Grid Integration of an Increasing Share of Renewable Power Generation

- Geothermal Power: Challenges for Network and System Operation -

Aims, Developments and Expectations of RES
Challenges for Network and System Operation
Smart Tools and Smart Grids
Geothermal Power Plant Connection
Procedure, Checklists and Costs
Results/Summary and Outlook

GEOELEC Training Course Potsdam
15.-18 April 2013

Dr.-Ing. Franz Heilemann
EnBW Regional AG
Brief portrait
EnBW Energie Baden-Württemberg AG

› One of the largest energy companies in Germany and Europe
› Business segments:
   electricity generation and trading, electricity grid and sales, gas, energy and environmental services
› Annual revenue 2011: in excess of € 18 billion
› Customers: some 5.5 million
› employees: some 20,000
Some figures of EnBW Regional AG

Status December 2011

- Network customers: 2,95 Mil.
- Employees: 3,283
- High voltage network (110 kV): 7,620 km
- Medium voltage network (30/2010 kV): 30,200 km
- Low voltage network (0,4 kV): 66,700 km
- Transformer stations: 329
- Network stations (own): 26,500
- Surface of network area: 18,800 km²
Environmental objectives and expectations

Framework conditions for power system development

The Measure of all Things

The 20-20-20 Energy and Climate Targets of the EU for 2020

The Ambitions for 2050
The EU 20-20-20 energy- and climate targets for 2020

The evolution of networks: Smart Grids

Targets

- CO2 Reduction - 20 % based on 1990
- Renewable Energy-Share + 20 % based on PrimaryEnergy
- Energy-consumption - 20 % based on Forecasts

Solution

- Generation
- Transmission Network
- Distribution Network
- Smart Meter
- Consumer

- Communication network for efficient Network Operation/Supply

Challenge

35 % generation from RES in Germany

“In this new World, it may not be economically feasible to operate the system as it is done today. Significantly more system monitoring and intelligent control will need to be introduced to securely meet the demand for energy with the optimum level of generation and network capacity. This will be achieved by the evolution of electricity networks: in short: Smart Grids“ (ERGEG)
Rapid installation of renewable generation
Lucrative promotional concepts

Renewable generation 2020
ca. 70.000 MW

Current peak load in Germany
ca. 80.000 MW !!

Substantial network problems (P, Q, U, f) (locally, regionally, holistically)

Network related load-/feed-in management for cost efficient network operation is indispensable!

Tendencies

Quelle BCG
Changing the dynamic control capability of generation
Redeployment from transmission- to the distribution network

The contribution of generating units in the distribution network for the control will have to increase substantially
- Frequency-Load Control
- Primary control, loss of inertia of the system/network needs to be compensated
- Mastery of faults (fault ride through)
- Voltage control
- Integration of storages (medium-term and long-term)
Increase of generation
Determinants for the Networks
The North-South Bottleneck

Wind Power
- already today critical network situations
- Massive expansion of off-shore plants in the North of Germany
- In-feed direction: from high voltage to medium / low voltage

Solar Power
- Massive expansion of PV-plants in the South of Germany
- In-feed direction: from low voltage level to high voltage level

Discussed Tendencies

Overlay grid? Congestion Management: 2 Trading Zones?
Increase of generation
Determinants for the Networks
The North-South Bottleneck

Off-shore – Nordssee bis 2020 geplant: 18.000 MW
Off-shore – Ostsee bis 2020 geplant: 10.000 MW
PV-Anlagen heute: 4.000 MW, bis 2020: 20.000 MW
Up to 40.000 MW

On-shore in Deutschland 2008: ges. 24.000 MW

Bottleneck North-South

Discussed Tendencies

### dena network study II

- a) 3.600 km 380 kV of lines
  - 10 Mrd. €
  - 0,2-0,5 Ct / kWh (High Voltage)

- b) 1.700 +(5.700) km 380 kV
  - high temperatur Ropes
  - 17 Mrd. €

- c) 3.400 km HGÜ
  - 22-29 Mrd. €

Approvals ?, t= ? ........

