Control Power and Variable Renewables

A Glimpse at German Data

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2013-04-19
Enerday / Dresden

Background and motivation

- For frequency stability in AC power systems, load and generation have to be balanced at any moment in time
- Control power is used to stabilize the active power balance integrated power systems at short time scales (seconds … one hour)
- Other names for “control power” (UCTE Operation Handbook) include regulating power (Regelleistung), balancing reserve, reserve power, balancing power, regulation, load following, operating reserve, contingency reserves, or frequency control.
- Policy debates and the literature on “system integration“ of wind and solar power often suggests that variable renewables are a major driver for control power needs
- Information and data are available, but very inaccessible (language, formatting, diverging terminology)

Purpose of this paper and contribution to the literature

1. Provide a **comprehensive overview** of UCTE balancing system and German balancing market – both the control power side and the imbalance settlement side

2. Discuss the **role of variable renewables** (wind and solar power) both as sources of imbalances and as suppliers of control power based on empirical market data

3. Develop **policy recommendations**, based on economic theory and foreign experiences

4. No (analytical, econometrical, numerical) modeling

1. **Fundamentals of control power**
2. Control power
3. Imbalance settlement
4. Policy recommendations

Actors in the balancing system

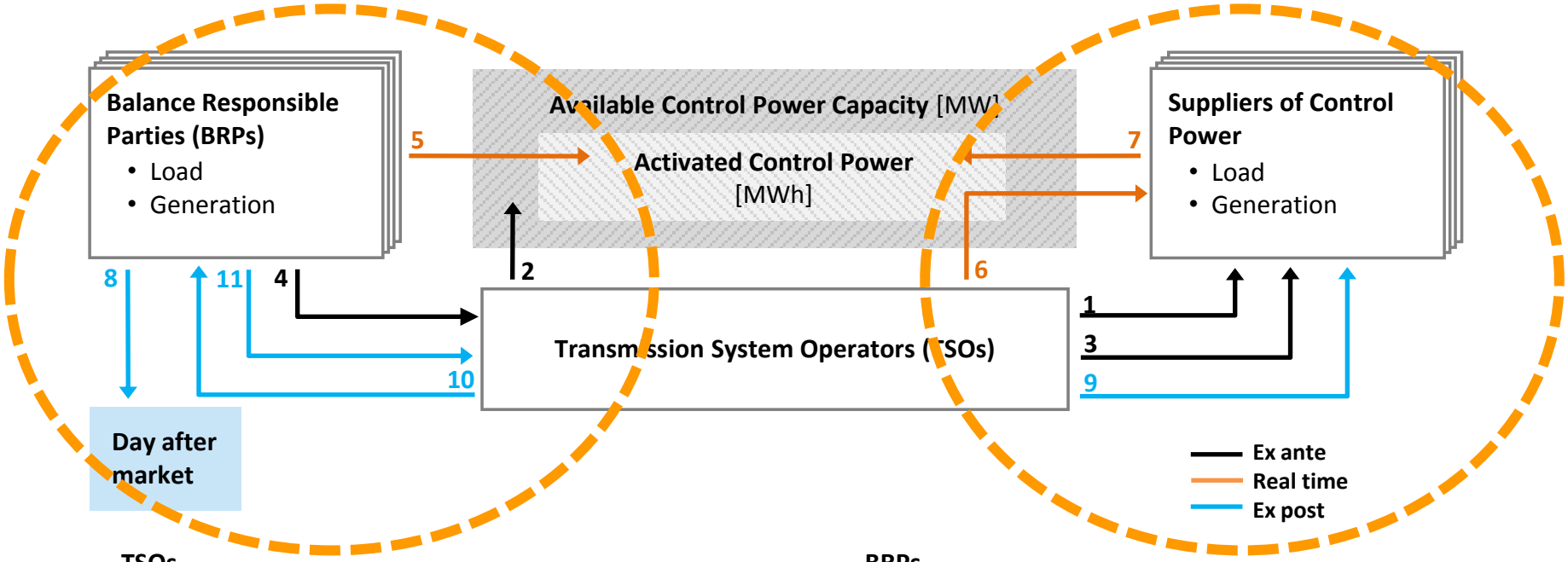
- Transmission system operators (TSOs)
  - operate the transmission network and are responsible to balance supply and demand in their control area (balancing area)
  1. determine the required amount of capacity that has to be reserved as control power
  2. acquire the control power capacity and determine the price paid for capacity and energy
  3. activate the control power in moments of physical imbalance; determine the imbalance price
  4. clear the system financially by charging BRPs according to their imbalance and/or recovering expenses via grid fees

- Balancing responsible parties (BRPs)
  - market entities (generators, industrial loads, sales companies)
  - deliver binding generation and load schedules to the TSOs
  - are financially accountable for deviations from their schedules, pay imbalance price (*Ausgleichsenergiepreis)*

- Suppliers of control power
  - generators and (sometimes) loads
  - reserve positive or negative capacity (*Regelleistung*)
  - supply energy if activated (*Regelarbeit / -energie)*
  - receive a capacity (€/MW) and/or energy payment (€/MWh) for this service (*Leistungs /-arbeitspreis*)

Imbalance settlement system / Imbalance market

Control power market



TSOs

1 Prequalification of control power providers

2 Dimensioning of required capacities $SC^{+/-}$, $TC^{+/-}$

3 Tender (pay as bid) and calculation of merit order lists for activation order of suppliers

6 Activation signal for $SC^{+/-}$, $TC^{+/-}$

9 Energy and capacity payments

10 Calculation of balancing energy expenses for activated control power

BRPs

4 Binding schedules of load and generation

5 Causing control power demand

8 Reduction of accounting imbalances

11 Remuneration of balancing energy expenses (note: in Germany, the capacity charge is socialized and reckoned up in grid fees)

Suppliers of Control Power

7 Supply of $SC^{+/-}$, $TC^{+/-}$

What control power is ….

