Grid integration of Variable Generation – best practices from international experience

Task 25: Design and Operation of Energy Systems with Large Amounts of Variable Generation

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Contents

• Lessons learned from challenges of wind and solar
  – Balancing: unlock flexibility through system operation practices
  – Grid infrastructure – connect and transport electricity
  – Using the grid support capabilities of wind and solar

• Long term: Changing the optimal generation mix
IEA Wind Task 25 –
Best practice of VG integration

- Started in 2006, now 17 countries + WindEurope participate to provide an international forum for exchange of knowledge
- State-of-the-art: review and analyze the results so far (Jan 2019)
- Formulate guidelines- Recommended Practices for Wind/PV Integration Studies (RP Ed.2 July 2018)
- Fact sheets and integration study time series (wind, solar, load...)

https://community.ieawind.org/task25
Experience from Wind and Solar Integration is Growing

- First 10-20% share of wind:
  - Updated information from online production and forecasts.
  - Possibility to curtail in critical situations.
  - Grid connection codes

[Map showing wind and solar energy distribution across Europe]
Using short term forecasting

- Wind and solar taken in the day-ahead unit commitment and dispatch, with smoothing impact
  - Energy traded at markets with forecasting
- Flexibility during operating hour – allocating reserves
  - Forecast errors determine the need for operating reserve – combining uncertainty from load, wind, solar and generation

Ignoring that events not correlated
Experience with grid codes:

- Requiring fault-ride-through, and setting frequency/voltage limits when trip-off

  - Low voltages due to short-circuits may lead to the disconnection of large shares of generation - modern turbines comply with this
  - Australia case, for weak systems need to require many consecutive faults
  - Germany, California case solar: setting of inverters to trip off at high frequency may also create an issue of losing too much generation instantly
Experience from Wind and Solar Integration for higher shares

• Sharing balancing
• Enabling also wind and solar in grid support
• Generation flexibility and adequacy
• Transmission a key enabler, with regional planning efforts
  – Local markets, PV and storages emerging as another solution
Trade with neighbouring areas will help balancing more than wind adds

- Sharing balancing task with neighbouring system operators in Germany has resulted in reduction of use of frequency control, while wind and solar have increased.

- Denmark integration of close to 50% wind share is based on using Nordic hydro power system flexibility.

Figure 13: Total activated German Secondary Reserves (or aPRR) per year marked with events considered in this paper.

Rena Kuwahata, Peter Merk, WIW17
Using flexibility of thermal plants. Case Denmark.

- Changing the tariffs of smaller CHP plants to operate according to market prices
- Retrofitting the larger thermal plants

**HIGH FLEXIBILITY OF POWER PLANTS**

Operational range: 10–100%

Regulating rate: 3-4% per minute
High share of VRE operation already well before 50% yearly share

- Instant 100% will be faced already when less than 25% on average

Example DK 2017 43% on average
First time in 2015 and several times since then, all central power plants shut down. The necessary system support from:

- HVDC link: 700 MW Denmark-Norway
- synchronous compensators 4 in DK-W and 2 in DK-E
- and small scale power plants

**Pushing the limits: Denmark operating the system without central power plants**

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2nd September 2015 without central plants
- hourly dispatch 31 August – 6 September 2015

Wednesday 2nd September: no primary plants in operation

Monday Tuesday Wednesday Thursday Friday Saturday Sunday
Curtailments are a signal of lack of flexibility

- Delays of transmission: Italy and Texas – diminished after grid build out. Germany, still an issue
- Inflexibilities of coal power plants and tariffs: China

Source: Prof Yasuda, Kyoto University

Denmark and Spain: market operation of wind power plants offering down-regulation (not in the graphs)
Operational practices: market design to enable wind integration

• Enabling wind power plants to bid their flexibility to the markets
• With extra gains from balancing products
Enabling system services from wind and solar

- Asking for capabilities in grid codes, and paying for services of system support if needed/used

![Figure 12: delta control mode – denoted with spinning reserve (Energinet.dk, 2010)](image)

![Figure 13: active power setpoint as a function of frequency deviation (ENTSO-E, 2012)](image)
Use wind power plants at AGC when otherwise curtailed

- Wind power plant in Xcel/PSCO is first manually block curtailed and then put on AGC regulation.

- Resulting area control error is shown in yellow.
Experience: Wind power frequency response is fast and high quality

- ERCOT in Texas:
  - fast response of WPPs reduce the overall need for automatically activated frequency support services
- California report showing responses from PV better than conventional generators

Source: Julia Matevosjana, ERCOT

https://www.caiso.com/Documents/UsingRenewablesToOperateLow-CarbonGrid.pdf
Long term planning for grid adequacy

• Transmission planning – towards regional planning

Source: http://www.nrel.gov/analysis/re_futures/

Source TYNDP (ENTSO-E, 2018)
Challenge- conventional power plant retirement

- Total operating time reduces, but capacity still needed
  - Challenges differ for high-growth systems and where load growth no longer substantial

(Source: Amprion)
Towards higher shares of wind and solar energy

- The time of base load power plants is over
  - Less and less time operating (full load hours), resulting in costs/MWh getting high
- The time of flexible power plants is here
  - producing less than 5000 hours per year, much of that time at part load operation
- Beware of stranded costs when investing in conventional power plants

Case North Europe
20 → 60 % share of wind and solar

40 % share of wind and solar

60 % share of mainly wind

60 % share of wind and solar

< 1000 h 1000 - 6500 h > 6500 h
Market challenge: revenue sufficiency

- Due to 0 marginal cost renewables
- Due to flexible loads
- Stakeholder changes
- Can P2X loads change the picture?
  - If timing when wind/PV available
- Storage may be an option
Market income for revenue sufficiency

- Larger market area – keeping prices up
  - less correlated wind power production
- Faster markets – balancing costs down
  - Improved load/net load following dispatch
- Frequency control from wind and solar
  - where surplus energy /very low prices, wind/PV can operate part load and offer fast up- and down-regulation
  - Often this becomes cost effective at larger (>20%) shares of wind and solar
Transition towards renewable future means adaptation

Integration challenge is easier if

- variable generation is built dispersed to larger area and including wind and solar – smoothing

- **power system operation** enables aggregation benefits from larger area: strong transmission/distribution grid and sharing balancing

- there is **flexibility** in the generation fleet – and in demand

Adaptation will greatly reduce the costs

- From cost of integration to cost of inflexibility
Opportunities: development happening helping renewables

• Load transition: changing the fixed load paradigm
  – Digitalisation, home appliances, prosumers
  – Energy system coupling, decarbonisation, electrification bringing new type of demand

• Decentralisation and Smart grids: local markets, DSO role

• Inverter controls: rapid responses, synchronous machine characteristics – grid forming converters enabling wind and solar to be the backbone of future 100% renewable grids
Balancing and flexibility – using more of the solutions we know

VIBREs – and loads and electrical storage can provide the system support services provided by generators today
Thank You!!

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