How project design can help to integrate vRE into power systems

Taking advantage of first experiences

Conference on integrating variable Renewable Energy into power grids
Copenhagen, October 21, 2014

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KfW Development Bank and Renewable Energy
Around 70 offices worldwide

› We are the world's largest financier of renewable energies in developing countries

Energy Sector Commitments 2013

Total Energy Commitments (2013): **1,586 m€**
thereof Renewable Energy: **683 m€**

- Wind: 7%
- Solar: 6%
- Hydro: 8%
- Thermal PP/ Combined Heat and Power/ District Heating: 19%
- Demand Side Energy Efficiency: 11%
- Renewables - Mixed: 22%
- Electricity transmission/distribution: 27%
- Sector/ Research Programs: 0.3%

› Goal: Increase German ODA for RE and EE to at least 3.6 bn € annually until 2030
Experiences from the German power market
High shares of vRE in power generation

- In 2013 some 25% of power consumption provided by RE, 9% from wind power, 5% from PV

Wind power and PV Capacity

Annual peak load:
81.8 GW

PV: 36 GW
WP: 35 GW

Sources: BMWi; BDEW
Experiences from the German power market
High shares of vRE in power generation - Consequences

› Decreasing value of power during traditional peak hours and negative power prices
› Need for grid extension and technological enhancements of RE plants

Yesterday: Dromedary-like price curve
Today: Camel-like price curve
Different time frames of variations
Technical challenges and mitigation strategies

- **Short run variations and technical challenges**
  - Variations caused e.g. by flurries
  - Technical challenges: missing inertia caused by increasing share of inverter based feed-in (PV and wind power), displacing rotating masses
    - Harmonic waves
    - Reactive power
    - Short circuit power
  - Technical solutions to be applied at the RE power plant itself and to be taken into account in project design ➔ experience of wind power in Egypt

- **Medium to long run variations and potential mitigation measures**
  - Geographic diversity ➔ experience of Albania
  - Technological diversity ➔ experience of Morocco
  - Storage ➔ experience of CSP with thermal storage
  - DSM and backup of flexible generation capacity
Addressing short run variations and technical challenges
The experience of wind power in Egypt - Gabal el-Zayt

› **Context**
  › Enormous wind power potential ➔ 20% to be generated from wind and solar power by 2020
  › Displacement of rotating mass by inverter based feed-in could cause instability in a Transmission System, which is deficient anyway

› **Approach**
  › 200 MW wind farm at the gulf of el-Zayt + preparatory studies for another 200 MW
  › Starting point: **power network analysis**
    ➔ **Enhancement of grid code**
      (Threshold values for harmonics)
    ➔ **Requirements in the tender documents**
      (Technical norms for power inverters)

› **Future Approach**
  › Requirements for short circuit power
  › Ex post network analysis
    ➔ **Readjustments of power inverters**
Geographic diversity
The experience of Albania

› **Context**
  › Albania is heavily dependent on hydro power (90% capacity)
  › Supply shortages during dry periods - seasonal and yearly variations

› **Approach**
  › Construction of two 400 kV transmission lines
    › Albania - Montenegro (60% hydro): commissioning May 2011
      › 155 km TL + extensions of substations
      › 44 m€ development loan to Albania
    › Albania - Kosovo (Tirana - Prishtina): procurement completed
      › 240 km TL, 600 MW + extensions of substations
      › 42 m€ development loan to Albania + 33.5 m€ dev. loan to Kosovo

› **Impact**: Important contribution to the extension of the SEE power network and connection of Albania with the ENTSO-E network
Technological diversity
The experience of Morocco: wind, solar and hydro power

› Context
  › High solar radiation and abundant wind power potential
  › Target of the GoM to increase the RE share of installed capacity to 42% in 2020

| 2,000 MW Wind power | 2,000 MW Solar power (CSP + PV) | 2,000 MW Hydro power | Grid extension to integr. vRE |

› Approach
  › KfW contributes to the achievement of all these sub-goals

› Impact
  › Complementary technology mix to balance different variations
  › Avoidance of fossil fuel imports
Storage I - thermal storage
The experience of Ouarzazate CSP in Morocco (1/2)