Overlay grid?  Congestion Management: 2 Trading Zones?
Discussed scenarios for grid reinforcements

discussed scenarios for grid reinforcements
2020 was the beginning! Stepwise towards the supergrid
2050 80 % from renewable energy is targeted
Dessertec und Seatech inspire the phantasie
The future has already begun
EnBW with Baltic I as a pioneer
Off-shore hot spot Nord Sea and Baltic Sea

Fresh Energy

<table>
<thead>
<tr>
<th>Project</th>
<th>Capacity (MW)</th>
<th>Turbines</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltic I</td>
<td>48</td>
<td>21</td>
<td>2010</td>
</tr>
<tr>
<td>Baltic II</td>
<td>288</td>
<td>80</td>
<td>2013 planned</td>
</tr>
</tbody>
</table>

Initial future planning: in total 1200 MW
Challenges and problems

Technical, economical problems for power plants, TSOs and DSOs

The nature as a power plant operator volatile/stochastic generation

The customer „load follows generation“
Problems for the Distribution System Operator
What must be mastered?

Enormous increas of RES in 2020 ca. 80% of today's peak performance!
Extremely high volatility/intermittency of the generation
Substantial network problems (P, Q, U and f), (locally, regionally, holistically)

TSO ==⇒ „Load Leveling“ / “Balancing” ⇒ Net-/system stability
reinforcement of transmission system

DSO ==⇒ „Peak Shaving
network related preventive coordinated Customer supply
load- and in-feed management
costefficient network operation
automation of network, network expansion

Regulatory Framework
⇒ Recognition of the DSO costs / investments
⇒ requirement for an investment-friendly climat

Invest EU-wide up to approx. 1,000 BILL. Euro
500 BILL. Generation
100 BILL. Transmission
400 BILL. Distribution
acc. to EURELECTRIC
Control loop to efficiently solve network economic and network technical problems

Overview of the Smart Grid Approaches

<table>
<thead>
<tr>
<th>Network technology-planning/-operation without customer involvement</th>
<th>Load- and In-feed management with customer involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Monitoring (MV, LV)</td>
<td>7. In-feed management RES</td>
</tr>
<tr>
<td>2. Controlable step transformator</td>
<td>8. In-feed management powe-heat coupling (CHP)</td>
</tr>
<tr>
<td>4. Dynamic definition of loadability</td>
<td>10. Household loads unsing also über Sm@rtHome</td>
</tr>
<tr>
<td>5. Online reactive power settings</td>
<td>11. Special loads of the industry</td>
</tr>
<tr>
<td></td>
<td>12. Services</td>
</tr>
</tbody>
</table>

Network problems

- Load flow
- Voltage
- System stability

Network reliability (interruption-frequency and -duration)

II Problems (Amperage)

- Voltage
- System stability

Network reliability (interruption-frequency and -duration)
Solutions and approaches

Intelligent network control

Load- and feed-in control

Electrical equipment

Customer involvement,

Smart Box

Time dependent network tariffs
Balancing (f-problem)

Load and generation in equilibrium

momentary demanded power

momentary generated power
Intelligent, preventive and network-related load-/in-feed management
Options for costefficient network operation

1. Ramp down Control power plant
2. Shut down decentralized generation (RES)
3. Load-activation
4. Renewables disconnection
5. Load shifting + activation by incentives

Usage of all advantages
Intelligent, preventive and network-related load management
Load follows generation (paradigm change)

- Cost efficient smart and economic network operation
- Preventive load management
- Priority feed-in for RES
- Usage of RES by load activation
- Preventive net expansion
- Preventive control power

max. net capacity
load activation/shifting
original power curve

current power after incentives/smoothing

network incentives for load shifting

original network fees

Satisfaction

Customer

Network

G

P

t

NF

Network fees

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Incentives for network friendly/related load management
e. g. Heat pump (by the DSO)
by means of release and cut-off times

Realisation of a cost efficient network operation and network expansion

With preventive Load management

Without preventive Load management

Network-capacity

grid-load

WP

lokale/regionale Diffrenzierung möglich

From the DSO point of view

Working time

Restricted periods

11:30-13:00

17:30-19:00
Smart grids may mitigate the cost increase of the integration of renewable energy sources.