- an ancillary service to balance the active power supply
- of both the synchronous system (UCTE) and each control area
- both negative (upward) and positive (downward) reserve
- a contingency and operational reserve
- spinning and stand by; manual and automatic reserve (depending on the type)

… and what not…

- a service to balance reactive power supply (voltage support)
- an instrument for congestion management of power lines (re-dispatch, counter-trading)
- (in small island systems the difference between ancillary services is less clear)

1. Fundamentals of control power
2. **Control power**
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Control power types in the UCTE

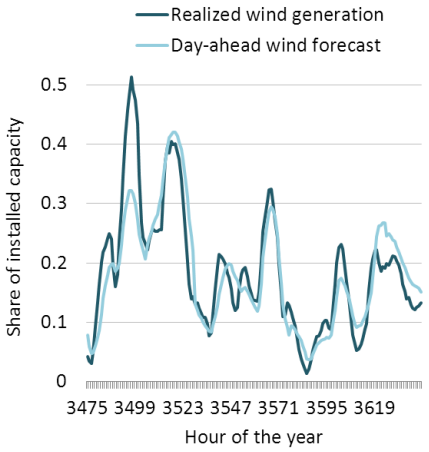
	Primary Control (PC)	Secondary Control (SC)	Tertiary Control (TC) (Minute Reserve)
Response Time	30 s (100%), direct (continuously)	5 min (100%), direct (continuously)	7-15 min (100%), direct or schedule
System	UCTE	Control area	Control area
Control Variable	Frequency deviation from 50 Hz (UCTE system)	Balance of the control area; Frequency deviation	Amount of $SC^{+/-}$ activated
Activation	Based on local frequency measurement	Centralized (TSO); active call through IT	Centralized (TSO); active call through phone / IT
Suppliers (typically)	Synchronized generators, (industrial consumers)	Synchronized generators, stand-by hydro plants, large consumers	Synchronized and fast-starting stand-by generators, large consumers
Reserved Capacity	3000 MW in UCTE (600 MW in Germany)	Decided by TSO (2500 MW in Germany)	Decided by TSO (2500 MW in Germany)

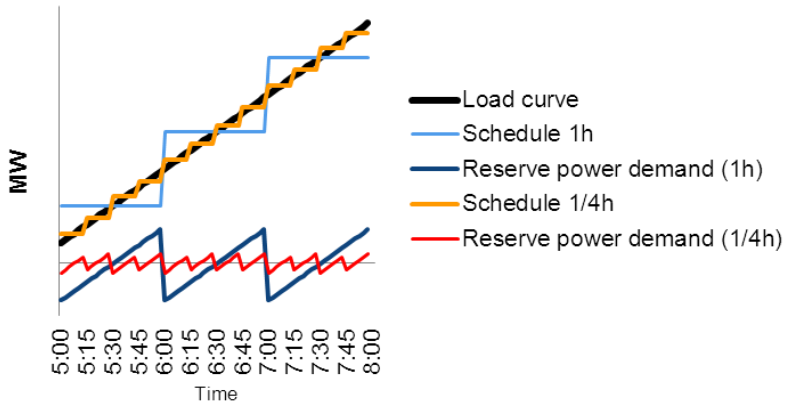
Control power and power markets in Germany

