Intermittent power generation: Market implications

IEEE Workshop

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Agenda

1. Introduction
2. Some issues on the power system level
3. Other issues on the power plant level
4. Conclusion
1) Introduction

- The question addressed here is: What are the consequences for the power markets of a large share of intermittent power generation (i.e. the direct consequences of the intermittent character, irrespective of the underlying technology)

- Focus on the European markets

- No pretention to be exhaustive

- But the attempt to be objective
1) Introduction: Capacity mix in EU (2010)

- Gas 24% (212,131 MW)
- Coal 26% (231,050 MW)
- Nuclear 15% (127,383 MW)
- Large Hydro 14% (120,578 MW)
- Wind 10% (84,278 MW)
- PV 3% (25,300 MW)
- Biomass 1% (5,851 MW)
- Small Hydro 1% (4,843 MW)
- Fuel oil 6% (54,735 MW)
- Peat 0% (2,030 MW)
- Waste 0% (3,703 MW)
- CSP 0% (435 MW)
- Geothermal 0% (1,466 MW)
- Tidal & wave 0% (245 MW)

Source: EWEA annual statistics
1) Introduction: New installed capacity in EU during the last 15 years

Source: EWEA annual statistics
1) Introduction: New installed capacity in EU in 2010

- Gas: 51% (28,280 MW)
- Coal: 7% (4,056 MW)
- Wind: 17% (9,295 MW)
- PV: 22% (12,000 MW)
- Peat: 0% (200 MW)
- Waste: 0% (149 MW)
- Nuclear: 0% (145 MW)
- Biomass: 1% (573 MW)
- CSP: 1% (405 MW)
- Small Hydro: 0% (25 MW)
- Large Hydro: 1% (208 MW)

Source: EWEA annual statistics
1) An example: Share of the intermittent power generation over a year

Eon control Area, 2008
1) Introduction: Sum up

- In the last 10 years, the new installed generation capacities were mainly gas power plants and solar or wind power plants.

- The capacity share of the intermittent power generation in EU is significant today, about 15%, i.e. 120 GW. For comparison, it corresponds to about 10 times the maximum load in Switzerland.

- Note: Generation capacity is not generated energy. The presentation focuses on capacity as it is the fundamental challenge regarding intermittent power generation.
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2) Some issues at the power system level

- Forecast errors
- Production variability

Flexibility in the power system is needed

- How much does flexibility cost?
- Who does bear these costs?
- Who does invest?
- What are the market rules?
2) The concept of residual load

- Residual load = Load – Generation of intermittent power plants
  = Load to be covered by the conventional power plants

- The math:
  \[ E_{\text{Residual Load}} = E_{\text{Load}} - E_{\text{Intermittent}} \]
  \[ \sigma_{\text{Residual Load}} = \sqrt{\sigma_{\text{Load}}^2 + \sigma_{\text{Intermittent}}^2 - 2\rho \sigma_{\text{Load}} \sigma_{\text{Intermittent}}} \]

- Two consequences:
  - The load level to be covered by the conventional power plant will diminish
  - The variability of the load to be covered by the conventional is likely to increase. (low correlation factor \( \rho \) between load and intermittent power generation, except for solar power)
2) The concept of residual load, an example

Source: Fraunhofer Institut, IWES, 2009
2) Some issues at the power system level

1. The **forecast errors** must be reduced as far as possible
   → A lot of confusion in the concept

2. The load factor of the conventional power plants will diminish
   → **Fixed costs recovery** of the conventional power plants?

3. The variability of the power to be supplied by the conventional power plants will increase
   → How to **increase the flexibility** of the power system?

4. **Market rules** and **Cost allocation** of the balancing energy
   → How to design a consistent system?
2.1) Forecasting of the production of intermittent power generation

- The forecasting error is diminishing thanks to the introduction of new forecasting techniques

- Example for the wind power generation:

![Wind forecast errors. (Source: Red Eléctrica de España.)](image)
2.1) Forecasting of the production of intermittent power generation

- Be careful, the forecasting error is expressed in percent:
  - Balancing a 10% forecast error in the case of an intermittent generation share of 5% is likely to be manageable
  - Balancing a 5% forecast error in the case of an intermittent generation share of 50% is likely to be challenging

- The forecast error depends on the time of the forecast

- The power plants used to balance a 10 hours ahead forecast will not be the same as the power plants used to balance a hour ahead forecast, due to their different ramping time.
2.1) Forecasting of the production of intermittent power generation

- The energy produced by intermittent power plants remains variable.

- Even assuming no forecasting error, the conventional power plants or the demand must adapt to follow the production variations of the intermittent power generation.
2.1) Forecasting of the production of intermittent power generation

- Good news: Smoothing effect when considering the aggregated production over a large region (continent)

![Graph showing Windy days in December 2000 with data from Netherlands, Benelux, France, Germany, and UCTE.]
2.2) Fixed costs recovery: One of the most challenging market design issue

- The fixed cost recovery issue (also called the missing money issue) has long been identified as one of the main challenges when designing power markets.

