Wind offering in energy and reserve market

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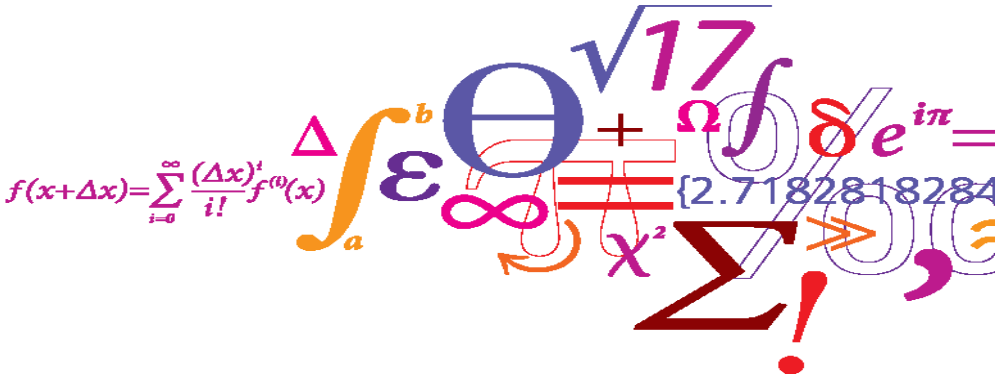
Wind Europe SUMMIT 2016
29 September 2016



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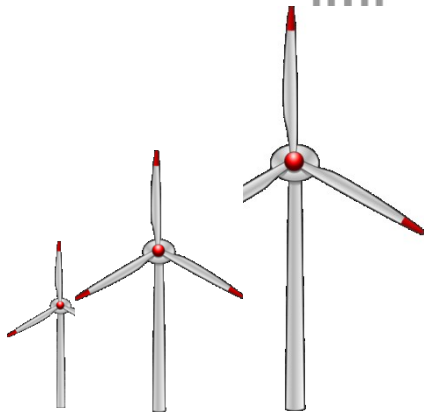
Outline