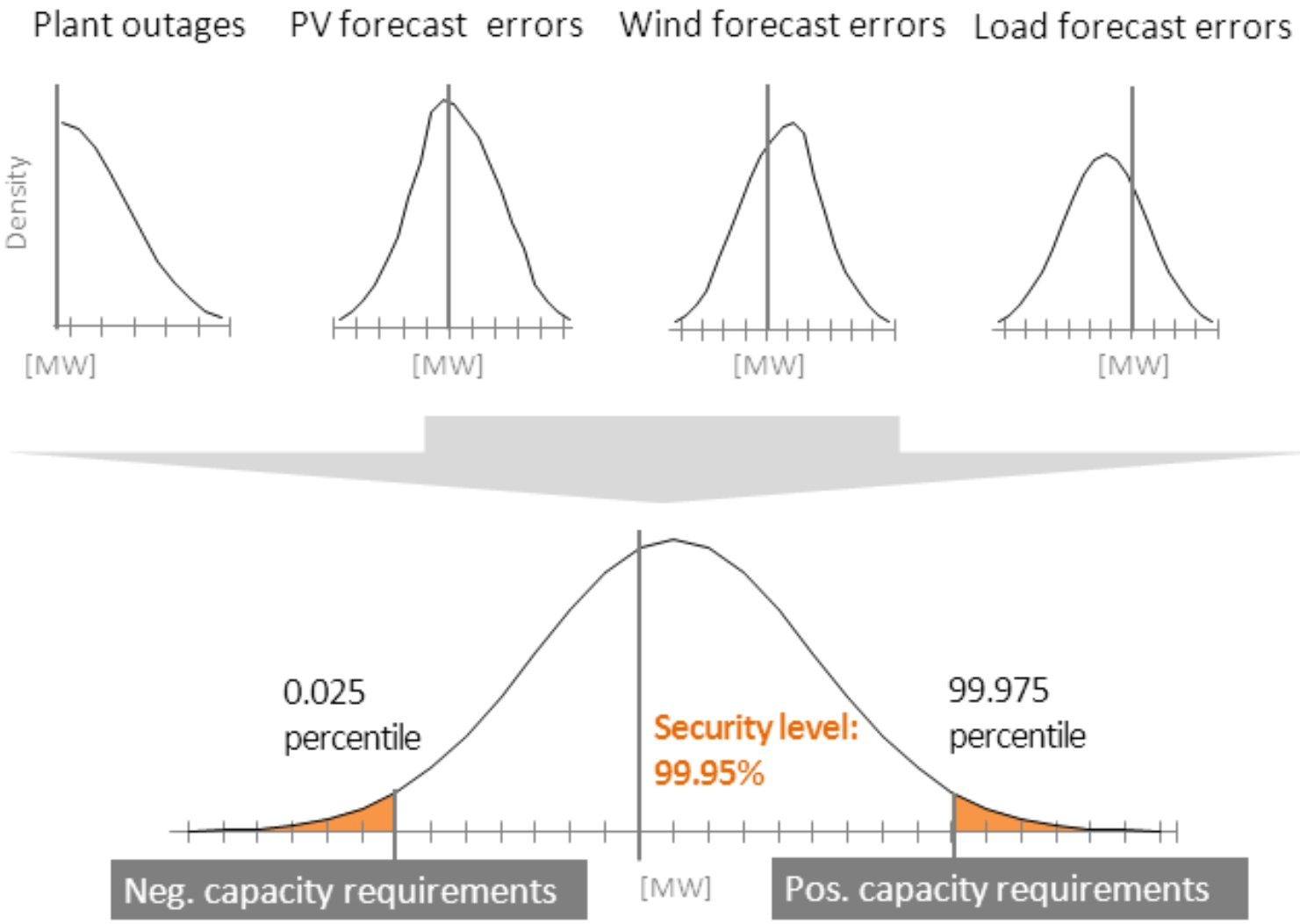
	PC	SC	TC	Intra-day	Day-ahead	Forwards & Futures
Gate closure (time between activation ad delivery / time between last bid and delivery)	30 sec	5 min	7 min	45 min	12-36 h	days … years
Program time unit (“schedule”; time span during which the product is supplied)	- (continuous)	- (continuous)	15 min	15 min / 1 h	1 h … 1 day	day … years
Capacity payment	yes	yes	yes	no	no	no
Energy payment	no	yes	yes	yes	yes	yes
Trading platform	www.regelleistung.net			Power exchange, over the counter (OTC)		
Pricing rule	pay-as-bid auction			price per contract	common clearing price auction (PX); price per contract (OTC)	
Buyer	TSOs			Market actors (consumers, traders, retail companies)		

What causes system imbalances?

	Stochastic	Deterministic
Thermal & Hydro Generation	Unplanned power plant outages	Schedule leaps → **Dobelke's key note**
VRE Generation	Forecast error for wind and solar generation	
Load	Load forecast error	

