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Integration of Renewable Sources in the Electric System using Virtual Renewable Power Plants

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Agenda

- The Virtual Renewable Power Plant (VRPP) concept
- Power fluctuations of Renewable Energy Sources (RES)
- Case Study
- Results

Virtual Renewable Power Plants (VRPP)

- Smoothing of power fluctuations from RES
- Use of natural resources complementarity
- Relies on common electrical control systems
- Optimizes use of electrical infrastructures

Power Fluctuations of RES

- Particularly accentuated for wind energy
  - Fast fluctuations (seconds, milliseconds) are naturally smoothed
  - Slower fluctuations (hours, days) can be tackled with the combination with other RES

Case Study

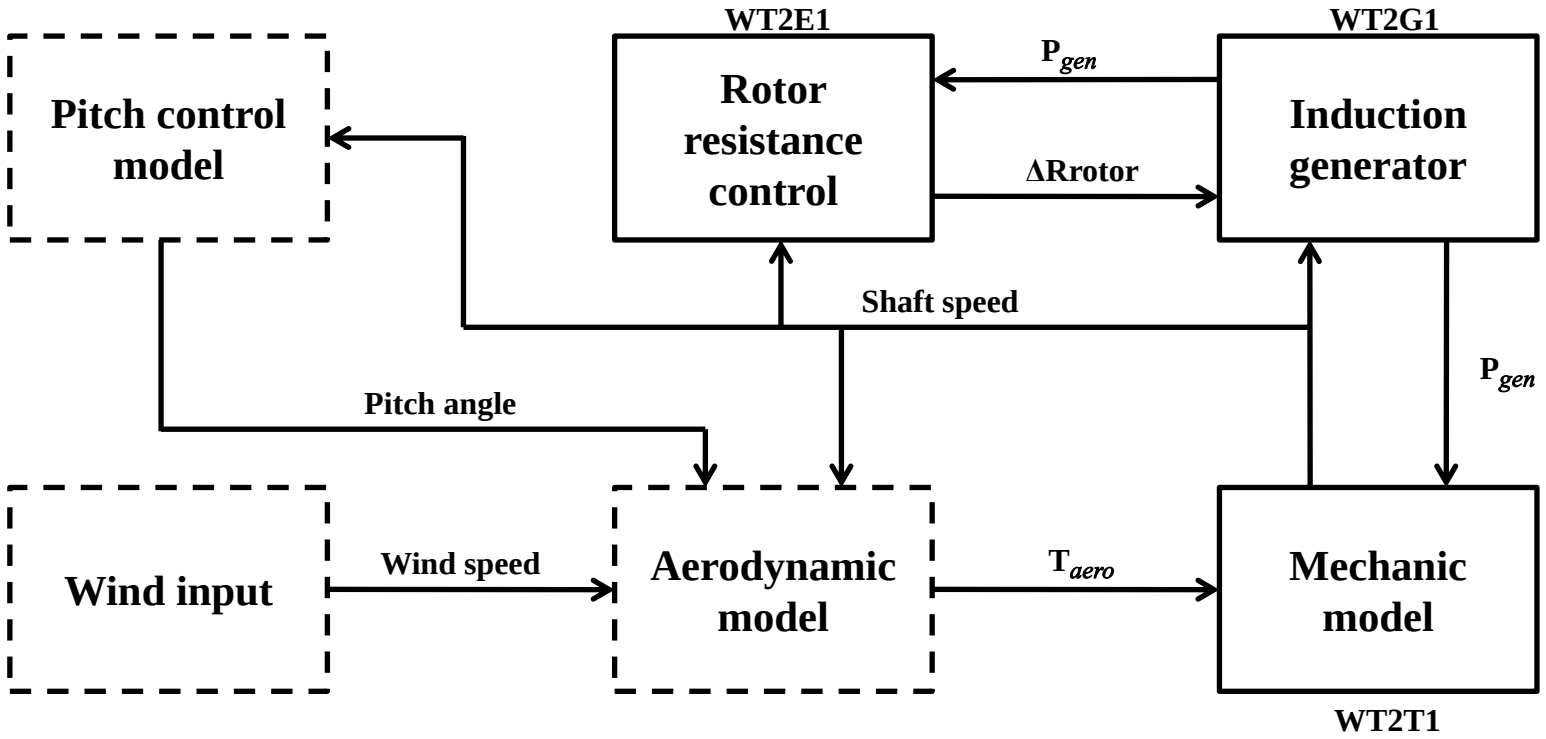
- Portuguese legislation allows existing wind power plants to have 20% of installed capacity over its nominal (nameplate) limit (a.k.a. “overcapacity”)
  - Installation of overcapacity with PV (or other RES) enables the opportunity to complement wind generation in a synergic manner

Case Study

- Simulation using time domain models (PSS/E) fed with:
  - Wind data
    - Real 30 minutes average wind data (central region of Portugal)
    - Modeled turbulence using Davenport spectrum
  - Irradiation data
    - Test reference year at the optimal slope with resolution of 1 hour