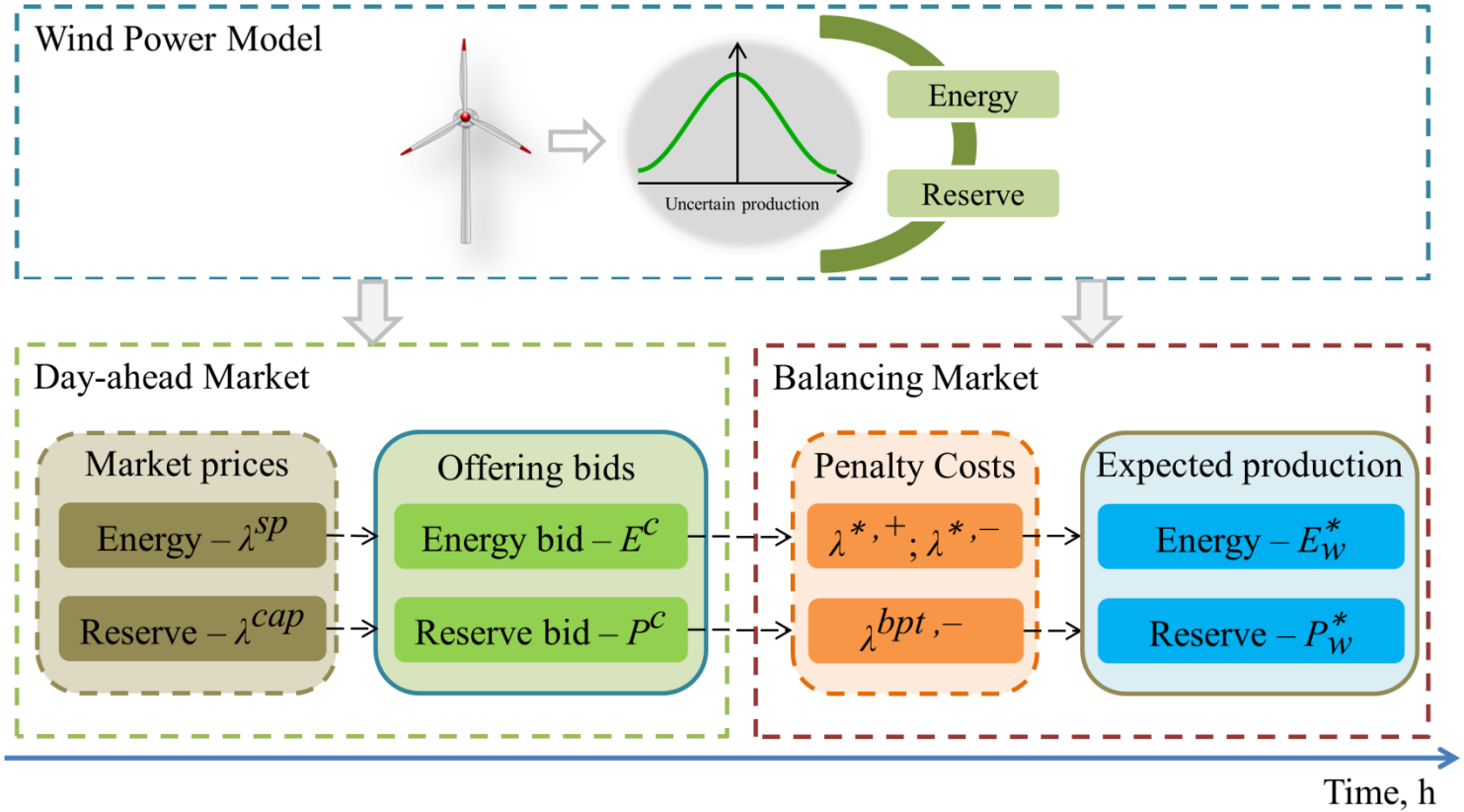
- Introduction
- Wind power model
- Model development – Stochastic Approach
- Case study
- Conclusions

Introduction

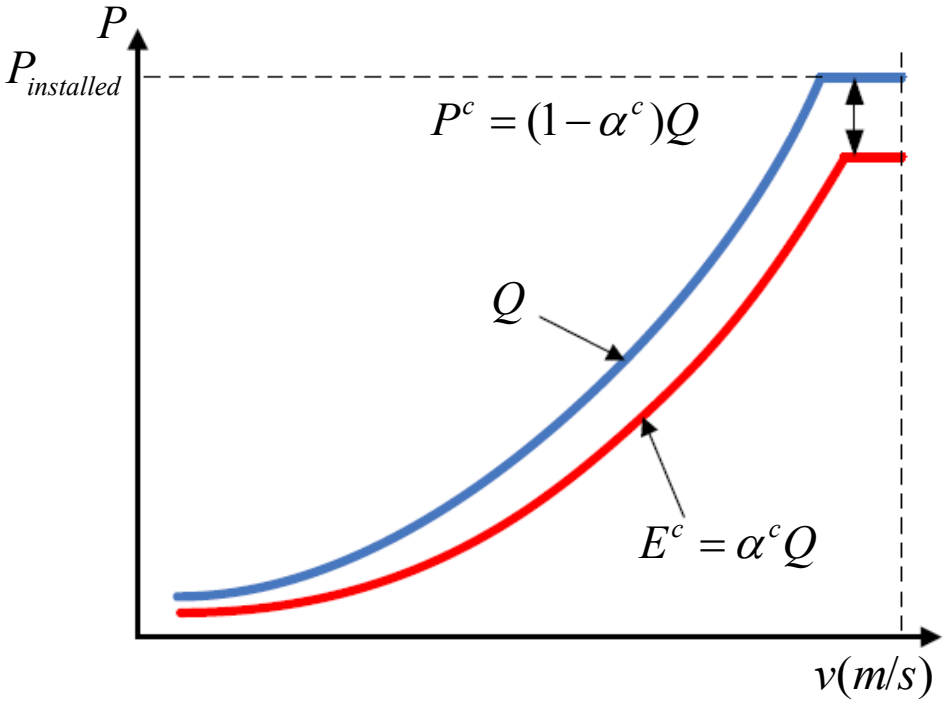
- Increasing wind power penetration in power systems
- New business models (energy and ancillary services)
- Maximizing expected return



