Cost-benefit analysis of a flexibility market model (“Ampelmodell”) for the electricity market of Switzerland

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- Offices and consultants in over 30 countries
Topics of presentation

- The presentation is about the results of the project “cost-benefit analysis of a light-solution-model for the power market of Switzerland”
- Client: Federal Agency for Energy (BFE), joint project with ef.Ruhr
- Central topic: potential role of local flexibility markets in distribution grids in a future power market shaped by the Energy Strategy 2050
- Focus: “Ampelmodell”, flexibility market model proposed by BDEW
  - Distinguishes three states of the distribution grid: green, yellow and red, depending on shortage (related to voltage & thermal limits)
  - Yellow state: activation of local flexibility market
  - Technical requirements: smart grid technology for feed- and load management
  - Trade-off between benefits in efficiency by Smart Market and cost for the Smart Grids
- Project analyses cost and benefits of the “Ampelmodell” as well as drivers of change in Swiss distribution grids
Overview

- Background energy policy of Switzerland
- Challenges for future distribution grid
- “Ampelmodell”
  - Setup and regulatory challenges
  - Technical requirements
  - Technical use cases
- Quantitative cost benefit analysis
  - Modelling
  - Results
- Conclusions & Recommendations
Swiss energy strategy based on target scenarios ("Energieperspektiven 2050")

- Swiss energy policy is based on "Energiestrategie 2050"
- "Energieperspektiven 2050" are official target scenarios of the Swiss Federal Government
- Basis for further studies, including distribution grids or storage expansion
- Three main scenarios: NEP, POM, WWB

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Energy perspective 2050</th>
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<tbody>
<tr>
<td><strong>New energy policy</strong></td>
<td>NEP</td>
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<td>RES-expansion and</td>
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<td><strong>Political package of measures</strong></td>
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<td>RES-expansion</td>
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<td>WWB</td>
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<td>(continue like before)</td>
<td>Continue the trend</td>
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<td>fossil central, nuclear</td>
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<td>energy exit delayed</td>
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Energy strategy 2050:

- nuclear phase-out by 2035
- Target scenarios assume strong increase of new renewable energies after 2035
- Photovoltaics dominates, Wind & Photovoltaics deliver two thirds of energy
- connection of Photovoltaics & Wind on low- and middle voltage level
Background Energy policy of Switzerland

EP2050 scenarios

- Figure shows the development of electricity demand for the scenarios from EP2050
  - WWB: Demand will rise
  - POM: Demand will be constant
  - NEP: Demand will decline
- But major changes are not predictable before 2020
- Decreasing of energy consumption by ambitious goals in regulation of efficiency
- Trend is uncertain – Climate policy goes along with higher usage of power utilities (electro mobility, heat pumps)

source: BfE/Prognos, EP 2050
Challenges for the distribution grid

Increasing feed-in of intermittent RES-E leads to potential need for network expansion in distribution grid

- In the future, residual load in times of high solar PV feed-in will potentially exceed current thermal limits in low voltage grid
- Depending on distribution of installations, voltage problems could add to the challenges

- Potential solution: (massive) conventional grid expansion
- Consentec Study on Swiss distribution grids: conventional expansion is expensive
  - 2035: distribution grid tariffs 35-40% higher than today
  - 2050: distribution grid tariffs 25-35% higher than today
**Technical options for distribution grid operator**

From the DSO’s perspective conventional and smart grid solutions are competing technical options to tackle challenges.

Distribution grid operators facing RES-E expansion dispose of different technical options:

- **Construction of new infrastructure (lines & trafos)** vs. **Extension of existing infrastructure** vs. **Capacity expansion by optimized operation** vs. **Avoiding grid expansion by activation of flexibility**

(Macro-)economic and DSO perspective are different:

- **Economic perspective:**
  - Minimization of total cost for a fixed level of

- **DSO perspective:**
  - Profit maximization (under given regulatory regime)
  - Ensure network stability & quality of supply
“Ampelmodell” by BDEW – decentral flexibility market

Model proposed by German Energy Association BDEW in 2012, applied to Switzerland, is in the focus of the project.

Ampelmodell by BDEW (2012)

- **Green State**: No congestion, market operations implemented as foreseen
- **Yellow State**: Impending grid congestion, flexibility used by DSO to cope
- **Red State**: Grid stability in danger, technical intervention by DSO

- **Goal**: "DSOs should have a choice between grid expansion and flexibility provided in a separate market to ensure a cost-efficient expansion resp. operation of the grid as well as a high quality of supply."