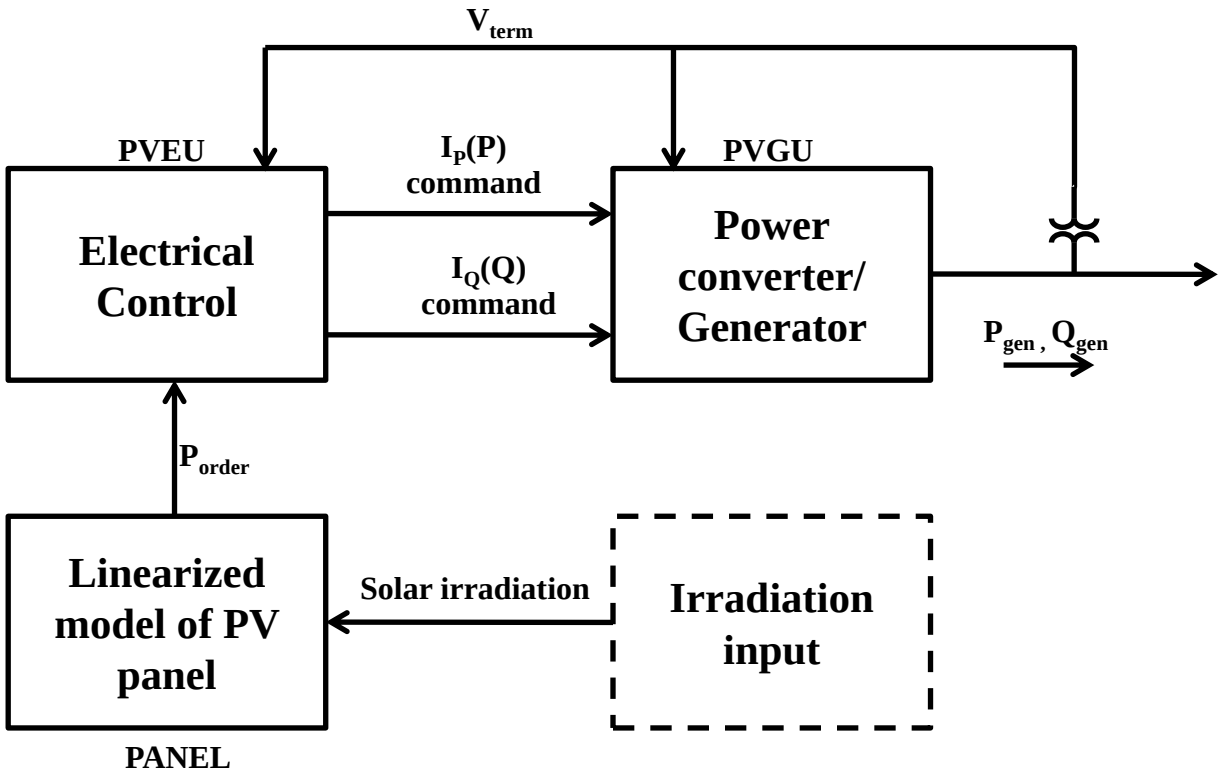
Case Study

- Wind Turbine Generator (WTG) Type 2 model diagram



Case Study

- Solar Photovoltaic generator model diagram



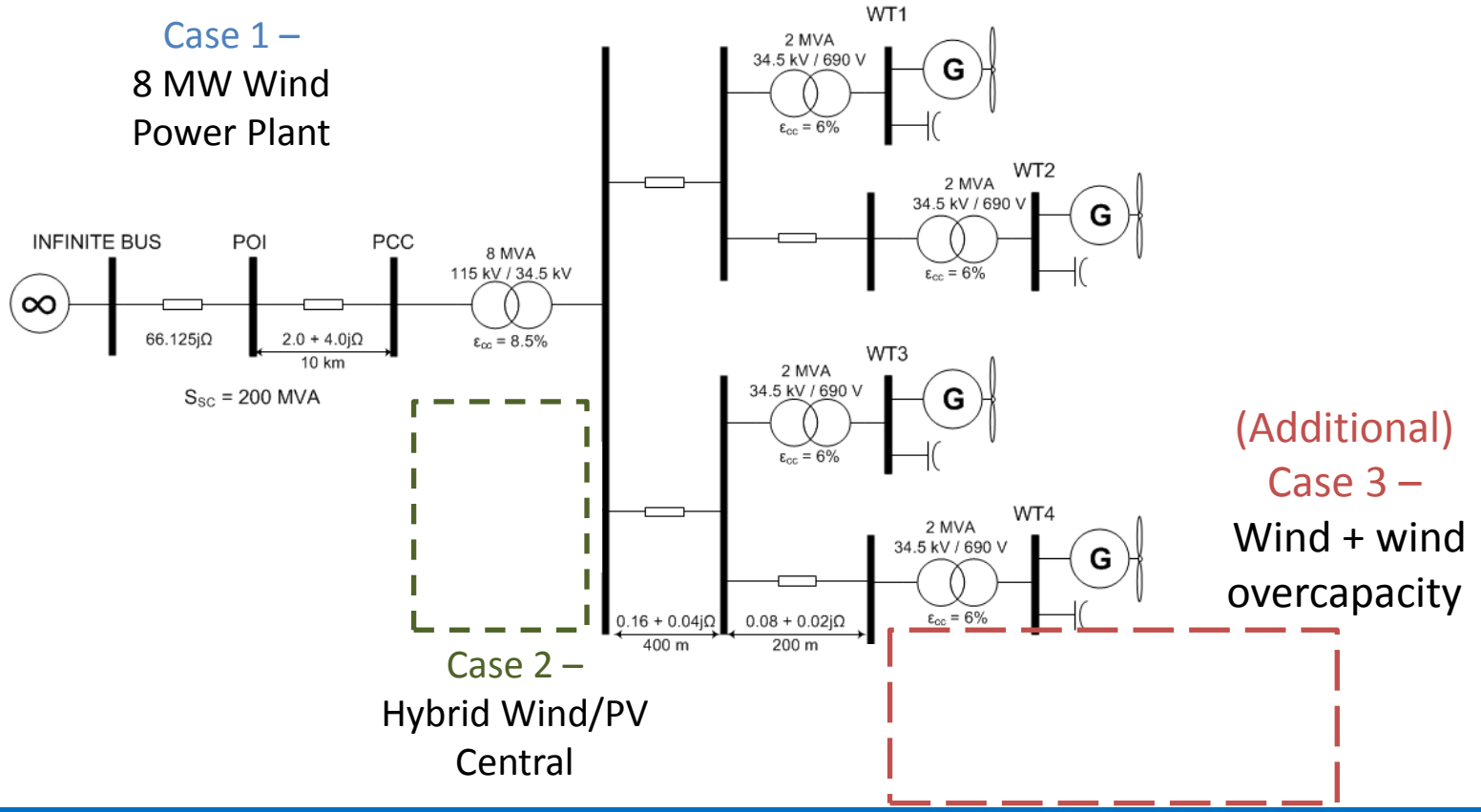
Case Study

- 2 Cases
  - Base case : 4 x 2 MW wind farm
  - VRPP case: 4 x 2 MW wind + 2MWp PV central

- Additional case (not included in the paper)
  - Wind overcapacity: 4 x 2 MW wind farm + 2 MW wind turbine

