A REVIEW OF FLEXIBILITY OPTIONS IN AN INTEGRATED ENERGY SYSTEM

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Abstract

Increasing share of variable renewable energy (VRE) is creating various problems for energy systems operation and planning due to its variability and intermittency. Flexibility options are essential tools for future energy systems. In this study, different flexibility options have reviewed with technical, economical and sociological aspect.

Motivation

- VRE share has rapidly increased from %8.6 to %46 last 17 years.
- VRE highly depends on weather → **Variability** ↑ **Intermittency** ↑

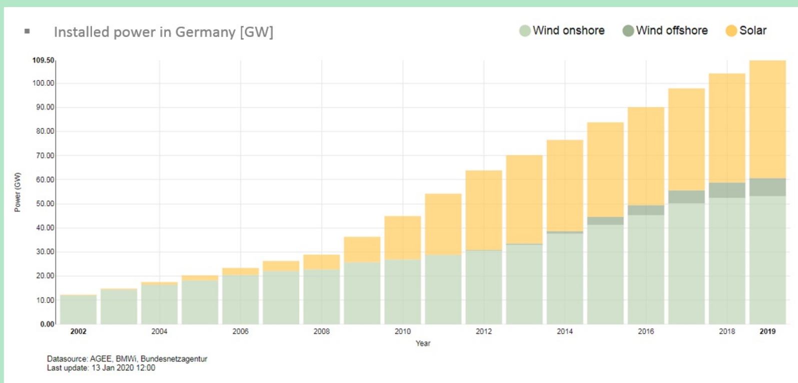

Fig. 1: VRE Share for last 17 years[1]

- Mismatch caused by forecasting is getting challenging

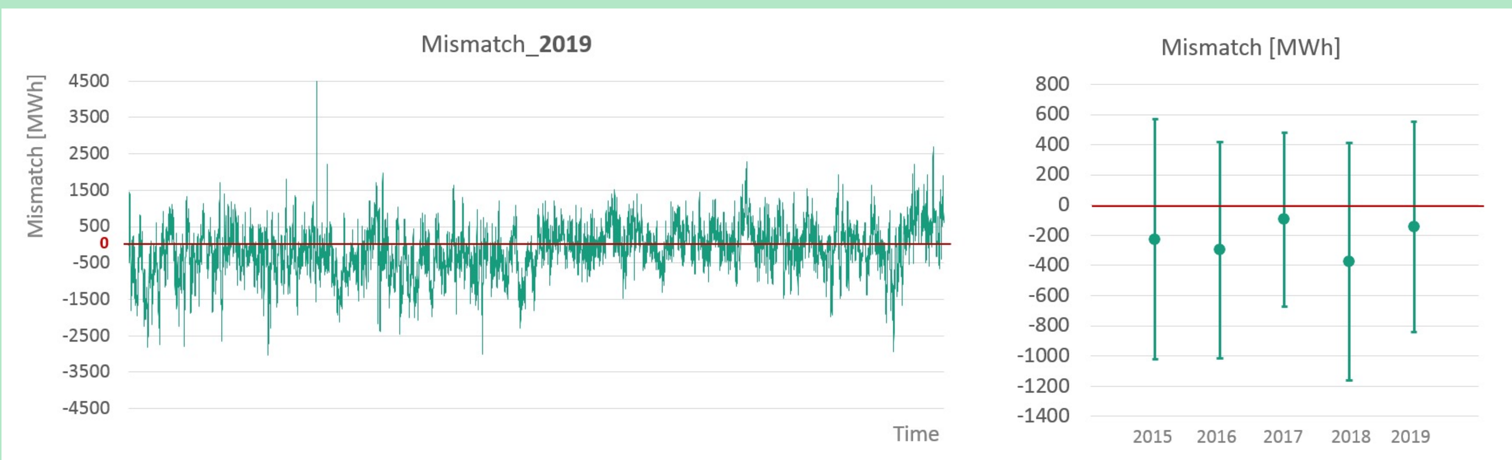

Fig. 2 : Mismatch of 2019 (left) and Average mismatch from 2015 to 2019 (right).
Source : SMARD, Time step : 15 minutes, Data : Solar, Onshore wind, Offshore wind, Pre-treatment : if any data is missing in any category, the corresponding time step is totally excluded

$$\text{Mismatch} = \Delta E_{gen.}\ (\text{Forecasted generation}) - (\text{actual generation}) + \Delta E_{dem.}\ (\text{Forecasted demand}) - (\text{actual demand})$$

Background : Flexibility Options

- **Definition**[2]

Flexibility is the ability of a power system to cope with variability and uncertainty in both generation and demand, while maintaining a satisfactory level of reliability at a reasonable cost, over different time horizons.