- The green state today is represented by the normal market action and the red state by technical shortage- and disturbance management

- The yellow state is a new concept
  - **Aim**: Activation local /regional flexibility
  - **Accounts for network constraints**
  - **Local market for flexibility**: DSO is single buyer, flexibility offered by DSM, Storage or generation assets in distribution grid
  - **Localizes the demand of system services**, in particular demand for operating reserve
Comparison of „Ampelmodell“ with Redispatch

- Comparison of flexibility market in yellow state bears some resemblance to redispatch on transmission system level
- Flexibility market could be preventive and/or curative (design element)
Introduction of a flexibility market as part of an „Ampelmodell“ entails a number of regulatory challenges (typical for smart grid solutions)

- DSO is Single Buyer – should he also be market operator?
- How to organize market monitoring? How to deal with lack of / concentration of supply of flexibility?
- How to regulate quality of supply (acceptance of red states)?
- How to ensure balancing group of flexibility providers are observed? Who takes responsibility for balancing?
- How treat CAPEX, how to treat OPEX associated with flexibility under grid regulation?
  - Specific problem for any „smart solution“: load maximum is key parameter in TOTEX based incentive regulation (not in Switzerland!, but in Germany)
- Switzerland:
  - How to treat vertically integrated utilities at distribution grid level – how to prevent abuse of flexibility market?
  - What requirements to impose on DSO investment planning?
Technical requirements for Ampelmodell

Ampelmodell requires considerable investments into smart grid elements

- ICT-requirements for the provision of flexibilities in yellow phase include both information and control elements
- Technical elements include:
  - Sensors
  - Meter Gateway
  - Control device DSM
  - Control device RES-E
Technical requirements for Ampelmodell

Ampelmodell requires considerable smart grid elements

- Inherent trade-off: Determination of trade-off between required rate of ICT and security margins within the distribution grid
### Technical Use Cases

The introduction of smart grid elements required for “Ampelmodell” yields a number of use cases. Not all are remunerated for in a potential flexibility market.

**Classification of use cases of smart grid required for “Ampelmodell”**

<table>
<thead>
<tr>
<th>Use Case</th>
<th>TSO</th>
<th>DSO</th>
<th>BGM</th>
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<tbody>
<tr>
<td>UC 1</td>
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<tr>
<td>Voltage control &amp; blind power compensation</td>
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<td>UC 2</td>
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<td>Vertical congestion management (thermal limits)</td>
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<td>UC 3</td>
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<tr>
<td>Avoidance &amp; Shortening of supply interruption</td>
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<td>UC 4</td>
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<tr>
<td>Availability of data / information in distribution network</td>
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<td>UC 5</td>
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<tr>
<td>Optimization of flexibility in system markets</td>
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<tr>
<td>UC 6</td>
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<tr>
<td>Optimization of flexibility in local market</td>
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<tr>
<td>UC 7</td>
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<tr>
<td>E-Mobility infrastructure</td>
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Prior to modelling costs & benefits of the „Ampelmodel“, scenarios of development have to be selected and framework assumptions have to be fixed.

- **Scenarios**
  - Expansion of renewable energy sources and conventional generation as in Energy perspectives 2050 scenarios WWB, POM & NEP
  - We simulate stylized distribution grids for 2020 and 2035

- **Assumption on stylized distribution grid**
  - Distinction between rural and urban network as of today
  - Includes network levels 5-7, with simplified network topology
  - “typical” Swiss network in terms of grid and transformer capacity
  - Load connected in line with Swiss average
  - Variation of connected RES-E (in line with EP2050 scenarios)
Structure of the cost-benefit-analysis for Ampelmodell

Modeling include three steps.

1. Identification of potential yellow states in the distribution grid
   a) Rural and urban grids modelled according to MC simulation over RES-E
   b) In parallel calculation of system price
2. Generic simulation of cost & benefits of “Ampelmodell” in smart market (ef.Ruhr Modell)
3. Extrapolation of “Ampelmodel” simulation to Swiss electricity system
Modeling step 1a: Configuration of stylized network

Configuration of stylized distribution grid for Monte-Carlo-simulation.

- Configuration of low voltage grid
  - Number of HH, farms, commerce, electric vehicles, heat pumps (with standard load profiles)
  - Power of transformer

- Configuration of medium voltage grid
  - Connection of low voltage grids
  - Connection of wind power plants (feed-in profile based on weather year 2011)

- Monte-Carlo-Simulation
  - Variation around mean for low voltage grid
  - 250 realizations (weather year 2011)
  - PV: Weibull-Distribution
  - CHP: normal distribution
  - Small hydro: uniform distribution

Connection of low and medium voltage grids

Weibull- and normal distribution (exemplary)
Modeling step 1a: Identification of red & yellow states

Identification of network problems, including both excess of thermal limits and voltage problems, in stylized grids

- Simplified approach, detailed calculation of load flows and economic reactions in step 2
- Identification of red & yellow states
  - Exceeding thermal limit (Transformer)
  - Voltage problems

\[
\text{Residual load exceeds thermal limit} \quad \text{Prob(Voltage problem)} \quad E \cdot F > E \cdot F
\]

Residual load exceeds thermal limit

Probability of voltage problem in Distribution grid
Modelling step 1b – simulation of system prices

Simulation of wholesale & balancing market prices as basis for flexibility market price calculation in step 2

- BFE Project: Energy storage for Switzerland (2013)
  - Simulation of wholesale and balancing market prices
  - Combination of EP2050 with EU 2050 roadmap scenarios
  - Wholesale market prices calculated in PLEXOS based European market model
  - Derivation of balancing market prices by opportunity cost analysis

