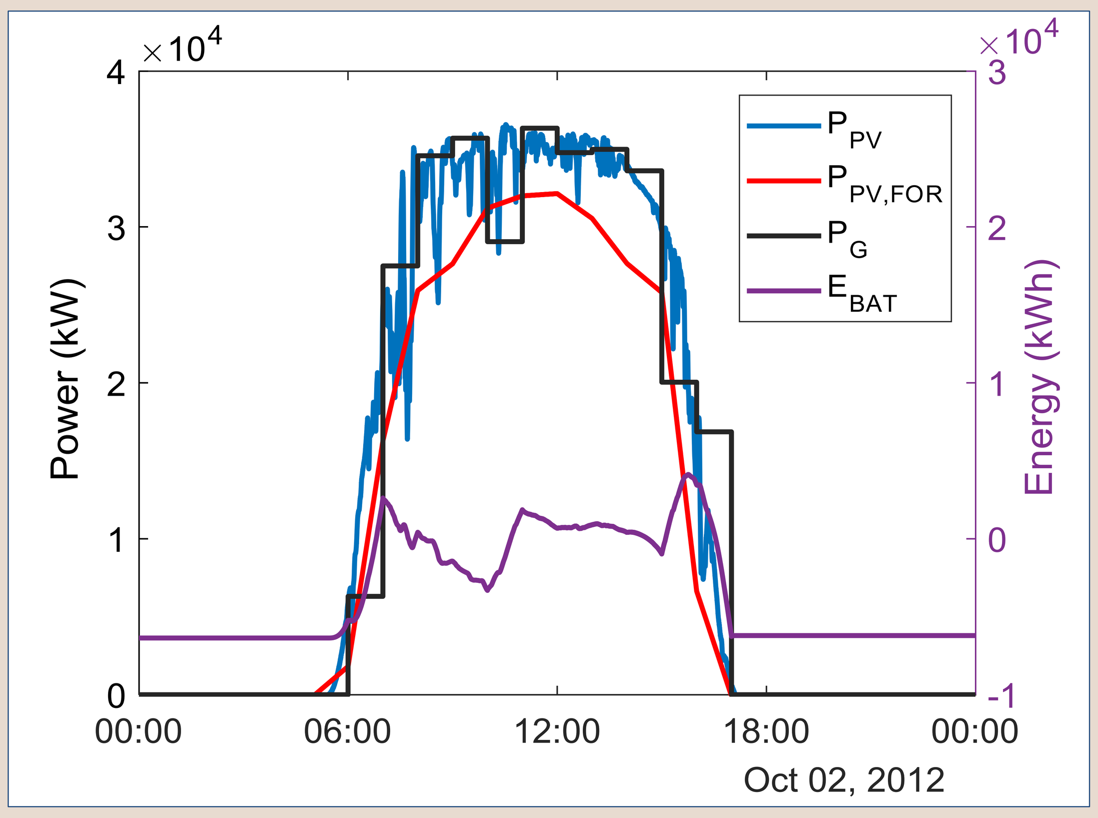
P_{PV}	PV power generated
P_G	Power injected to the grid
E_{BAT}	Energy demanded to the battery

STRATEGY 2: FORECAST AND SOC CONTROL

Algorithm

- $P_G(H) = P_{PV,FOR}(H) + ME_{FOR}(H-1) + e_{BAT}(H)$





- Power injected to the grid depends on: current PV power forecast, last hour forecast mean error and energy in the battery.
- SOC control is needed to compensate the energy forecast error.

P_{PV}	PV power generated
$P_{PV,FOR}$	Power injected to the grid
P_G	Power injected to the grid
E_{BAT}	Energy demanded to the battery

RESULTS

- Both strategies have been successfully simulated during two year data (Oct'12- Sep'14) of 38.5 MW PV power plant .
- Strategies have been analyzed against Storage Time and Cycling Degradation [2] merit indexes.

SUMMARY OF THE VALIDATION RESULTS	STRATEGY 1	STRATEGY 2
Worst day storage time required (h)	0,96	1.10
Annual storage time required (h)	0.98	1.31
Cycling degradation (*) (%)	13.46	3.32

[2] Dufo-López, R.; Lujano-Rojas, J.M.; Bernal-Agustín, J.L. Comparison of different lead-acid battery lifetime prediction models for use in simulation of stand-alone photovoltaic systems. Appl. Energy 2014, 115, 242–253.

CONCLUSIONS

- These strategies have demonstrated that with roughly 1 hour of storage it is possible to fully compensate the forecast errors in a large PV plant, according to future market regulations.
- Likewise, the use of open source meteorological forecast can extend the battery life in more than 4 times compared with not having it.
- Although present BESS prices can be high enough to balance economic penalties, **there are no technical barriers in order to make a large PV plant completely full predictable** and hence, reduce the cost of TSO energy reserves

33rd European Photovoltaic Solar Energy Conference and Exhibition
EU PVSEC 2017. 25 - 29 Sept. 2017, RAI Convention & Exhibition Centre, Amsterdam, The Netherlands