Escuela Técnica Superior de Ingeniería - ICAI
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Adequate Regulation Reserve Levels In Systems With Large Wind Integration Using Demand Response

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JOSITE
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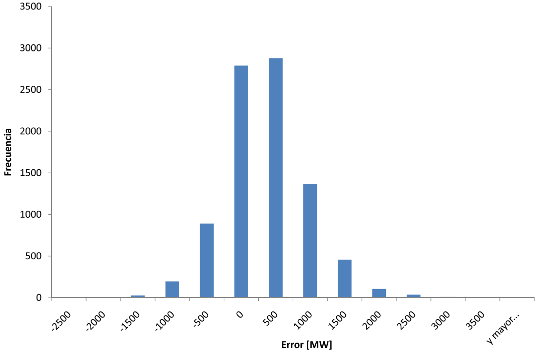
Introduction

Large-scale integration of wind energy

Large-scale integration of wind energy

Intermittent Energies

Intermittent energies are characterized by their variability and uncertainty in prediction.



Introduction
Reserves

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Uncertainty in operation:

- Variations in demand.
- Generator outage.
- Variations in wind.

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- Variations in demand.
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Reserves necessary to keep the balance between generation and demand.

- Upwards and downwards reserves.
- Provided historically by thermal and hydro generators.

Reserves by demands

Introduction
Reserves by demands

- No ramping nor minimum on or off constraints.
- Small or no impact on efficiency.

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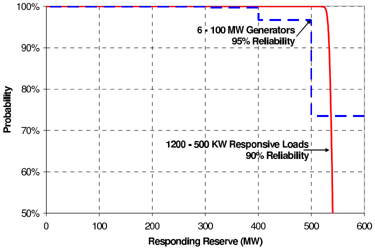
Kirby (2003): Larger numbers of individually less reliable responsive loads can provide greater aggregate reliability than fewer large generators.



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Model for the UC Problem

Modeling approach for the Unit Commitment

Modeling approach for the Unit Commitment

Cost Minimization

$$COp_{ante} = \sum_{p,t} [CFix_t \ uc_{p,t} + CVar_t \ ProdTMin_{p,t} \ uc_{p,t} + CVar_t \ prodt_{p,t} + COn_t \ on_{p,t} + CNse \ nse_p]$$

Modeling approach for the Unit Commitment

Cost Minimization

$$COp_{ante} = \sum_{p,t} [CFix_t \; uc_{p,t} + CVar_t \; ProdTMin_{p,t} \; uc_{p,t} + CVar_t \; prodt_{p,t} + COn_t \; on_{p,t} + CNse \; nse_p]$$

s.t.

Demand balance

$$DemRef_p - ProdI_p - nse_p = \sum_t ProdTMin_{p,t} \; uc_{p,t} + prodt_{p,t}$$

Reserve up/down

$$\sum_t (ProdTMax_{p,t} - ProdTMin_{p,t}) \; uc_{p,t} - prodt_{p,t} \geq RsUp_p$$

$$\sum_t prodt_{p,t} \geq RsDo_p$$

Generation limits min/max

$$prodt_{p,t} \leq (ProdTMax_{p,t} - ProdTMin_{p,t}) \; uc_{p,t}$$

Ramping constraints up/down

$$prodt_{p,t} - prodt_{p-1,t} \leq ProdTUp_t$$

$$prodt_{p-1,t} - prodt_{p,t} \leq ProdTDo_t$$

Logic coherence for start-up and shutdown ties

$$uc_{p,t} - uc_{p-1,t} = on_{p,t} - off_{p,t}$$

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Modeling Demand Side Management

Definition of DSM

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Demand Side Management: Activities which aim to influence the demand profile, for example in magnitude and time of electricity usage, are called demand side management (DSM) programs.

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- Demand Shifting:
  - Demand is moved from peak to offpeak hours.
  - Modeled as a centralized decision making process.

Demand Side Management

Modeling Demand Shifting

Centralized decision making process

Cost Minimization

s.t.

Variable demand

$dem_p = DemRef_p + demVar_{p,up} - demVar_{p,do}$

Demand balance including demand as variable dem_p

Limits of shiftable demand

$Lim_{do}\ DemRef_p \geq demVar_{p,do} \geq 0$

$Lim_{up}\ DemRef_p \geq demVar_{p,up} \geq 0$

Balance of shiftable demand during day

$\sum_p demVar_{p,up} = \sum_p demVar_{p,do}$

Modeling Demand Shifting

Centralized decision making process

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Reserve up/down

Generation limits min/max

Ramping constraints up/down

Logic coherence for start-up and shutdown ties

Modeling Demand for providing Reserve

Modeling Demand for providing Reserve

Reserve by demand

Cost Minimization

s.t.