Wind power participation model



Proportional wind offering strategy



Q – Total power bid

P^c – Reserve contracted (offered)

E^c – Amount of energy offered

α^c – Strategy parameter for controlling the share of energy and reserve (between 0 and 1)

Mathematical formulation

- Objective function

$$\text{Maximize} \quad R = \lambda^{cap} P^c + \sum_{w \in \Omega} \pi_w \left[\lambda^{sp} E_w^* - T_w^* - W_w^* \right]$$

$$T_w^* = \begin{cases} \lambda^{*,+} \left(E_w^* - E^c \right), & E_w^* - E^c \geq 0 \\ -\lambda^{*,-} \left(E_w^* - E^c \right), & E_w^* - E^c < 0 \end{cases}$$

$$W_w^* = \begin{cases} \lambda^{bpt,+} \left(P_w^* - P^c \right), & P_w^* - P^c \geq 0 \\ -\lambda^{bpt,-} \left(P_w^* - P^c \right), & P_w^* - P^c < 0 \end{cases}$$

- Subjected to

$$E^c = \alpha^c Q$$
$$P^c = (1 - \alpha^c) Q$$

Day-ahead constraints

$$E_w^* = \alpha_w^* E_w^{obs} \quad , \forall w \in \Omega$$
$$P_w^* = (1 - \alpha_w^*) E_w^{obs} \quad , \forall w \in \Omega$$

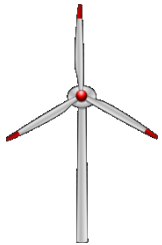
Balancing stage constraints

$$\alpha_w^* = \alpha^c \quad , \forall w \in \Omega$$

Non-anticipativity constraint

Case study – numerical example

- Wind power producer - 15 MW

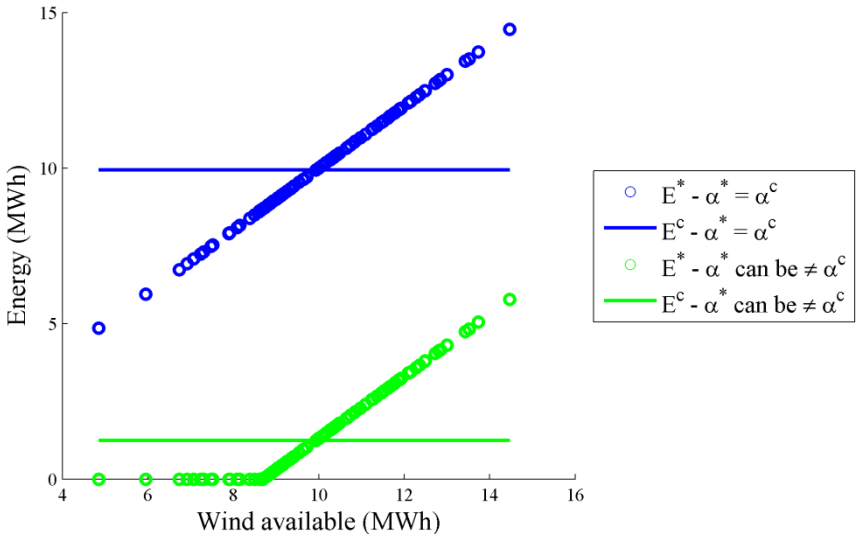


- Prices and penalty costs in energy and reserve market

Energy	Price (€/MWh)	Reserve	Price (€/MW)
λ^{sp}	40	λ^{cap}	41
$\lambda^{c,+}$	30	$\lambda^{bpt,+}$	0
$\lambda^{c,-}$	50	$\lambda^{pt,-}$	96