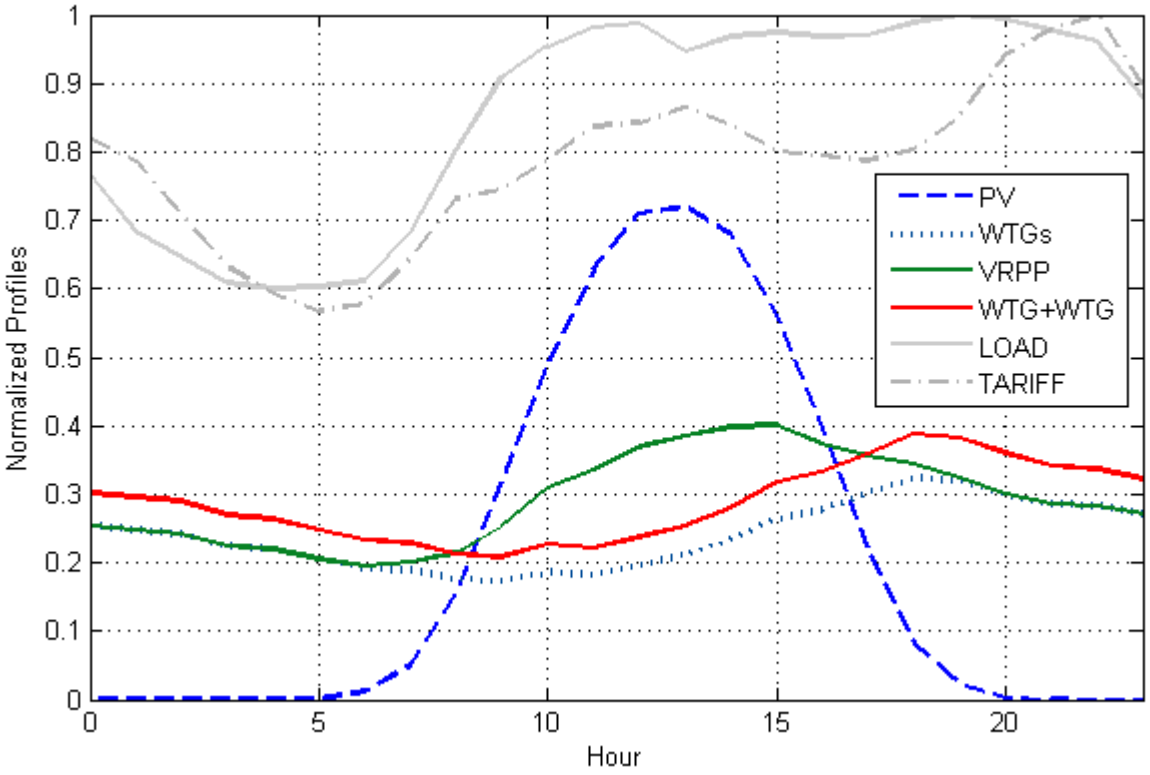
Case Study

- Base system



Results

- Average daily power profiles



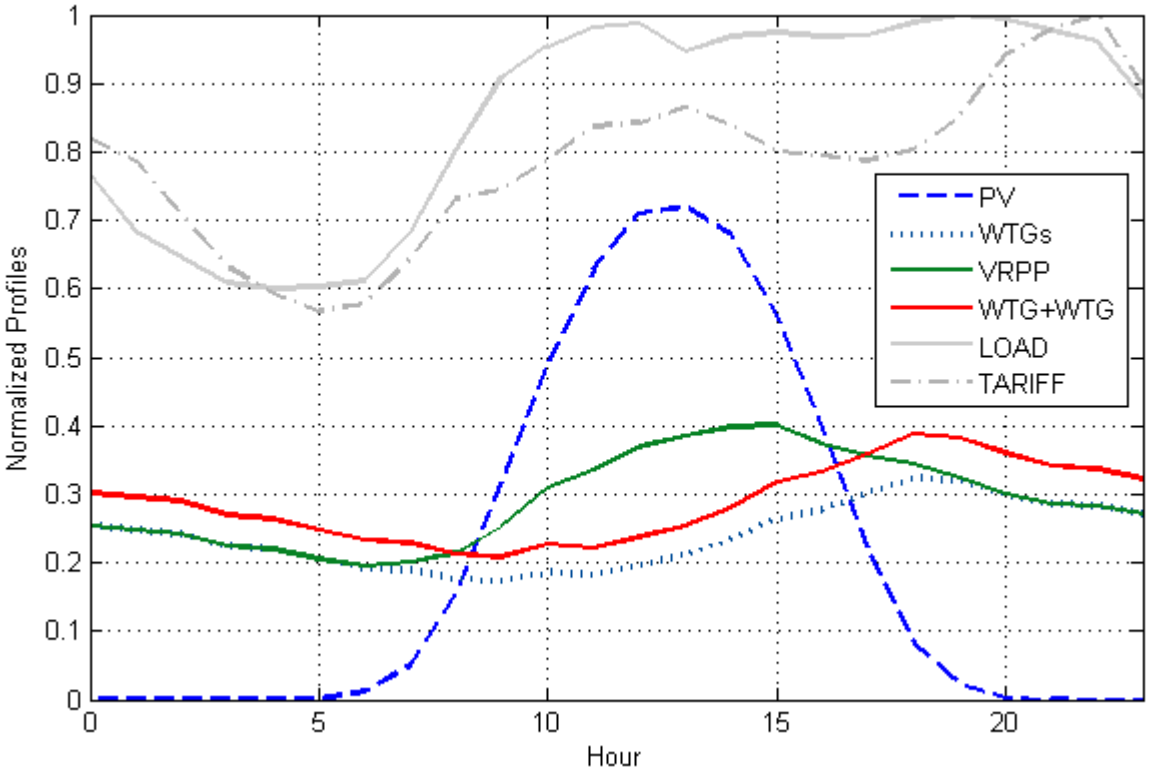
– Correlations

	Load	Tariff
WTG	0,41	0,52
PV	0,54	0,21
WTG+WTG	0,41	0,52
VRPP	0,82	0,57

WTG→PV	-0,41

Results

- Average daily power profiles



– Capacity Factor

	%	NEPS
WTG	24,0	2 104
WTG+WTG	28,8	2 523
VRPP	29,2	2 558

Results