Scenarios

- Annahmen Schweiz
  - Weiter wie bisher - C
  - Polit. Massnahmen - C&E
  - Neue Energiepolitik - C&E
- Annahmen EU Szenarien
  - Reference Scenario
  - Low Nuclear
  - High Energy Efficiency

Simulated price duration curves for Swiss spotmarket
Modeling step 2: agent based grid model

Detailed simulation of selected model grids with an agent based model

- Agent based simulation for certain grids (in yellow states), which are chosen by the Monte-Carlo-simulation
- System prices are taken from the market simulation from step 1b
Modeling step 2 – details of network model

Basic setup

- Simulation of a MV-network with LV-networks (Cigré Benchmark-Netz)
- All network users are parameterized individually and located in grid.
- Network users have individual utility functions and react to prices
- System price is underlying simulation

Interpretation of „Ampel“ states:

- „green“: unlimited market activity
- „yellow“: network problems identified, flexibility price (as deviating from system price) is
- „red“: introduction of flexibility price does not solve problem
Modeling step 3 - aggregation of results

Aggregation of local Cost and Benefits leads to an aggregate picture for the Swiss electricity system.

Aggregate consumption and RES-feed in are similar to the scenarios in EP2050.

Forecast population development

City

Country

Urban grids

Rural grids

Benefits - Step 2

Cost – AP 3

Number of phases up to step one

Aggregate - Benefit

Aggregate - Cost
Results of MC-simulation of distribution networks

- Figures show results of evaluating steps 1a with the following definitions:
  - **Green**: during 8760 h of simulation just green states of grid
  - **Yellow**: several yellow phases (and a few red) come up in simulation
  - **Red**: overwhelming red phases come up in simulation
- Only configuration with yellow state: urban networks in 2035
Results – investment costs in MV-network

- We compare three solutions based on grid for shortages
  - Conventional grid expansion (where necessary / all LV strands of MV-Grid)
  - Usage of variable secondary substation within LV-Grids (where necessary, as new- or replacement investment)
  - Ampelmodell (*three different technical implementations*)
- Figures shows CAPEX for different solution approaches within Distribution grid.
Results - Cost Scenario WWB (continue like before)

- For the time between 2010-2020 is no need for expansion, therefore no cost.
- For 2020-2035: Need for rural grids to avoid shortages, but no need for urban grids.

Concerning the assumptions about SM- and variable secondary substation -Rollout, RES goals and ML-Grids volume of WWB, results from step 1 & cost for each MV-Grid
Results - Cost Scenario NEP

- For the time between 2010-2020 is no need for expansion, therefore no cost.
- For 2020-2035: Need for rural grids to avoid shortages, and space for a light solution for urban grids
The production is depend on supply. If price is negative all RES-E will stop producing together. No fine tuning is possible. Typical situation in rural network.
DSM is more useful to control a light model, because the demand is price sensitive. Urban networks include sufficient DSM to enable operation of flexibility market.
Results – cost-benefit-analysis over all scenarios

- Results for WWB and NEP
  - Ampelmodell does not generate benefits in a rural grid (both scenarios)
  - No need for expansion between 2010 and 2020, thus no direct benefit of the Ampelmodell (both scenarios)
  - Scenario WWB: no shortage in urban grids

- Evaluation focused of urban grids under NEP 2035
  - direct benefit of Ampelmodell:
    - Huge reduction of red states
    - Tackling situations with local shortages (yellow states)
      - Stabilize grid operation
  - Indirect Benefit of the light model
    - Incentives for local flexibilities (plus extra benefit in green phases, e.g. storages)
    - DSO gets detailed information from the ICT and also a better control

- REMARK: to reach a stable network it is also possible to use conventional grid expansions and variable secondary substation.
Results – changes in utility under flexibility market

Result for urban model grid (NEP 2035)

- Just a few yellow phases (11h for ICT high, 29h for ICT medium)
- By activating the market for flexibility the price is higher compared to the system price
- Difference in prices is highly significant (ratio 10:1)

Profit 100kW DSM-plant p.a.

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<tbody>
<tr>
<td>ICT high</td>
<td>81 CHF</td>
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<tr>
<td>ICT medium</td>
<td>230 CHF</td>
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Figure shows example for Price development in a Flex- and system market during a yellow phase

- Local flexibility (DSM) can benefit from the light model during few hours within the year
- **Indirect Benefit is small**
Conclusions & Recommendations

- In general activating flexibilities by the DSO could be a good alternative to a grid expansion, if enough flexibilities exist to enable operation of flexibility market.
- No need for Switzerland today and in foreseeable future, because local shortage caused by decentralised Energy production.
- Ampelmodell is rather suitable for urban areas (load dominated) than for rural areas (feed-in dominated).
- Costs for flexibilities with Ampelmodell are high compared with other alternatives.
- Coordination model based on bilateral agreements between Grid operator and supplier of flexibility is probably better suited for the purpose.
Thank you for your attention!

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