Net costs currently without RES, net costs with RES connection traditionally, net costs with RES in the "Intelligent Smart Grid".

Smart Solutions for network improvements IKT + FE, CU, AL.

### Smarte Tools
- Intelligent communication-, control and steering technology
- Intelligente load-/generation management by attractive incentives
- Smart stations
- Intelligent metering systems
- Smart boxes
- Smart customers
- Smart regulatory framework
Smart Station (I), controllable step transformers
Avoidance/postponement of net and line constructions
Dynamic voltage control: Voltage problem (U-problem)
Smart Station (II)
Avoidance/postponement of net and line constructions
Dynamic load control

20-kV Netz  
Smart Station  
0,4-kV Netz  
z.B. warm-water  
PV  
PV-feed-in  
Loads  

Voltage measurement at the customer’s „Eyes“ for network optimization

Voltage

Control Range Transf.

Line length

Voltage limit

Voltage limit

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Smart Station (III)
Additional features and advantages

Measured data for network monitoring and state estimation
- Advantage for planning, steering and asset management

- Loading control/monitoring of the equipment
  - Protection and optimal use of assets (lines, transformers, network configuration)

- Data hub for smart meter data
  - Synergies for data systems

- Remote control of switches and status feedback of:
  - Short circuit & earth fault indicators to control centre
  - Fast fault localisation/remedy.
  - Improvement of the reliability and quality of supply

Installation of BB Powerline coupling in an open air station
Interaction of participants in the Smart Grid

Participants

Customers

Network operators (DSO and TSO)

Supplier

Trader

Service provider

Storage operator

Regulator
Connecting and integrating geothermal power plants

Geothermal Integration

Procedure

Checklists

Costs
Flow diagram: Connecting a power plant to the network

1. Network Connection Request by PPO
   - \( P_{\text{max}}; S_{\text{max}}; \text{Location} \)

2. Determination of Network Connection Point by DSO
   - Voltage level, Costs, Timing

3. Application for the Network Connection by PPO
   - Voltage level, Costs, Timing

4. Projecting by DSO
   - DSO Components; Timing Details; Construction; Grid Update

5. Projecting by PPO
   - PPO Components; Construction

6. Commissioning and Protocols

7. Power Plant Operation

Specification of Remuneration (Marketing)
Enquiry for connection
Request for connection of a generating plant and order to perform network calculations.

Required data for the DSO:
✓ Name/Adresses of the DSO, the customer/client, communication partner, installer
✓ System/plant location and a true to scale site plan
✓ Plant data: RES-feed-in according the law (e.g. EEG),
✓ Type of the generator
  -- synchronous, asynchronous, double fed asynchronous generator
  -- max real power $P$, max apparent power $S$, additional feed-in, ..
✓ Mandate for ordering a data signal transmission device according to the law (EEG)
  -- incl. a cost absorption declaration
✓ Selecting the measuring concept
  -- direct measurement, commercial financing transit or full feed-in model, need for a metering exchange
✓ Planned commissioning of the power plant
✓ Assignment for the accomplishment of network calculations ($< 30$ kW)
  -- cost absorption declaration (blanket $1200$ €)

Regarding the remuneration/feed-in compensation, the customer itself must inform.
The Reservation of the feed-in power are binding for six month. Afterwards extension is possible.
Determination of the Network Connection Point (NCP)

Most significant key point for connecting a power plant considering costs, property borders and operating responsibilities

Public grid (DSO) Public grid (DSO) Public grid (DSO) Public grid (DSO)

11 11 11 11

NCP NCP NCP NCP

Connection Connection Connection Connection

Connection lines may be considered as single or as double lines in terms of n or (n-1) security.