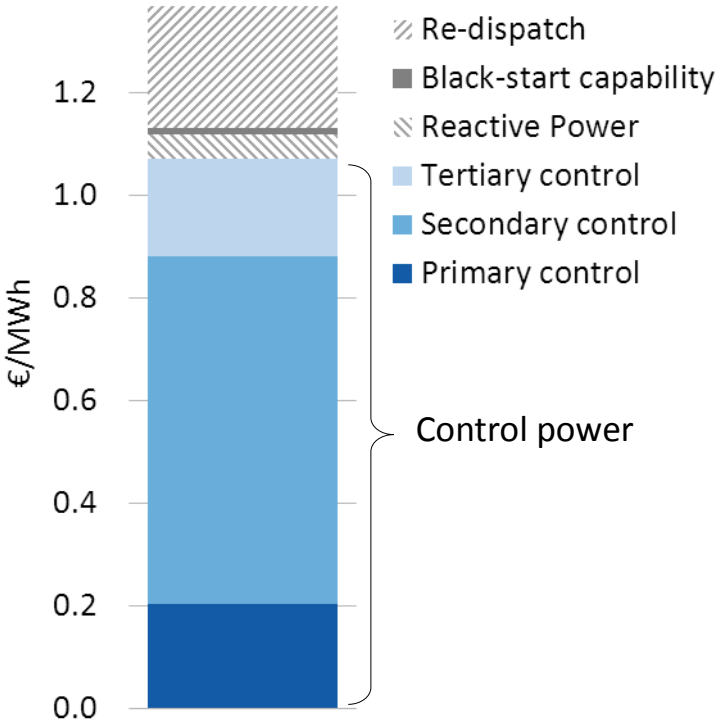


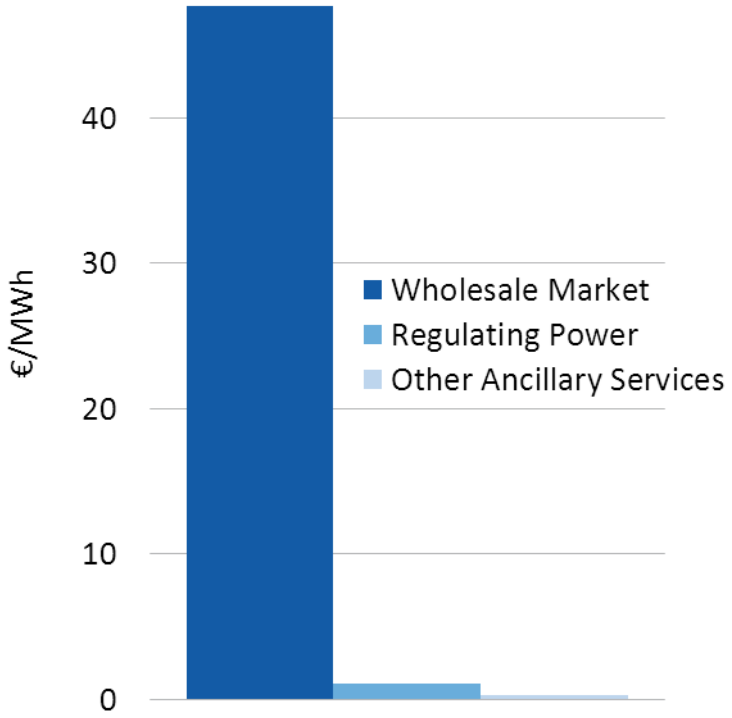



Plant outages
PV forecast errors
Wind forecast errors
Load forecast errors
Density
[MW]
[MW]
[MW]
[MW]
0.025
percentile
Security level:
99.95%
99.975
percentile
Neg. capacity requirements
[MW]
Pos. capacity requirements

A glimpse at market data

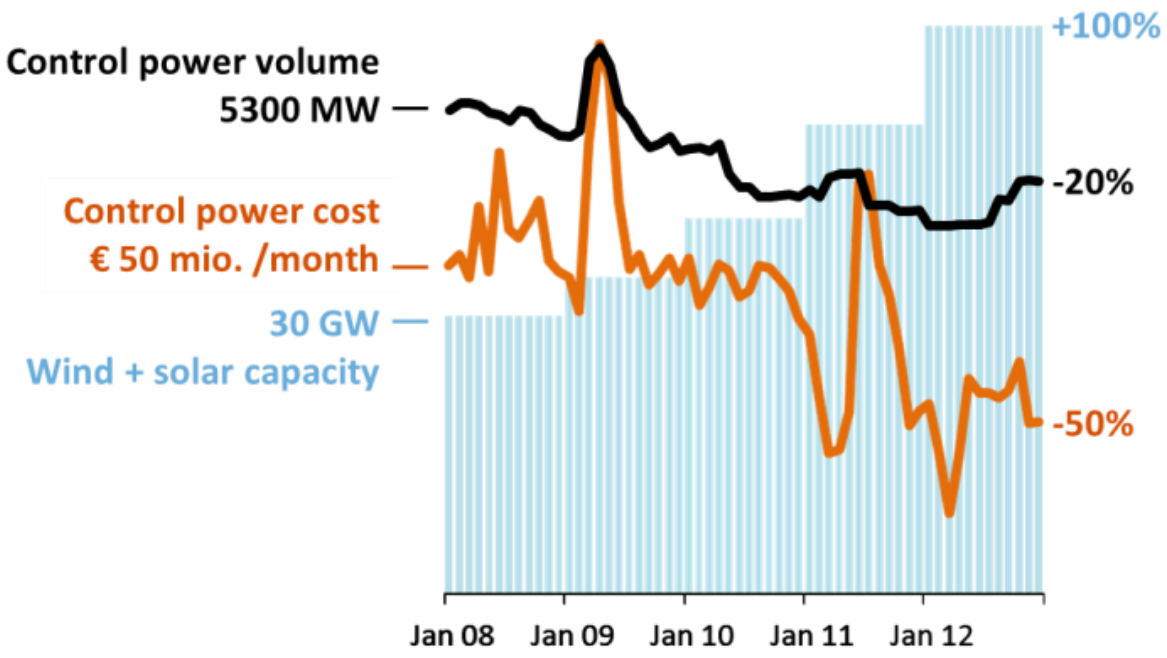
Control power is a niche market





Balancing costs (capacity+energy) are only 3% of the costs of energy on wholesale market price or 0.4% of the household price. Of that, more than 2/3 are capacity costs. Other ancillary services are even smaller.