- Few experiences today as it is a long term issue, per nature

- In theory, two approaches:
  - Energy market only (without a cap on the energy price)
  - Energy and capacity markets

- Due to practical reasons (political unacceptability of prices spikes, risk aversion of investors), a capacity market will be required in the future

- Two basic issues:
  - How much capacity does a TSO daily need? → Capacity credit concept
  - How is the capacity price determined? → Market rules
2.2) Fixed cost recovery: Capacity credit concept

- Calculating the capacity requirements becomes more dynamic (not only for yearly capacity adequacy assessment, but also on a daily basis)

- Two calculation methods based on estimating the risk of a power deficit
  - Equivalent firm capacity
  - Load carrying capability

- "Paradox": For a given power system, increasing the intermittent power generation share results in a reduction of its capacity credit expressed in percentage of the intermittent installed capacity. The reason is that the possibility of very low generation becomes more important on the system scale.
2.2) Some figures about the capacity credit of wind power

- Aggregating wind energy production strongly increases wind power’s contribution to firm power capacity in the system.

- Harmonized method for calculating capacity credit of wind power for system adequacy forecasts should be established.

Source: Trade Wind

(*) FR, LU, BE, NL, DE, CH, AT
2.2) Fixed cost recovery: Capacity markets

- Possible buyers of capacity:
  - The TSO purchases centrally the needed capacity
  - The load serving entities (LSE), obliged to purchase capacity in accordance to their load

- Possible sellers of capacity:
  - The generators
  - The load serving entities (LSE)

- Different pricing mechanisms
  - **Fixed payment** combined with a price cap: The capacity payment mechanism distributes the income that generators would have in a small number of hours with very high prices over all the periods of operation. This gives more revenue certainty for the investors.
  - **Regulated quantity**: The capacity is calculated by the TSO and is set fixed
  - **Regulated price**: The TSO determines a demand curve for the capacity
  - **Competitive market**: The LSE purchases a certain level of capacity and install a load limiting device. The price of capacity represents the consumers’ willingness to pay uninterrupted supply.
2.2) Fixed cost recovery: Capacity markets, some issues

- A capacity product is basically like a call option
  - The rules to set the premium and the strike price must be carefully designed

- The capacity market is related to the power system reliability
  - The TSO is clearly involved and clear market rules are necessary

- Capacity market may undermine the demand side participation
  - The capacity market should enable LSE to bid.

- When calculating the needed generation capacity, the TSO has to assess the corresponding transmission capacity
  - The implications for the calculation of the reliability margin of transmission capacity are to be considered

- A capacity market means a reduction of the capacity available for energy trade.
  - Market power and interaction with other markets are issues to consider when designing capacity markets
2.2) Fixed costs recovery: In the long term, the merit order curve will be affected

- The merit order curve is likely to become more nonlinear in the future: Low marginal costs must run generators and peakers earning revenue in the capacity markets

- Consequences: a higher power price volatility and more frequent price spikes
2.3) Increasing the flexibility

- Increasing the flexibility of the markets and the role of the intra day market
- Demand side management
- Markets for ancillary services (regulation)
2.3) Increasing the flexibility: Intraday, balancing and transmission capacity markets must be integrated
2.4) Market rule issues

- The current (EU) priority scheme for the injection of the intermittent power generation results in negative prices (EEX: 60 hours in 2009) and suboptimal economic outcome.

- With an increase of the intermittent power generation, the current priority of dispatch scheme in the EU will have to be reviewed.

- Cost allocation of the balancing energy: Currently in the EU the intermittent power generators do not bear the costs they cause regarding balancing energy (these costs are transferred to the network tariff).

- More costs transparency is necessary to foster a more efficient power market.
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3) Some issues related to individual power plants

- **Investment:** The project valuation requires appropriate techniques to take the uncertainty and the different revenue sources into account.

- **Operation:** The increasing flexibility requirements imply technical measures and economical consideration to optimize the power plant operation.
3.1) Investment: Valuation of power plant projects

- Investors are currently making big bets when considering conventional power plant projects due to the high uncertainty of the future and the complexity of the power markets.

- Intermittent power generation is contributing directly or indirectly to this uncertainty:
  - The energy to be supplied by the conventional power plant is likely to diminish
    → How much will be the expected operating hours (with positive contribution)
  - New electricity products will be necessary to cope with the increasing share of intermittent power generation
    → How will these products be designed and priced?
  - The market rules are likely to evolve as the share of the intermittent power generation increases
    → What are the possible rule changes and their consequences?
3.1) Investment: Valuation of power plant projects

- Input data, assumptions
- Price scenarios (electricity products, fuel, CO2, ..) taking the correlation of the different parameters into account
- Assessment of the optimal bidding strategy regarding the different electricity products
- Sensitivity analysis of critical assumptions
- Stochastic valuation, risk assessment
- The right level of detail for the appropriate time frame (i.e. long term)
3.2) Increasing flexibility requirement has operational implications

- Stability & Control
- Wear
- Maintenance planing
- Efficiency reduction in case of part load
3.2) increasing flexibility requirement has operational implications

- Unit commitment: In which market to bid?
  - Energy markets (forward/future, day ahead, intraday)
  - Ancillary services market
  - Capacity market

- Daily stop/start sequence → Wear, higher maintenance costs, higher fuel consumption during the transition period

- Existing power plants may have to be refurbished to increase their flexibility

- Control issue: The TSO should control with appropriate techniques that the generators comply with their commitment regarding ancillary services and capacity, because these products must be available but are not necessary called.
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4) Conclusions

- Intermittent power generation is primarily an energy resource and not a capacity resource.

- Considering the whole system is necessary to find the economical and technical optimum.

- With the increasing share of intermittent power generation, some market rules will have to be reviewed, including the regulation fostering the intermittent power generation. Intermittent power generation will have to be more subjected to the market forces.

- Conventional controllable power plants must be rewarded for capacity.