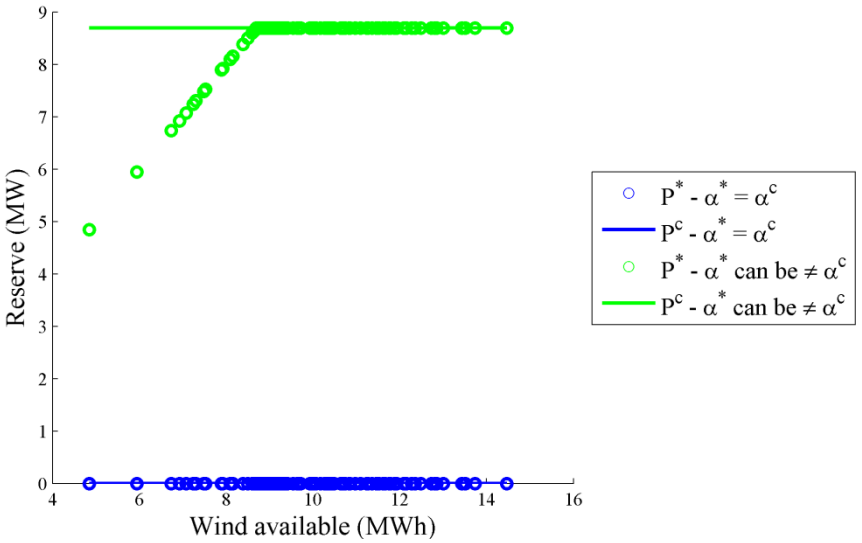
Case study – results

- The standard approach offers only to the energy market, since the gain from participating in the reserve market is not much higher than participating in energy-only (risk adverse behaviour)
- In contrast, flexible approach offer in both markets, thereby, increasing the expected revenue (risk neutral behaviour)



Case study – results

- For lower levels of available wind power (until $P^{*}=P^{C}$), the flexible approach allocates all the available power to the reserve market, where the penalty for failing is higher.
- Flexible approach improves the revenue in about 2%



Conclusions

- The results strongly depend on the **prices and penalties** for energy and reserve
- The use of proportional strategy may able to provide **additional profits** to wind power plants, in expectation
- The standard strategy performs a **risk averse behaviour** where all the available energy is submitted in either energy or reserve market.

Market design implications

- Allowing wind power plant to bid in the **energy and reserve market** may require some changes in the market design.
- Time for service provision availability. Bring energy and reserve market closer to the delivery.
- Reducing the minimum size bids / aggregation of bids
- Prediction intervals for availability concerns

Thank you!

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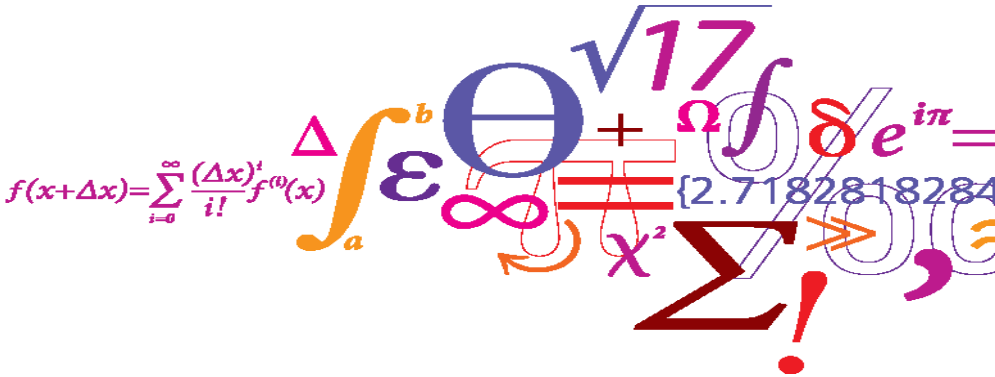

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