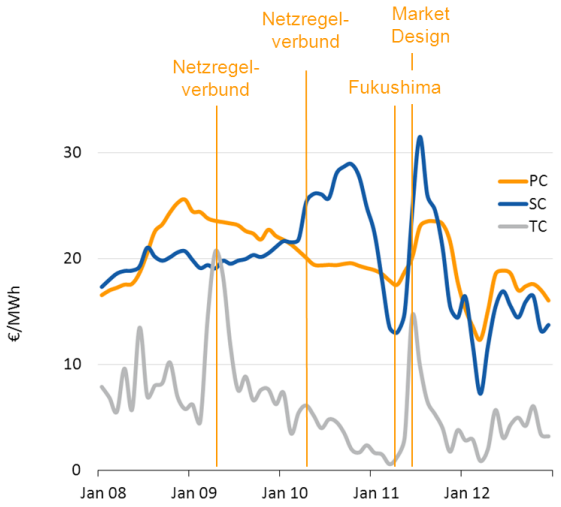
Market development in Germany: summary



While variable renewable capacity doubled in Germany since 2008, TSOs reduced control power requirements by 20% and could reduce costs by 50%.

What happened since 2008?

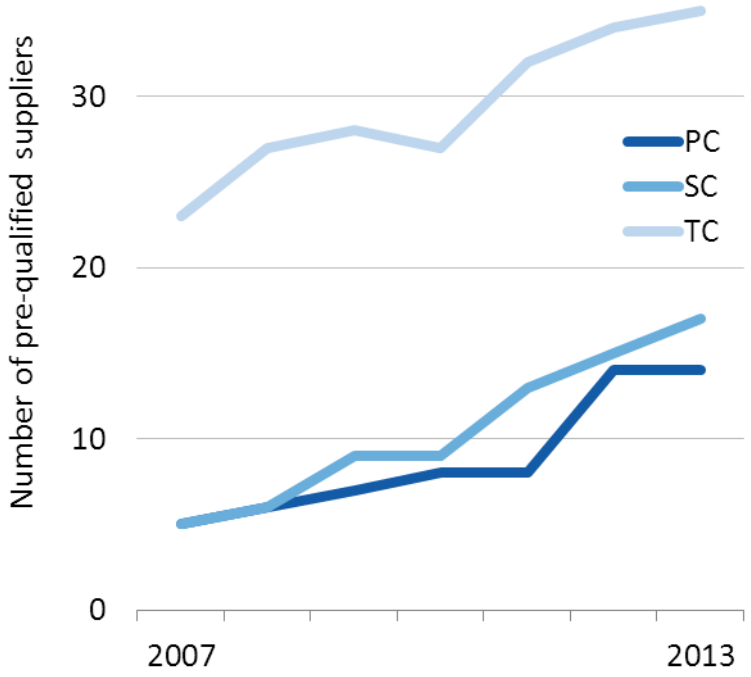
1. TSO control power cooperation (*Netzregelverbund*)
   - Introduced 2009/10 for three/four German TSOs
   - International expansion to Denmark, Czech Republic, Switzerland, Netherlands (IGCC)
2. Variable renewables (wind and solar)
   - Capacity doubled 2008-12
   - Forecasts improved; feed in premium introduced
3. Market design reforms
   - Common market (*regelleistung.net*) in late 2007
   - Broad market design reform in mid 2011
4. Supply shocks
   - Entry of new players including small generators and loads
   - Recession and overcapacity
   - Nuclear phase-out



5. Intraday markets
   - become more liquid
   - shorter gate-closure, 15‘ trading
6. Regulator
   - New rules for dimensioning reserve capacity
   - Investigation on market power abuse

→ significant impact on control power volumes (1,2,6) and (1-6) prices

Massive market entry



Today, unconventional suppliers are active in all sub-markets (consumers, Stadtwerke, aggregators, …).

Präqualifizierte Anbieter je Regelenergieart

Anbieter	PRL	SRL	MRL
Alpiq AG	●		
ArcelorMittal Eisenhüttenstadt GmbH			●
Axpo AG	●		
Axpo Deutschland GmbH			●
BalancePower GmbH			●
BKW FMB Energie AG	●		
Clean Energy Sourcing GmbH			●
Centralschweizerische Kraftwerke AG	●		
CURRENTA GmbH & Co. OHG			●
E.ON Energy Trading SE	●	●	●
E.ON Westfalen Weser Energie-Service GmbH		●	●
EnBW Kraftwerke AG	●	●	●
Energy2market GmbH		●	●
envia Mitteldeutsche Energie AG		●	●
GDF SUEZ Energie Deutschland AG	●	●	●
GETEC Energie AG			●
Hamburg Energie GmbH			●
Infracor GmbH			●
Kraftwerke Mainz Wiesbaden AG		●	●
Lechwerke AG			●
Mark-E AG		●	●
MVV Energie AG			●
Next Kraftwerke GmbH			●
N-ERGIE Kraftwerke GmbH			●
RWE Supply & Trading GmbH	●	●	●
Stadtwerke Düsseldorf AG			●
Stadtwerke Hannover AG	●	●	●
Stadtwerke Leipzig GmbH			●
Stadtwerke München GmbH	●	●	●
Stadtwerke Rosenheim GmbH & Co. KG			●
Statkraft Markets GmbH	●	●	●
Steag GmbH	●	●	●
swb Erzeugung GmbH & Co. KG			●
ThyssenKrupp Steel AG			●
TIWAG - Tiroler Wasserkraft AG		●	●
Trianel GmbH		●	●
Trimet Aluminium AG	●		
Vattenfall Europe Generation AG	●	●	●
VSE AG			●
VW Kraftwerk GmbH			●
Xstrata Zink GmbH		●	