Connection Alternativ 1

Connection Alternativ 2

Customer (PPO) area Customer (PPO) area Customer (PPO) area Customer (PPO) area

Network operator area Network operator area

Criteria for the determination of the network connection point (NCP) is the minimum of “Total Costs” incl. reinforcement of the network

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The Soultz Project
Geothermal plant in the Upper Rhine Valley.

Exploitation of 1 production well, 5000 m, 200 °C hot rock, and 2 injection wells

Power plant with Organic Rankine Cycle (ORC) process, 1.5 MWel
The Soultz Project
Geothermal plant in the Upper Rhine Valley.
Technical components

- Separators
- OCR process and components
- Technical facilities
- Generator (12,000 rpm) and gear box
- Long shaft pump
- Long shaft pumping motor
The Soultz Project
Geothermal plant in the Upper Rhine Valley.
Electrical connection scheme and supply devices

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- 1,25 MVA
- 33
- The Soultz Project
- Geothermal plant in the Upper Rhine Valley
- Electrical connection scheme and supply devices

- 20 kV customer switchgear
- Capacitor banks
- 20/0.4 kV transformer station
- 66 kV public HV grid
- HV transformer station
- Network Connection Point (NCPI)
- Relevant for responsibilities and costs
- Capacitor Banks for Compensation
- 11 kV Asynchronous generator (12,000 rpm) and gear box
- Flywheels for stabilizing supply
- Pumps ORC process
- Control devices

- Pmax = 2.5 MW, asynchronous
- Capacitor Banks for Compensation 1.92 MVAr
- 66 kV
- 20/0.4 kV transformer station
- 1,25 MVA
- 0.4 kV
- AUX1 0.6 MW (pumps, air coolers for ORC,...)
- AUX2 0.6 MW (pumps, air coolers for ORC,...)
- MV grid
- HV grid
- MV grid
- MV grid
- MV grid
- MV grid
Costs of some main components for connecting a power plant to the grid (Rough figures)

**Soultz Project**

**Generation**
- Transformer generator: 46 T€
- Switchgear equipment: 68 T€

**Auxiliaries.**
- Transformer: 93 T€
- Switchgear: 112 T€

**Compensation**
- Capacitor banks: 24 T€

Network Connection Point is in front of the site
- No construction subsidy for the network

**Connection devices in general**
- Medium voltage lines/cables: 70 - 120 €/m
- Medium/Low voltage substation: 30 - 50 T€
- High/Medium voltage transformer station: 1 - 1,5 Mil €

Influencing circumstances: terrain conditions, power plant key figures, local infrastructure,......
Plants bigger than approximately 20 MW connected to 110 kV, depending on network conditions
Checklist for documents required (categories) for application and commissioning of generating units

- **Request/Enquiry**
  General data, max feed-in power, location, DSO form, Site plan

- **Application form for connecting a generating plant**
  DSO form
  Measurement concept
  Declaration that the construction is made in accordance with applicable laws and official directives as well as accepted engineering standards VDE.

- **Provisions before connecting the generating unit to the general supply grid**
  Proofs and certificates
  Constructions to VDE guidelines, Attestation of conformity
  Construction to bdew guidlines (connection to the medium voltage network)
  Any other network operator relevant regulations

- **Documents for the commissioning of the power generating unit.**
  Data sheets / protokolls
  Other generating units, number size and complementary documents
Measurement concept and counting for the remuneration of RES “Full feed-in”, „commercial financial transit“ and surplus feed-in“ model

Public network (DSO)

Full feed-in model

Commercial financial transit model

Surplus feed-in model

Customer network

feed-in purchase RES

feed-in purchase RES

feed-in purchase Total

Auxiliary

other loads

RES

RES

RES

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**Required capabilities for generation units (RES)**

**Feed-in management according to EEG §6**

- In general all plants > 100 kW
  - remote controllable steps (60%, 30%, 0%, 100%) of $P_{\text{max}}$

- PV plants > 30 kW < 100 kW
  - remote controllable steps (60%, 30%, 0%, 100%) of $P_{\text{max}}$

- PV plants < 30 kW
  - choice of the PPO
    - like bigger plants
    - fix limitation of peak power to 70%

In addition all PV plants < 10 kW will be equipped with frequency relays to drop them when frequency > 50.2 Hz (according to the system stability act).