- **Flexibility features**
  - Short reaction time
  - Wide operating range
  - Start up capability
  - Low fixed cost low variable cost
  - Long duration

- **Signs of inflexibility**[3]
  - Area balance violations
  - Significant Renewable curtailment
  - Negative market prices and price volatility

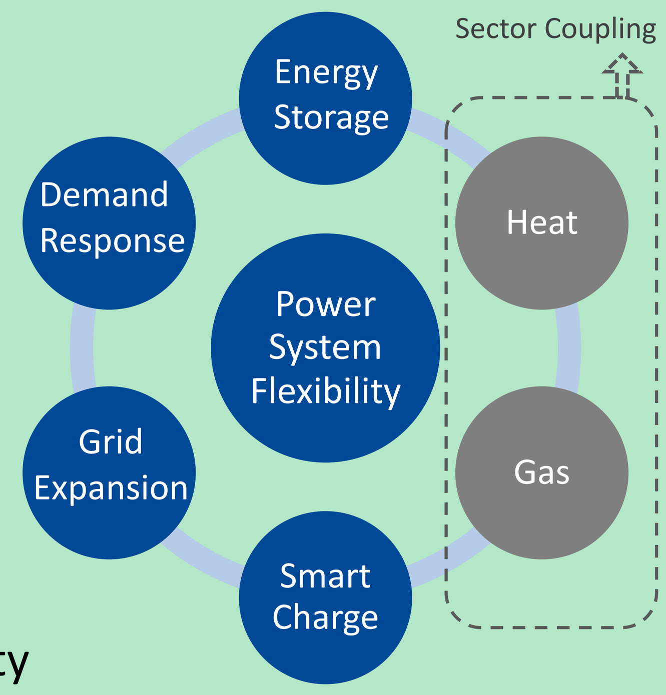

Fig. 3: Flexibility options

- **Services of flexibility options**

Generators →
- RE curtailment
- Diesel gen. reliance
- Capacity firming

TSO →
- Frequency regulation
- Flexible ramping
- Black start services
- Operational Reserve
- Seasonal Arbitrage

