Regeneratives Kombikraftwerk Deutschland: System Services with 100% Renewable Energies

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Objective: Demonstration of feasibility of 100% RES Energy Supply

Method: ICT linkage of wind, solar and biogas power plants to a RES VPP
Energy mix and capacity of plants correspondent to 100% scenario

Open Question: Is a 100% RES scenario technical reliable and robust?

Quality of supply? (voltage, frequency and grid stability)
Development of Generation System in Germany

Source: BMU-Leitstudie 2011 (2020/2050)
"Kombikraftwerk 2"

- **Objective**: Analysis of stability of 100% RES electricity supply in Germany
  (not considered: heat and mobile sector and economical aspects)
- **Supported**: Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit
- **Total Budget**: 3,053 Mio Euro
- **Support**: 1,810 Mio Euro
- **Duration**: 3 years
- **Finished**: December 2013
- **Team**: 10 partners from science, industry and service provider
- **www.kombikraftwerk.de**
Part I: Simulation of a Future Electricity Generation with RE

Development of a consistent, spatial high-resolution scenario
- energy mix
- detailed modelling of future generation park
- determination of storage capacity
- determination of generation peaks, surpluses and lacks
- where and when appear extreme situations in terms of frequency and voltage in future?

Analysis of the system concerning its stability
- amount of demand on control power and reactive power in the system
- can RES deliver all needed system services?
Modelling of spatial distribution

- High diversity of technology
  - 5 WPP-types
  - 5 PV-plant types
  - 10 bio energy types
  - Geo thermal
  - Hydro power
  - Methane power plants
  - 4 Energy storage types
  - 7 Demand scopes
  - Import and export

- considering potential areas, todays distribution and weather conditions
- unique high spatial resolution (exact location or 100m x 100m)
  - interactive scenario map
Temporal Characteristics of Energy Supply System

- Weather dependent generators
  - high resolution historic weather data from Deutscher Wetterdienst (DWD)
  - physical plant models i.e. turbine characteristics, wake effects (wind), orientation, inclination (PV)

- Demand
  - historical load series
  - standard load profiles
  - load management strategies

- Balancing system (bio energy, storage systems, methane power plants)
  - determination of capacity and site selection by cost optimizing commitment and dimensioning

> Load flow animation
Stability Analysis and Calculation

- **Congestion detection** by n-1-reliability analysis
- **Congestion management** by multitude of decentralized plants
- **Reactive power demand** by AC-load flow calculation
- **Reactive power provision** by estimation of impact of connected plants
Improvement of Frequency Characteristics

Main PRP contribution:
- PV
- Electrolysis
- Batteries

Main PRP contribution:
- Methane
- Pump storage
Control Power Provision: Field Test - Record
A safe and stable 100% RES power supply is technically feasible if renewable energy generation, storage and backup power plants with renewable gas interact intelligent.

1. System design
   - 100% RES are only feasible by the massive use of new storage technologies (e.g., electrolyzer, methanation, batteries).
   - Weather independent producers (mainly methane, biomass and hydro) must be available for safety's sake, with a total power of the order of the maximum load.
   - The DC lines of the NEP have a positive effect on network congestion and voltage stability.

2. Frequency stability
   - The rise of average control power demand is not expected due to a new type of dynamic dimensioning and can always be covered easily in the 100% RE system.
   - The reduction of rotating mass by increasing use of converter systems can be compensated by the rapid deployment of PRP due to RE facilities and storage.

3. Voltage control
   - Reactive power demand will always be covered, possibly with additional compensation systems in consumption centers.
   - Distributed generation systems can be used to compensate the inductive reactive power demand of the loads.

4. Congestion management
   - The flexible generators and storage devices were positioned and adapted to minimize grid loads. This limits the re-dispatch and grid expansion efforts.
   - Multiple (n-1) bottlenecks can be overcome by optimized re-dispatch with distributed, small plants.
Thank You for Your Attention