Bigger plants need to participate to the primary control.
Commissioning protocol (form)
according to VDE-AR-N 4105

- Plant address, plant installer
- Max apparent power $S_{\text{max}}$, max real power $P_{\text{max}}$, $\cos \phi \geq 0.95, 0.9$
- Peak power of the individual modules/generators kWp
- Order for commissioning is available
- Compliance with data
- Measurement for billing was tested
- Conformity evidence
- Protection devices
  - Set point for voltage control $U_n$
  - Set value on integrated protection of the net connection $U_n$
- Trip test performed
- Feed-in management according to §6 EEG is well functioning
  - including power reductions to several levels (e.g. 70%,...)
- Limitation of the maximum power according to the contracted value $P_{\text{max}}$
- Carrier frequency locks are proved. Protocols
- Date of commissioning
Market and renumeration models
Choice of the power plant operator (PPO)

Remuneration models (Germany)

1. Feed-in according to the EEG. Will be payed by the DSO
   (In case of the Soultz Project, the remuneration is 20 Ct/kWh)

2. Direct Marketing models (PPO has to clarify with a supplier)
   - Direct Marketing + Avoided Network Charges
   - Direct Marketing (green power privilege)
   - Direct Marketing + Avoided Network Charges + Market premium

Payed by the supplier
Payed by the network operator

Geothermal
25 Ct/kWh
(§28, 33)

Avoided network charges for the next higher network level.

Market premium accord. to current market situation

(In case of the Soultz Project, the remuneration is 20 Ct/kWh)
Compensation of the power plant operator (PPO) in case of feed-in management by the network operator

In case of an impending network bottleneck, the DSO is entitled to reduce the generated power (0, 30, 60,....%)

General convention with regard to the law (EEG §11):

Compensation of lost revenues “As if”

Two variants for free choice for the PPO

- Blanket remuneration (Ct/kWh) according to the last actual performance for the time in question
- Billing based on a detailed generation profile (pointed billing)
Realistic potentials of geothermal power plants

Medium term (within the next 15 years)
probably no unit size bigger
than 100 MW in low enthalpy areas
not anticipated at present

Germany
biggest plant currently $3.3 \text{ MW}_{el}$ (Unteraching Munich)
in 2009 total installed capacity $7.5 \text{ MW}_{el}$
in 2013 total installed capacity forcast $30 \text{ MW}_{el}$
Potential up to 2030 $200-500 \text{ MW}$
Uncertainties due to geological uncertainties and technical risks
Summary
EU 20-20-20 targets and challenges for the energy turnaround

Green light for geothermal generation

Building up Smart Grids to integrate the renewable sources is a huge network economic challenge for distribution- and transmission system operators (DSOs, TSOs)

- Additional integration of new loads (e-mobility and storages) make it further challenging
- DSOs as carrier of enormous investments. Increased pressure for efficiency
- Integrated perspectives needed. Network operators in the centre of responsibility
- Paradigm change „Load Follows Generation“
- Fundamental challenge for planning construction and operation of networks by means of
  - system monitoring, communications systems, smart Meters as well as
  - feed-in and preventive load management through incentives

Geothermal generation and connection is no problem in general

- Potentials are relatively low compared to wind, PV and biomass from a today’s grid point of view
- Checklists for connection should be available at the local DSO
- Larger units are required to attend primary and voltage control
- The power plant operator can select a model to market its current
- Obstacles to the development of geothermal power plants should in general not be expected from the part of the network

Smart Customers
- Incorporation and empowering of the customer is required including Home Automation Systems.

Smart Regulation
- Incentives for implementation of Smart Grids are overdue. Creating an investment-friendly climate
Grid Integration of an Increasing Share of Renewable Power Generation
- Geothermal Power: Challenges for Network and System Operation-

Thank you for your attention

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