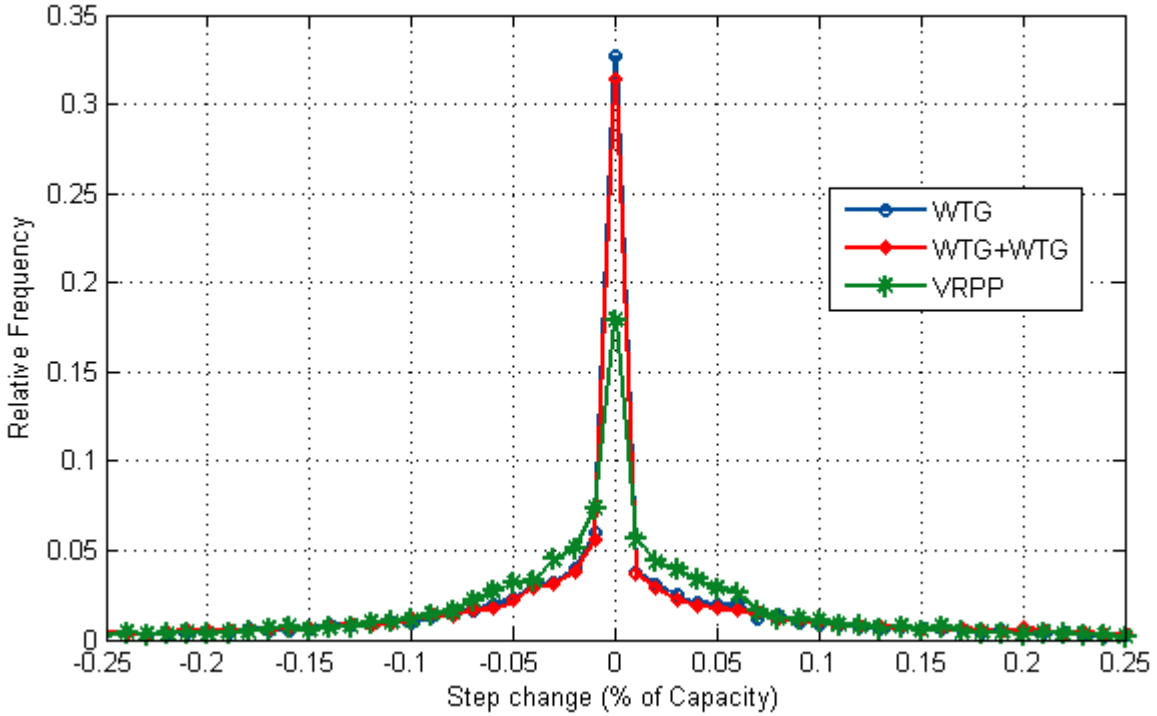
- Power fluctuations
  - Standard deviation of Step Changes

Time Horizon	$3\sigma_{WTG}$ [pu]	$3\sigma_{WTG+WTG}$ [pu]	$3\sigma_{VRPP}$ [pu]
30 minutes	0,2253	0,2727	0,2223
1 hour	0,3540	0,4290	0,3513
4 hours	0,5628	0,6834	0,5736

Results

- Power fluctuations
  - 1 hour step changes

$3\sigma_{WTG}$ [pu]	$3\sigma_{WTG+WTG}$ [pu]	$3\sigma_{VRPP}$ [pu]
0,3540	0,4290	0,3513