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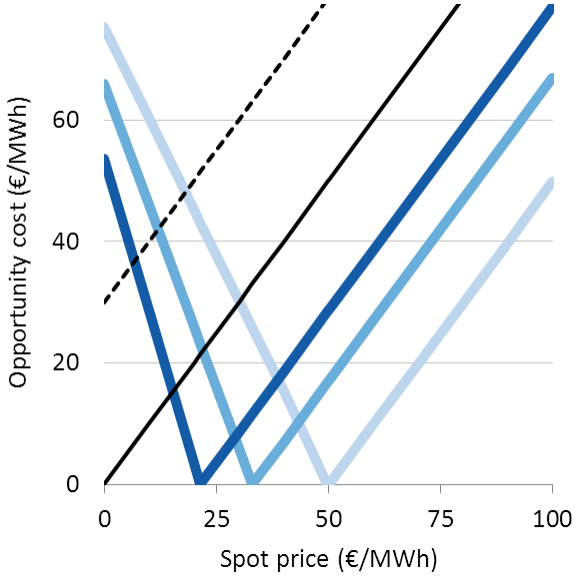
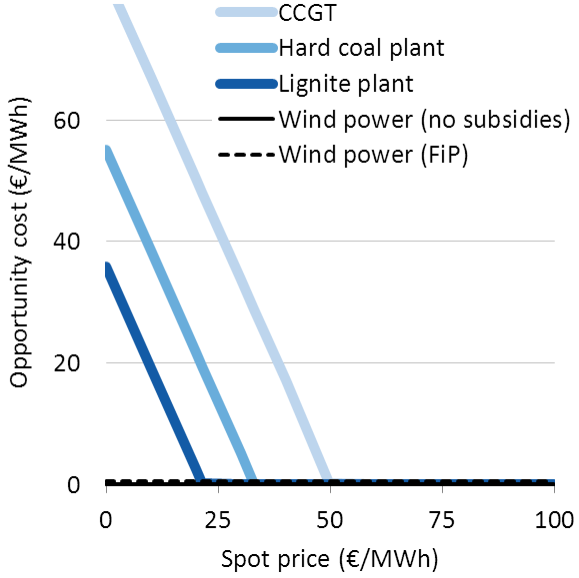
Opportunity costs for capacity reservation



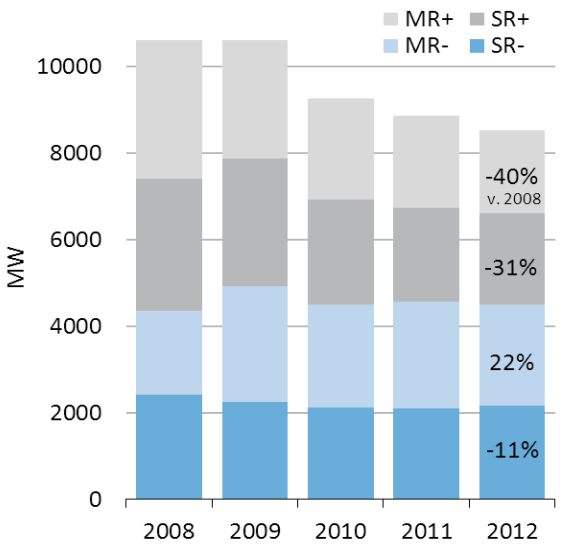
Positive reserves



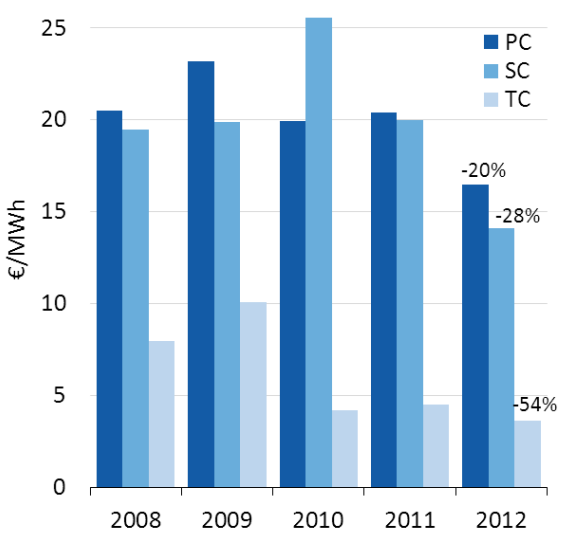
Negative reserves

High margins tend to lead to high opportunity costs for positive reserves, but low opportunity costs for negative reserves. The reality is (much) more complex: portfolios, uncertainty, dynamic constraints, …

