Adequate Regulation Reserve Levels In Systems With Large Wind Integration Using Demand Response

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Introduction
Introduction

Large-scale integration of wind energy
Introduction
Large-scale integration of wind energy

Intermittent Energies

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

Uncertainty in operation:

- Variations in demand.
- Generator outage.
- Variations in wind.
Uncertainty in operation:

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

Reserves necessary to keep the balance between generation and demand.

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

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

Kirby (2003): Larger numbers of individually less reliable responsive loads can provide greater aggregate reliability than fewer large generators.
Model for the UC Problem
Basic Model
Modeling approach for the Unit Commitment
Basic Model
Modeling approach for the Unit Commitment

Cost Minimization

\[ COp_{ante} = \sum_{p,t} \left[ CFix_{t\ uc_p,t} + CVar_{t\ ProdTMin_{p,t\ uc_p,t}} + CVar_{t\ prod_{p,t}} + COn_{t\ on_{p,t}} + CNse_{nse_{p}} \right] \]
Basic Model
Modeling approach for the Unit Commitment

Cost Minimization
\[ COp_{ante} = \sum_{p,t} [\text{CFix}_t \ uc_{p,t} + \text{CVar}_t \ ProdTMin_{p,t} \ uc_{p,t} + \text{CVar}_t \ prod_{p,t} + \text{CON}_t \ on_{p,t} + \text{CNet} \ nse_{p}] \]

s.t.

Demand balance
\[ \text{DemRef}_p - \text{ProdI}_p - nse_p = \sum_t \text{ProdTMin}_{p,t} \ uc_{p,t} + \text{prod}_{p,t} \]

Reserve up/down
\[ \sum_t (\text{ProdTMax}_{p,t} - \text{ProdTMin}_{p,t}) \ uc_{p,t} - \text{prod}_{p,t} \geq \text{RsUp}_p \]
\[ \sum_t \text{prod}_{p,t} \geq \text{RsDo}_p \]

Generation limits min/max
\[ \text{prod}_{p,t} \leq (\text{ProdTMax}_{p,t} - \text{ProdTMin}_{p,t}) \ uc_{p,t} \]

Ramping constraints up/down
\[ \text{prod}_{p,t} - \text{prod}_{p-1,t} \leq \text{ProdTU}_{p,t} \]
\[ \text{prod}_{p-1,t} - \text{prod}_{p,t} \leq \text{ProdTD}_{0,t} \]

Logic coherence for start-up and shutdown ties
\[ \text{uc}_{p,t} - \text{uc}_{p-1,t} = \text{on}_{p,t} - \text{off}_{p,t} \]
Modeling Demand Side Management
Demand Side Management

Definition of DSM
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Definition of DSM

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
\[ dem_p = \text{DemRef}_p + \text{demVar}_{p,\text{up}} - \text{demVar}_{p,\text{do}} \]
Demand balance including demand as variable \( dem_p \)
Limits of shiftable demand
\[ \text{Lim}_{\text{do}} \text{DemRef}_p \geq \text{demVar}_{p,\text{do}} \geq 0 \]
\[ \text{Lim}_{\text{up}} \text{DemRef}_p \geq \text{demVar}_{p,\text{up}} \geq 0 \]
Balance of shiftable demand during day
\[ \sum_p \text{demVar}_{p,\text{up}} = \sum_p \text{demVar}_{p,\text{do}} \]
Demand Side Management
Modeling Demand Shifting

Centralized decision making process
Cost Minimization
s.t.
Variable demand
\[ dem_p = DemRef_p + demVar_{p,up} - demVar_{p,do} \]
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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
\[ \sum_p demVar_{p,up} = \sum_p demVar_{p,do} \]
Reserve up/down
Generation limits min/max
Ramping constraints up/down
Logic coherence for start-up and shutdown ties
Demand Side Management
Modeling Demand for providing Reserve
Demand Side Management
Modeling Demand for providing Reserve

Reserve by demand
Cost Minimization
s.t.
Reserve up/down
\[ \sum_t (ProdTMax_{p,t} - ProdTMin_{p,t}) \cdot uc_{p,t} - prodt_{p,t} + demRES_{p,up} \geq RsUp_p \]
\[ \sum_t prodt_{p,t} - demRES_{p,do} \geq RsDo_p \]
Variable demand
\[ dem_p = DemRef_p + demVar_{p,up} - demVar_{p,do} + demRES_{p,up} - demRES_{p,do} \]
Demand balance including demand as variable \( dem_p \)
Limits of shiftable demand
\[ Lim_{do} DemRef_p \geq demVar_{p,do} + demRES_{p,do} \geq 0 \]
\[ Lim_{up} DemRef_p \geq demVar_{p,up} + demRES_{p,up} \geq 0 \]
Demand Side Management
Modeling Demand for providing Reserve

Reserve by demand
Cost Minimization
s.t.
 Reserve up/down
\[ \sum_t (\text{ProdTMax}_{p,t} - \text{ProdTMin}_{p,t}) \ u_{c,p,t} - \text{prodt}_{p,t} + \text{demRES}_{p,up} \geq \text{RsUp}_{p} \]
\[ \sum_t \text{prodt}_{p,t} - \text{demRES}_{p,do} \geq \text{RsDo}_{p} \]
 Variable demand
\[ \text{dem}_p = \text{DemRef}_p + \text{demVar}_{p,up} - \text{demVar}_{p,do} + \text{demRES}_{p,up} - \text{demRES}_{p,do} \]
 Demand balance including demand as variable \( \text{dem}_p \)
 Limits of shiftable demand
\[ \text{Lim}_{do} \text{DemRef}_p \geq \text{demVar}_{p,do} + \text{demRES}_{p,do} \geq 0 \]
\[ \text{Lim}_{up} \text{DemRef}_p \geq \text{demVar}_{p,up} + \text{demRES}_{p,up} \geq 0 \]
 Balance of shiftable demand during day
 Generation limits min/max
 Ramping constraints up/down
 Logic coherence for start-up and shutdown ties
Case Study in Gran Canaria
Case Study in Gran Canaria

Data for Case Study
Case Study in Gran Canaria

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)
Case Study in Gran Canaria

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
Case Study in Gran Canaria

Results: demand shifting and reserves
Case Study in Gran Canaria
Results: demand shifting and reserves

Demand shifting and reserve offered by demand on the average day

![Graph showing demand shifting and reserve](image-url)
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
Conclusions and Future Work
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Conclusions

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

Conclusions

• 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.
Conclusions and Future Work

Future Work
Conclusions and 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?