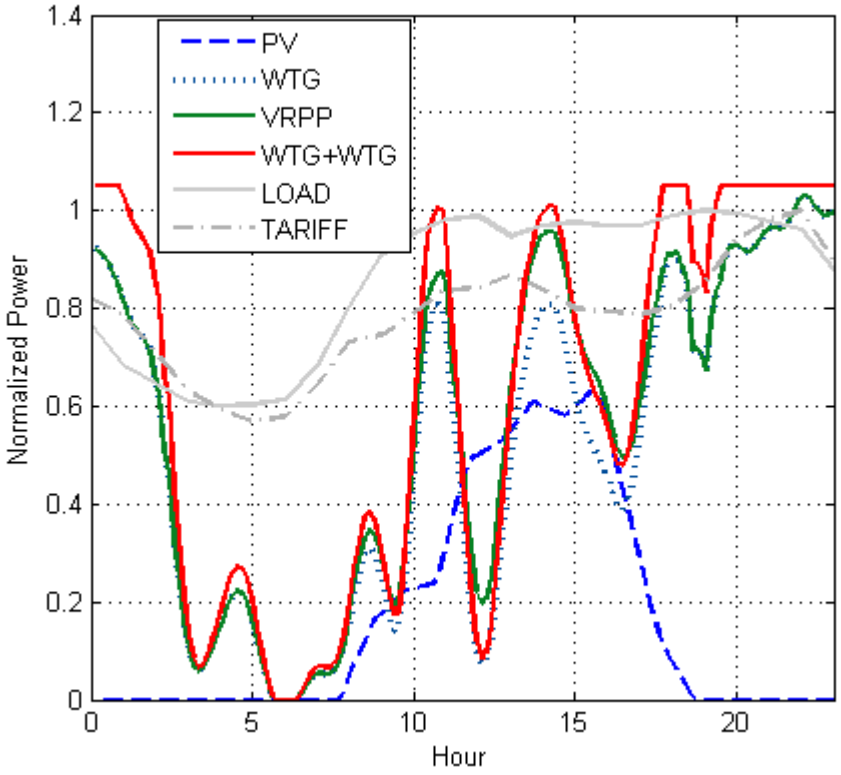
Results

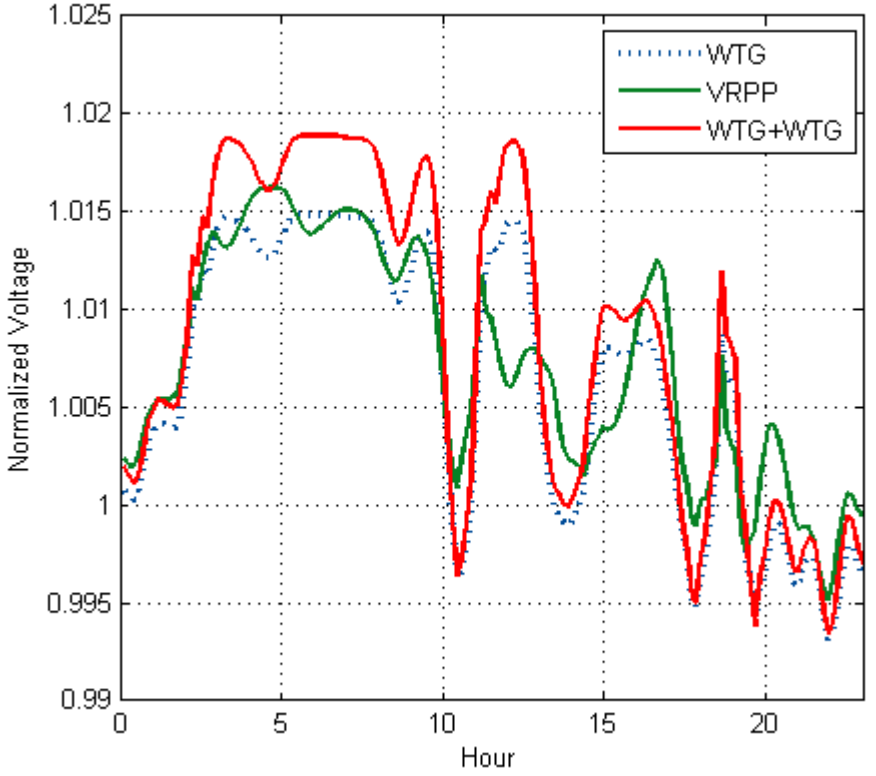
- Voltage profile in the PCC
  - Large reactive power regulation when aggregating RES connected through inverter

	Average Voltage [pu]	$\sigma_{voltage}$ [pu]
WTG	1,011	0,0058
WTG+WTG	1,014	0,0069
VRPP	1,007	0,0033