DSO
- Energy shifting and capacity investment deferral
- Grid congestion relief

Result

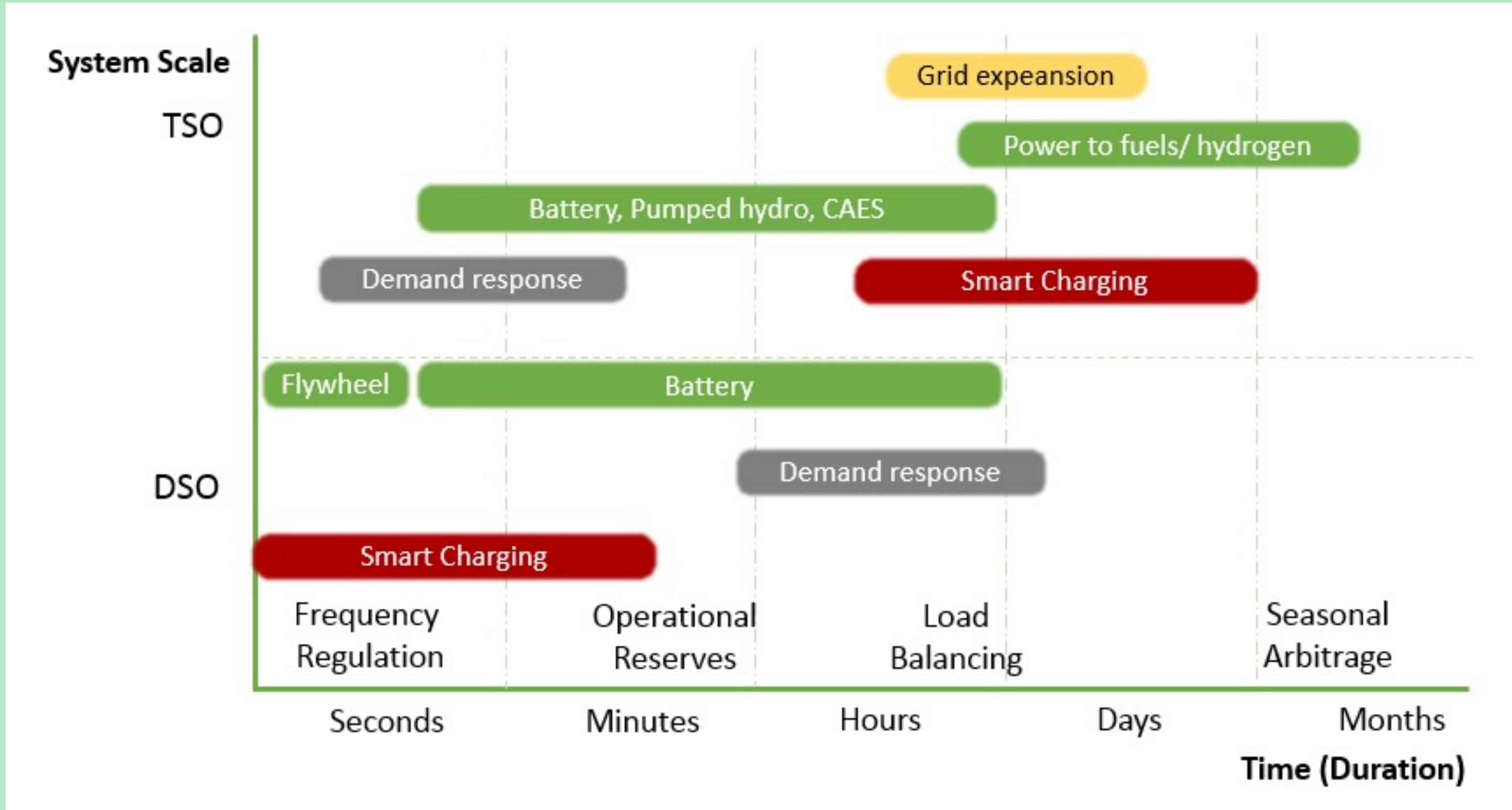

Fig. 4: Time – System scale graph for flexibility options

- **Demand Response**
  - Wide operation range with deployment in Capacity/Ancillary services
  - Already in-service for Load management (e.g. Direct load control)
  - Serving to Balancing market as a reserve capacity

- **Smart Charging** (mobile Energy Storage)
  - Offer Frequency regulation, Operational Reserve and Load balancing
  - Necessary due to high deployment in near future (6 MM EV in 2030 scenario)

- **Grid Expansion**
  - Offer flexibility on long time resolution by relieving congestions

- **Energy storage** (Battery)
  - Provide wide range of services in both TSO and DSO scale
  - Most prominent type is Li-ion battery sharing 90% of battery storage
  - Because of high cost, often applied with other options by optimization

- **Optimization options for flexibility scenario**

Purpose
- Sizing
- Deployment
- Management
- Operation

Method
- Dynamic and multi-objective Stochastic mixed integer linear programming (S-MILP)
- Particle Swarm Optimization (PSO) Multi-objective optimization with post-pareto optimality analysis
- Crow search algorithm (CSA)
  - with an adaptive chaotic awareness probability
- Genetic Algorithm (GA)
  - with linear programing (LP)
  - The elitist non-dominated sorting genetic algorithm (NSGAII)
- Monte Carlo simulation
- Markov decision process (MDP)

Objective function
- Minimize cost (investment/maintenance/ system energy/ unserved power/emission)
- Min. total power loss
- Min. diesel generator fuel consumption
- Maximize Profit (Arbitrage/transmission access fee/profit from energy&emission Reduction)

Constraints
- Kirchhoff's current law (Active power balance)
- The bounds of power capacity
- Service quality (voltage profile)
- Logical constrains, Radiality
- Charge and discharge rate

Conclusion

- Stochastic nature of VRE causes mismatches between forecasting and actual values in VRE generation and demand. Both short and long term mismatches lead to need of flexibility options, which is expected to increase as portion of VRE increases.
- Options of Demand response, Smart charging, Grid expansion, Energy storage have been reviewed. No flexibility application can offers all the flexibility needs efficiently, it is a mix of different options which performs best.
- This study outcome will be enough to start next step of modeling optimized deployment of flexibility options in an integrated energy system.

Acknowledge & References

1. Fraunhofer ISE, ENERGY CHARTS, https://www.energy-charts.de/
2. Juan *Ma et al,* Evaluating and Planning Flexibility in Sustainable Power Systems, *IEEE Trans. Sustain. Energy, vol. 4, no. 1, pp. 200–209, Jan. 2013*
3. P Linkenheil et al. Flexibility needs and options for europe's future electricity system, 2017

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