› **Context:** Evening peak

› **Approach**
  › Largest solar power complex of the world, comprising
    3 CSP and 1 PV plant, target capacity (2017): some 560 MW
  › **Molten salt storage**
    › Noor I: 160 MW Parab. Trough; 3 h storage cap. (comm.: Oct 2015)
    › Noor II: 200 MW Parab. Trough; about 5 h storage capacity
    › Noor III: 150 MW Solar Tower; about 5 h storage capacity
  › KfW financing 769 m€ (total cost: 2.3 bn€)

› **Impact**
  › **Solar power generation even during night hours!**
  › „Adding thermal storage to a CSP facility was found to be an effective measure to mitigate the decline in the value of CSP with increasing penetrations“ (Berkeley Lab „mitigation report“)
  › LCOE of **CSP can compete** in some countries with alternative dispatchable power plants!
Storage I - thermal storage
The experience of Ouarzazate CSP in Morocco (2/2)

Cost estimations

- Generation costs for CSP with molten salt storage:
  - Parabolic trough: some 13 €ct / kWh
  - Solar tower: some 13.5 €ct / kWh (forecast)

- Storage costs (non-CSP) - depending on technology and site: 5 - 9 €ct / kWh

Features of Andasol-1 Storage

- Tank volume 2 x 14,000 m³
- Salt inventory 28,000 t
- \( \Delta T = 386° C - 292° C = 94 K \)
- Storage capacity 1,000 MWh = 7.5 h
- Estimated investment cost 30 - 50 € / kWh
Storage II - Pumped-Storage HPP
The example of Vrilo PS-HPP in Bosnia-Herzegovina

› **Context**
  › High share of hydro power in BH: 50% of installed capacity
  › High wind power potential
  › Several hydro and wind power engagements of KfW in BH

› **Approach**
  › 66 MW PS-HPP at the river Suica, providing 106 peak + 84 GWh run-of-river generation p.a.
  › Height diff. upper to lower basin 155 m, 4.5 km distance
  › 100 m€ loan agreement signed mid-2014 (total cost: 110 m€)

› **Impact**
  › Grid stabilization (frequency and voltage regulation)
  › Enabling the exploitation of the high wind power potential by providing reliable large-scale and long-run energy storage
Thank you for your attention

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BACK-UP: Experiences from the German power market
Camel-like spot market results

- Price Chart EPEX Day-ahead: Trading Date: May 13, 2014; Delivery: May 14, 2014 (Wednesday)
BACK-UP: Experiences from the German power market
Spot market: merit order effect with high share of RE

- Wind + PV at noon on May 11, 2014: up to 67% of production...

Source: BCCONSULT
BACK-UP: Experiences from the German power market

Spot market: merit order effect with high share of RE

- … causing negative power prices on May 11, 2014
BACK-UP: Storage I - thermal storage
The experience of Ouarzazate CSP in Morocco

Solar Complex Ouarzazate: 4 plants, 3 technologies, 560 MW
→ the largest solar complex world wide

Next complexes of the Moroccan Solar Plan

„Noor I“
› 160 MW Parabolic Trough Plant with 3 hours storage capacity
› CAPEX: 633 m EUR
› KfW financing: 115 m EUR
› Start of construction June 2013
› Estimated commissioning October 2015

„Noor II“
› 200 MW Parabolic Trough Plant
› About 5 hours of storage capacity
› CAPEX ca. 1 bn EUR
› KfW: 330m EUR

„Noor III“
› 150 MW Solar Tower
› About 5 hours of storage capacity
› CAPEX ca. 0.7 bn EUR
› KfW: 324m EUR

„Midelt“
› Ca. 500 MW
› technologies to be decided

„Tata“
› Ca. 500 MW
› technologies to be decided
Demand is not only increasing, it is also fluctuating

- Demand is almost doubled in 2024; tripled in 2030!
- Differences between summer and winter (summer consumption tends to be higher)
- Evening-peak prevailing, noon-peak will develop strongly

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Δ = 1400 MW  
Δ = 2600 MW