Results

- Daily power and voltage profiles





Results

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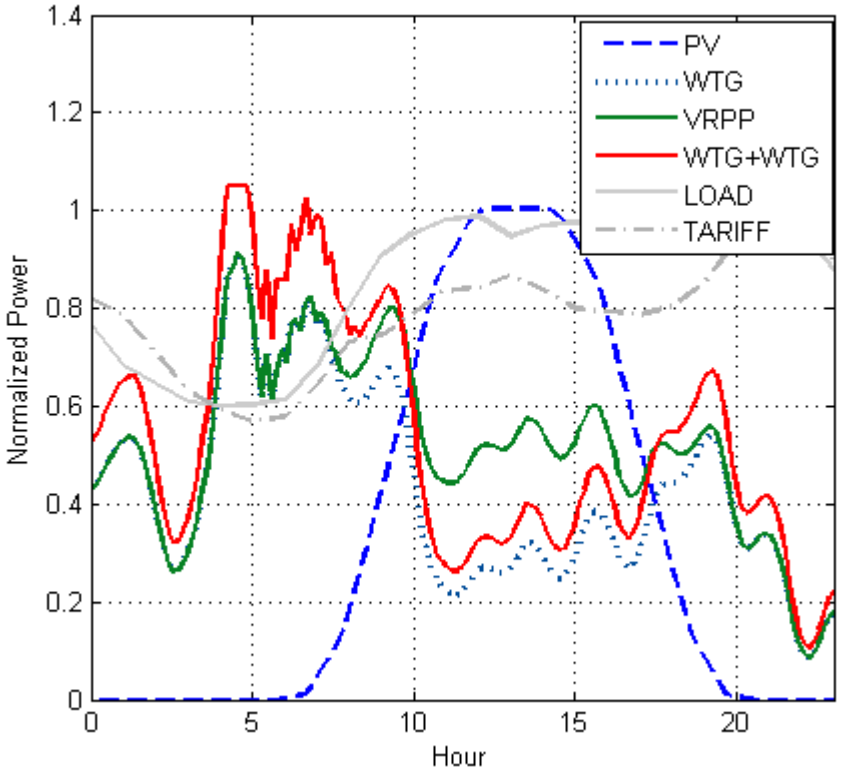
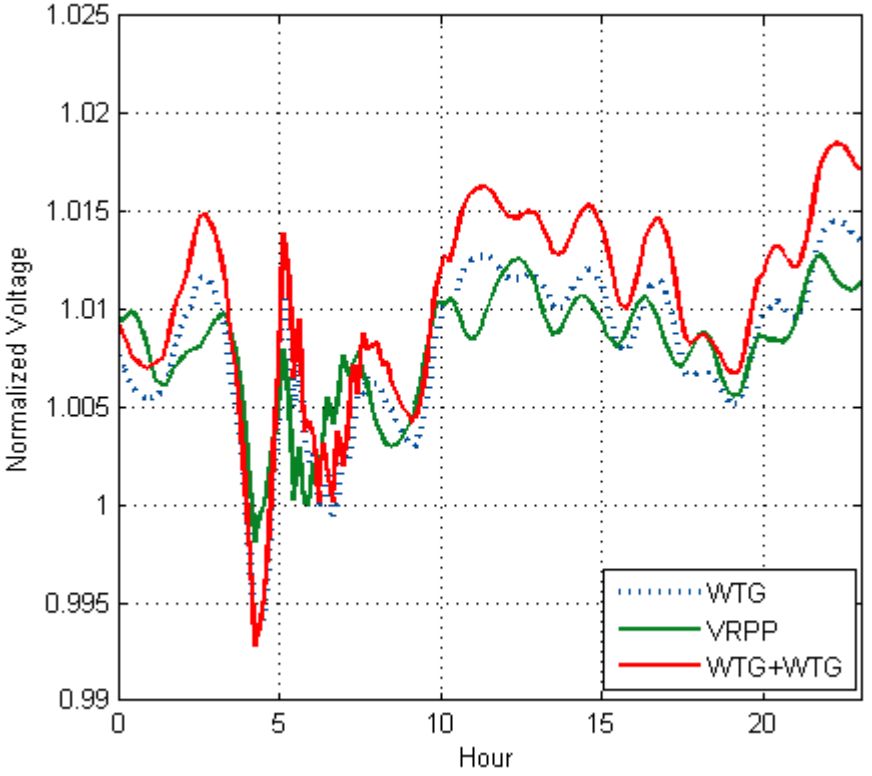
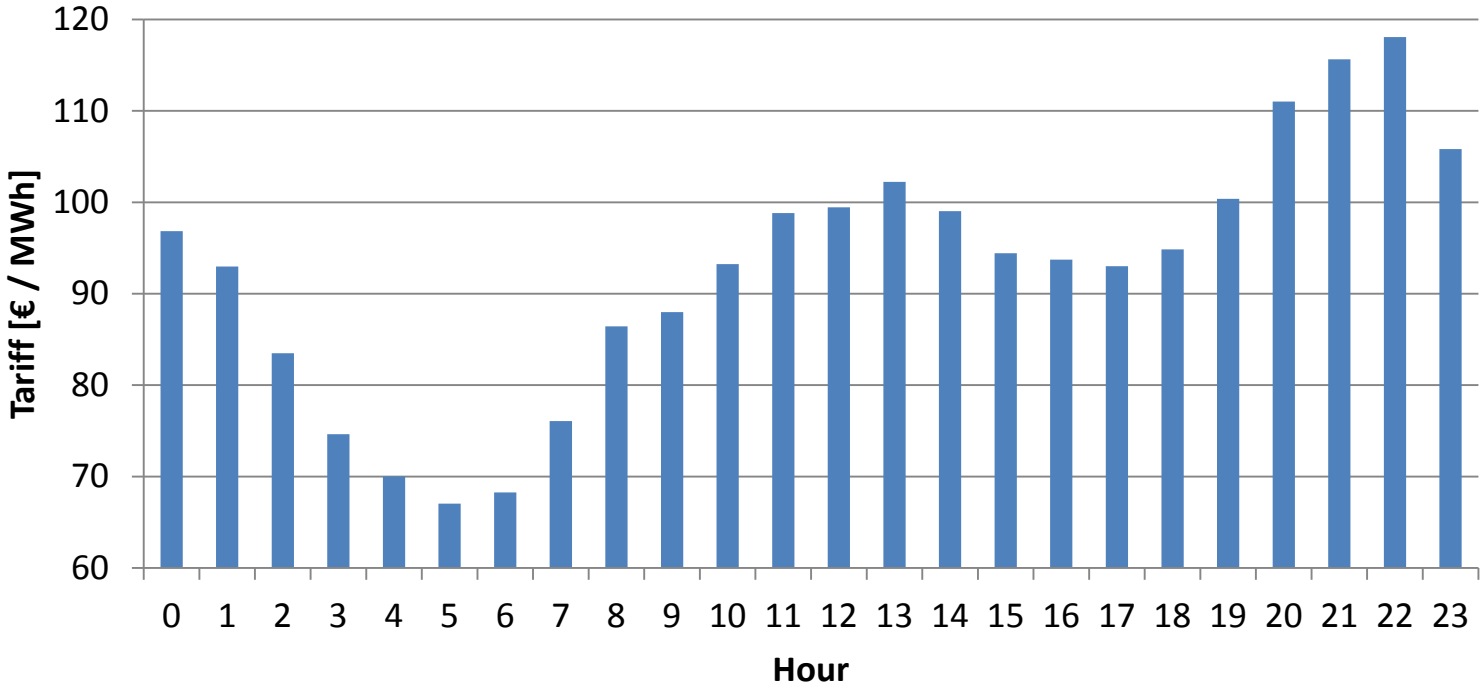