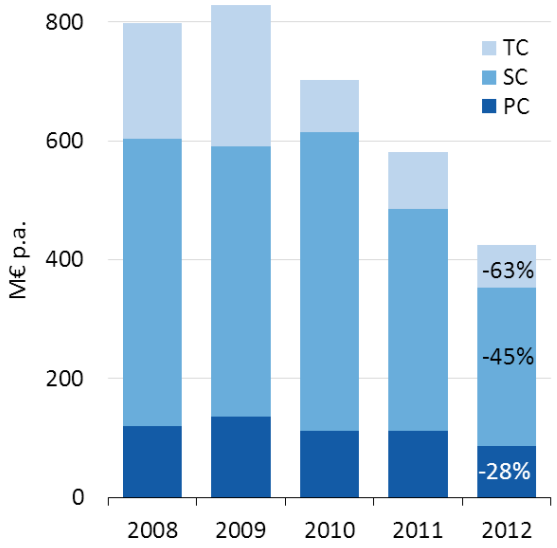
Overall, both volumes and prices decrease, reducing market size by half



Volumes



Prices



Market size

Overall, contracted control power capacity decreased by 20%, driven by lower positive reserves. In conjuncture with decreasing prices this lead to the market size (= total cost) to contract by half.

Wind and solar as suppliers of control power

- Wind and solar would be well suited for providing negative control power
  - Low variable cost
  - Low ramping cost
  - Only when they are producing
- Feed-in premium has removed legal entry barrier in support system
- Entrance barriers in control power markets remain
  - Weekly auction → daily
  - Long program time units (contract ducation) → hourly
  - Use the same platform as for day-ahead spot trading? (EPEX Spot)

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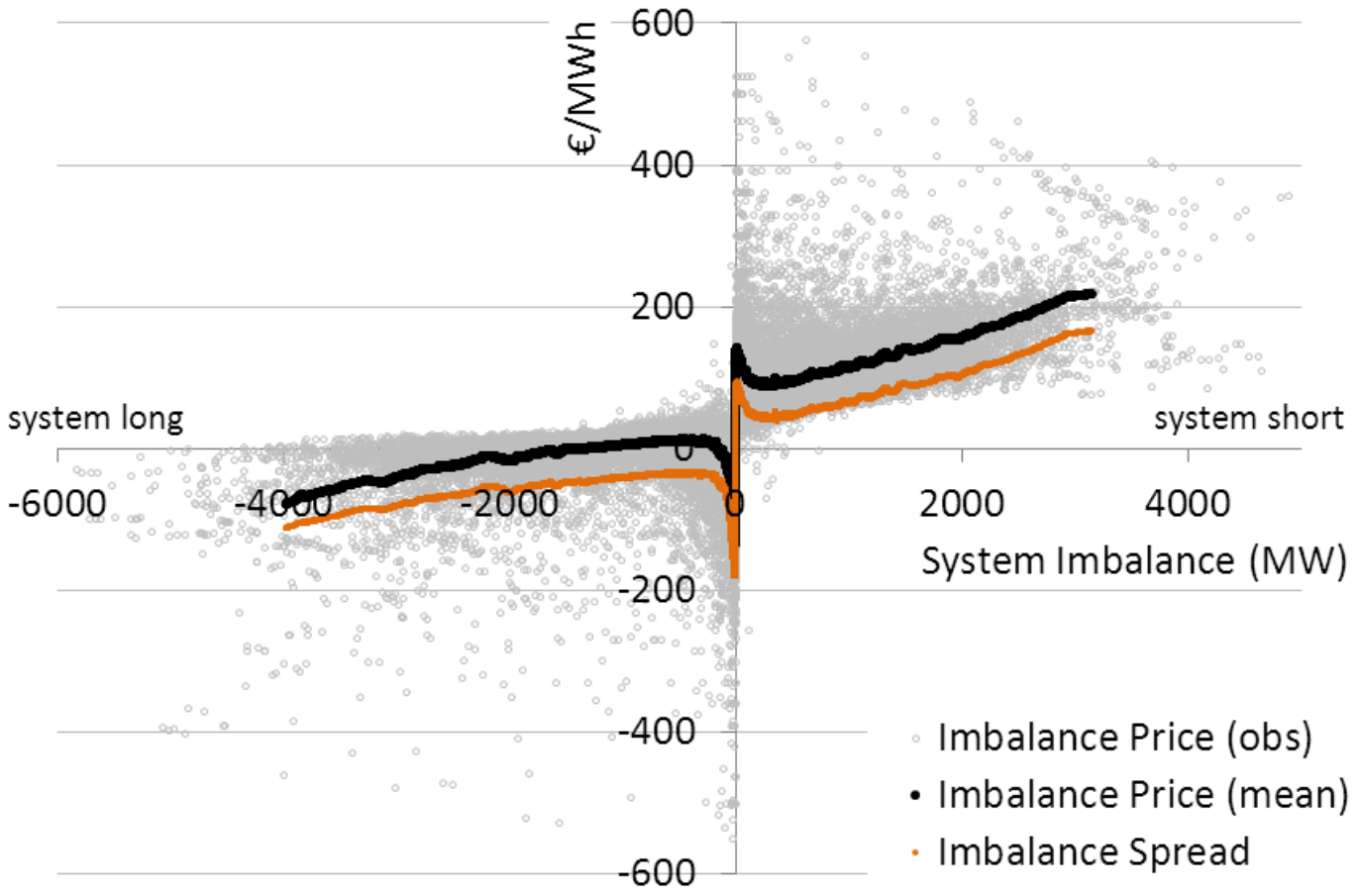
The other side of the medal: imbalance settlement and cost allocation