Reserve up/down

$\sum_t (ProdTMax_{p,t} - ProdTMin_{p,t})\ uc_{p,t} - prodt_{p,t} + demRES p, up \geq RsUp_p$

$\sum_t prodt_{p,t} - demRES p, do \geq RsDo_p$

Variable demand

$dem_p = DemRef_p + demVar_{p,up} - demVar_{p,do} + demRES_{p,up} - demRES_{p,do}$

Demand balance including demand as variable dem_p

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Modeling Demand for providing Reserve

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Balance of shiftable demand during day Generation limits min/max

Ramping constraints up/down

Logic coherence for start-up and shutdown ties

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Case Study in Gran Canaria

Data for Case Study

Data for Case Study

- Gran Canaria
  - small island in Spanish territory
  - chosen as it has to cope with demand coverage on its own
  - no interconections
- Generation units
  - 21 thermal units (CCGT,Gas Turbines,Fueloil,Gasoil)
  - Installed capacity: approx. 1160 MW
  - No hydro plants
- Generation data
  - Variable, fixed and start-up cost regulated und published in BOE (2006)

Data for Case Study

- Wind data
  - Time series of wind production and error of wind forecast adapted to Gran Canaria
- Demand data
  - Historic time series for Spain
  - Scaled down to Gran Canaria

Results: demand shifting and reserves

Case Study in Gran Canaria

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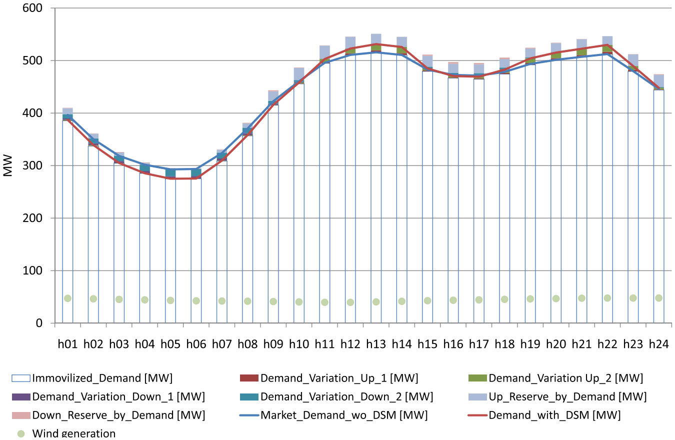
Demand shifting and reserve offered by demand on the average day



Case Study in Gran Canaria

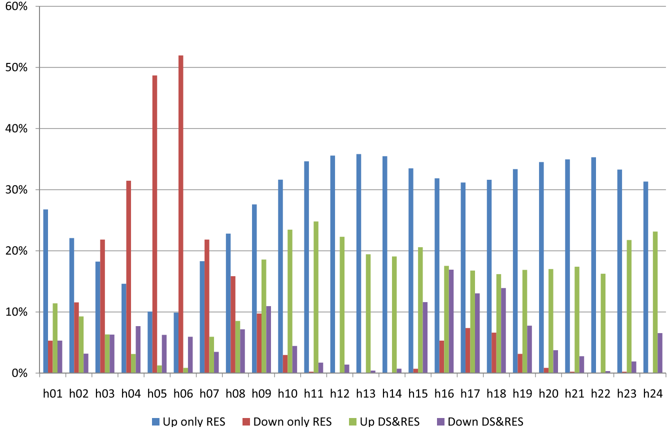
Results: Cost savings

- Demand shifting and demand offering reserve: 4 Mio.$ per year or 10,946$ per day or 0.93% of total operation cost.
- When demand offers only reserves: 4.91 Mio.$ per year or 17,000$ per day or 1.13%.

Case Study in Gran Canaria

Results: Reserves provided by demand

Share of total reserves provided by demands for different settings



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Conclusions and Future Work

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- Adaptations of the electric systems are necessary to integrate intermittent energies and maintain reliability.
- High wind generation capacity normally leads to higher reserve requirements.

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- Adaptations of the electric systems are necessary to integrate intermittent energies and maintain reliability.
- High wind generation capacity normally leads to higher reserve requirements.
- Reserve provided by demand can be an interesting alternative to conventional reserve providers.
- Reserve offered by demand is flexible, reliable and may be more economic.
- Reserve offered by demand interesting for spinning reserve and as well in emergency situations.

Future Work

Future Work

- Simulation of activation of reserves due to wind prediction errors.
- Future work may include probabilistic modeling of the reserve and wind.

Gracias a todos por venir!

Preguntas?