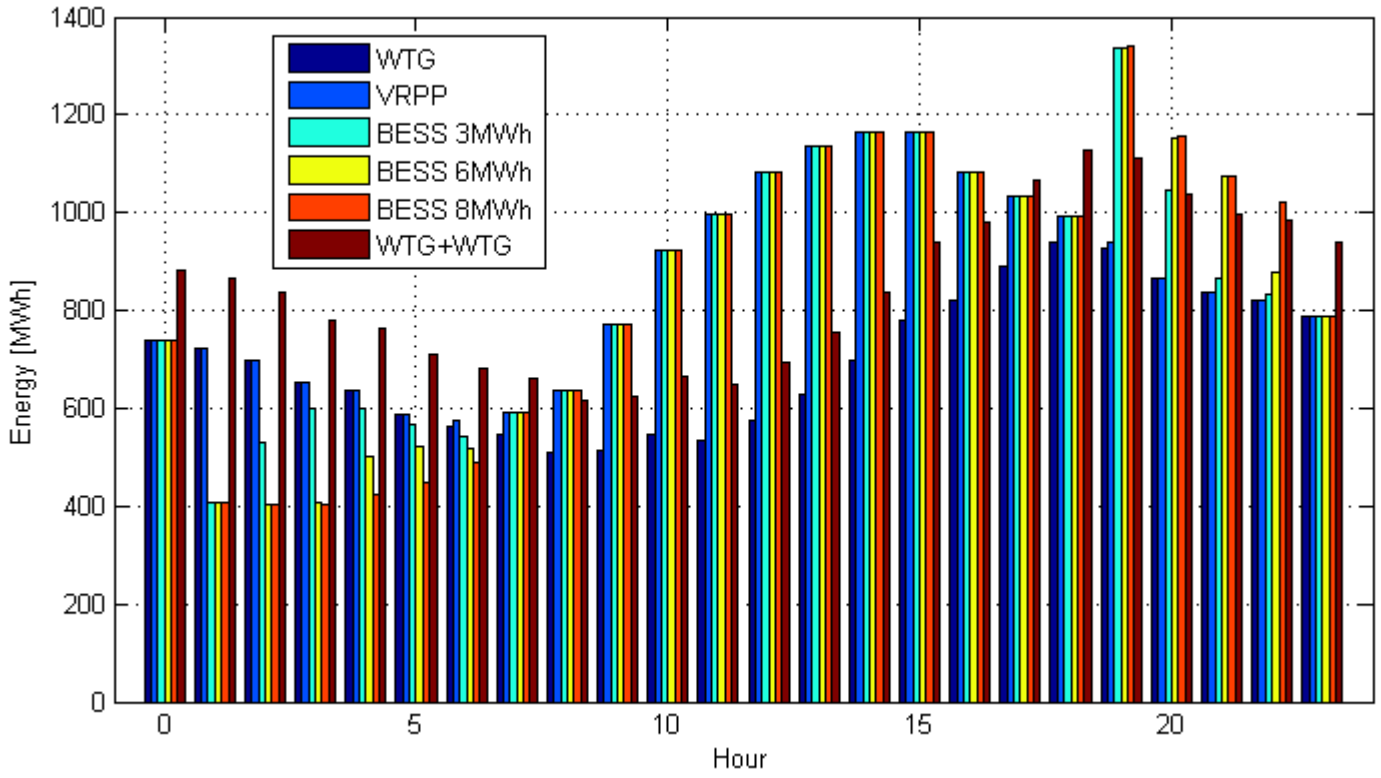
Results

- RES feed-in tariff considered



Results

- Total energy produced for each hour



Results

- Total energy produced and expected revenue

	Energy [GWh]	Revenues [€]	Potential Benefit [€]	Potential Benefit
WTG	16,87	1 582 617	-	-
WTG+WTG	20,21	1 899 858	317 241	20,05%
VRPP (WTG+PV)	20,44	1 930 426	347 810	21,98%
VRPP + BESS 3 MWh	20,43	1 940 713	358 096	22,63%
VRPP + BESS 6 MWh	20,31	1 946 558	363 941	23,00%
VRPP + BESS 8 MWh	20,27	1 950 806	368 189	23,26%

Conclusion

- Positive impacts:
  - Developers
    - Accentuated increase in the capacity factor of connection infrastructures
    - More valued energy (in a future scenario with no feed-in-tariff constant tariffs)
    - Less wind power curtailed by the wind farm dynamic control
  - System operator's (DSO, TSO)
    - Less power fluctuations
    - Better voltage profile
    - Better use of grid infrastructure
    - Possibility to use VRPP for primary frequency regulation and other ancillary services

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Questions?!?

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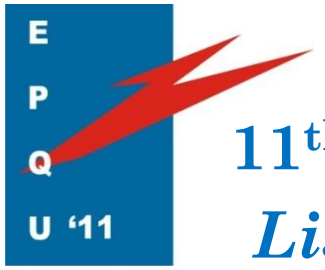

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Thank you!!!

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