- Unbalanced BRPs have to pay a price: the imbalance price (€/$MWh_{deviation}$)
- Pricing methanisms are very divers
  - One-price systems (short and long BRPs receive / pay the same price) are economically efficient
  - Two-price systems (punitive mark-ups, prices based on spot prices) are widespred
- Capacity costs are usually allocated to consumers via grid fees

The German imbalance settlement

- Common imbalance price for all control areas since May 2010 (reBAP)
- Settled in intervals of 15 min
- Imbalance price is calculated as the average price of control energy in that interval, does not include capacity costs
- Settlement takes several months (FRA, UK, Benelux < one hour)
- Day-after trading (netting) possible (done to reduce risk)
- Total costs of activating control power: € 300/200 million (2011/12), <30% of total costs
- Cost for capacity reservation (70% of total cost) is allocated to all consumers via grid fees

German imbalance prices and spreads



German imbalance prices and spreads (2)

	Average	System long (60% of all hours)	System short (40% of all hours)	System very long (<-2000MW) (4% of all hours)	System very short (>2000MW) (2% of all hours)
Imbalance price*	40 €/MWh	-4 €/MWh	109 €/MWh	-32 €/MWh	186 €/MWh
Day-ahead price*	47 €/MWh	46 €/MWh	48 €/MWh	41 €/MWh	52 €/MWh
Imbalance spread* (penalty for short BRP)	-7 €/MWh	-50 €/MWh	61 €/MWh	-73 €/MWh	134 €/MWh

*Time-weighted average.

Efficient price signals for BRPs

- Regulators and TSOs view imbalance settlement mainly as a cost allocation mechanism
- However, the imbalance price has an important allocative function: it is the incentive for BRPs for balancing their portfolios
- In economic equilibrium, it reflects both the marginal costs of providing control power and the marginal costs of improving forecasts
- Therefore, the imbalance price should to be a *marginal price* and *include capacity costs*

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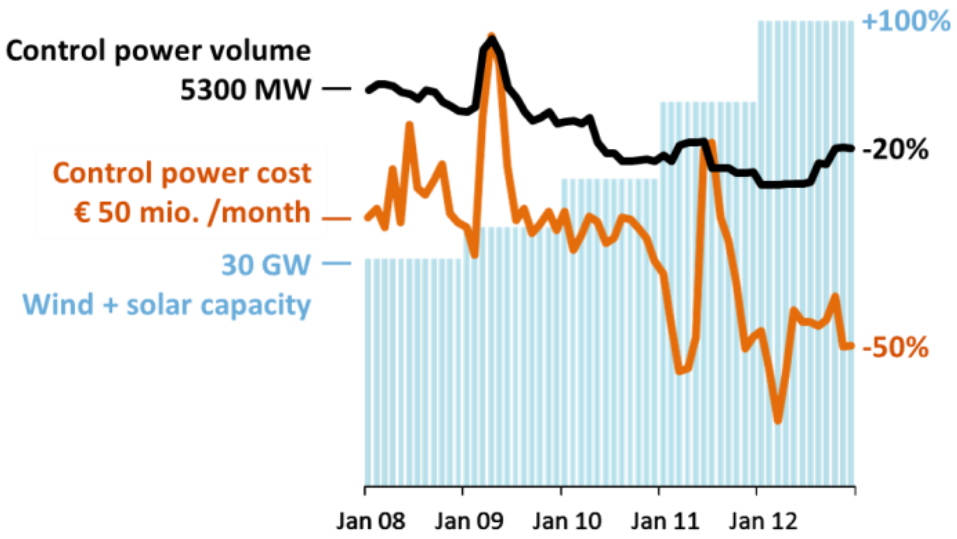
Conclusions: wind & solar market integration

- Variable renewables increase the need for both capacity reservation and utilization
- However, there are many other factors that drive balancing needs and costs
- Empirically, other factors have dominated in Germany during the last years
- → at moderate penetration rates, control power and short-term balancing does not seem to be a major issue for wind and solar market integration



Policy recommendations: control power markets

1. Tender capacities daily (today weekly)
2. Reduce contract duration to hours (today blocks of four hours or peak/off-peak)
3. Marginal pricing (today pay-as-bid)
4. Smart buyer model: common auction for PC/SC/TC (today separate auctions) → US
5. Dynamic and price-elastic reserve dimensioning (today static and price-inelastic) → CH

Policy recommendations: imbalance settlement

1. The German imbalance price should be marginal (today average)
2. The price should also reflect the costs of capacity (today only energy costs).
   (Capacity reservation is about two thirds of total costs.)
3. Prices should be published within one hour (today this takes months).
   (This would provide a price signal to BRPs for passive balancing.)

Full paper prints are available.

Paper is currently under review at *Energy Policy*.

Any comments are highly welcome!

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