Steps towards Integration of PV-Electricity into the Grid

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Outline

1. Why the grid is a big issue in PV today?
2. Method description – Swiss Grid + PV
   ► limits in hourly electricity consumption
   ► scenarios: turn of base load plant at sunny noon
3. Reduction of annual PV production due to load limits
   ► reduction in nominal hours – refinancing the plant??
   ► additional storage power helps!
4. Discussion of the solutions

Why PV has a great future?
PV penetration in the German Grid: June 2010, 2%, ~15GW; 2010e: 20GW?

Week of maximum PV yield in Germany 2005

Wachenholz, SMA: “Mehr als 50 GWp PV ohne weiteres ins Deutsche Stromnetz integrierbar ohne neue Netze und ohne Speicher.”
If PV increases by a factor of 20 in the northeastern Germany load limits will be reached!
Grid Limits in Germany: Wind

2009-12-26

- Wind: 20GW
- Nuclear: 12GW
- Coal: 10GW

- 19 €cent/kWh
EEX Electricity price
ca. -1 Mio €

2010-01-04

- 18 peak pumped hydro

BRD DENA Netzstudie 2005:
Load limit low: 37GW
Load limit max: 74GW

http://www.eex.com/de/Marktdaten
http://www.transparency.eex.com/
Y.M. Saint Drenan et al., BEE Dyn. Load Study IWES Kassel, Germany, Dec 2009

BEE 50% Scenario 2020:
PV 6.6%  (40GW)
Wind 25%  (55GW)
Bio 9.2%  (9.3GW)

Today
<40GW / 0d
Result 50%RE: -35GW base load
daily av.
no storage / tran.
<10GW / 10d
<15GW / 19d
<20GW / 19d
<25GW / 3mo

Power capacity:
16/18GW
import/exp.
5GW pump. hyd.
Swiss electricity production 2008

- 56% hydro
- pumped hydro cap. 1.4 GW (2% elec.)
- pumped hydro cap. will be increased to 5GW in future

VSE Schweiz, 2008

http://www.strom.ch/de/dossiers/stromgrafiken.html
PV on top of base load plants!

Scenario A

15 min Load profile: Greater Zurich Area
Solar input of Scenarios - Swiss
PV powering daily peak load

5% PV

10% PV
Results: PV yield goes down

Scenario A: on top of base load

-8% in annual PV electricity production

640Wp per capita
PV turns off the base load plants!

Scenario B: with 17% PV penetration
### Results

#### A10

<table>
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<tr>
<th>PV Scenario</th>
<th>Base load rel. to P_M</th>
<th>Max. Storage rel. to P_M</th>
<th>PV load mismatch losses</th>
<th>Nominal PV power rel. to P_M</th>
<th>Nominal PV power Wp/capita</th>
<th>PV amount of overall electricity</th>
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Results: All scenarios

No other renewable sources included!

Storage power 30% annual average power (Switzerland about 3GW)
Solution 1: Storage

Technical Solution

• Battery storage at the residential house PV-inverters are ready! each kWp PV 0.5 to 1kWh battery needed

• Pumped hydro storage (costs about 0.1€/kWh)

• R&D on storage needed!! compressed air, flywheel…

• Storing electr. Bio-fuel, H₂

Remark

• Battery costs 0.5€/kWh (0.2) lead acid, lithium ion (twice the PV gen. costs)

• Larger scale: Li-Ion invest <1€/Wp_PV flow redox batteries about have the price ?

• Not so many ALPS around! (Switzerland today 1.5GW about 4 GW planned in the next years); limited!
Solution 2: Electrical Vehicles to Grid V2G

Technical Solution

- Charge the EV Batteries when the sun is shining (new public daylight charging infrastructure needed)
- PV potential of EV charging: ~7kWh daily load (2kWp/EV)
  Germany 2020: 2GWp/10^6EV
- New hard-/software infrastructure and marketing models needed
- No way out: 2050 peak oil?

Remark

- Battery costs are still higher than PV costs but only the costs for charging at the right time has to be financed
- Yearly balancing correlation of PV feed-in and EV consumption – special tariffs
- EV’s Switzerland 2009
  500 EV’s; 30 000 E-bikes
  11 000 hybrid vehicles
  (PV charging needs: ~5MW)
Solution 3: Investment into power lines

Technical Solution

- There is no sunset in my empire, 1520 Karl V, CEO of Habsburger
- Power line connection outside Europe – Desertec
- High voltage power lines across Europe

Remark

- Costs of HVDC lines lower >1000km than AC 4Bil.€ / 12GW / 2000km, 5% losses (invest 0.3€/W)
- PV ~1000 nominal hours (refinancing the power line)
- Takes time to comply regulations, administrative appeal, protests from environmental groups?
Solution 4: Smart washing machines

Technical Solution

• Switch on the load when the sun in shining!

• Today smart grid focus on electricity cost savings – PV will loos in the near future but not for the long run

• New loads will come: PV powered air condition!!!!

Remark

• Smart washing machine cost +1000€, use less electricity!

• Financing the IT and Electronic Hardware to get Smart Grid running!
Solution 5: Further PV cost reduction

Why PV has a great future?

Because further cost reductions will be done!

Other Support

• PV installations on EAST/WEST oriented roofs
• PV Trackers find no limits in the morning
• Feed-in-tarif have to support peak shift and the amount of self consumption

Remark

• Yield is lower than optimum south oriented
• There are still limits at noon
• at high PV penetration rates also small PV inverters have to shut down (power line)
Conclusion

• At PV penetration rates higher 10% (> 600W/Capita) annual electricity production will drop by >8%
• Refinancing of today’s installed PV plants will drop by about 10% in the second decay (after 2020 Ger.)
• Traditional solution in PV Industry have to work: further reduction of today's investment costs by another 5% (about -0.15€/Wp)
• This is today cheaper than all other solutions like battery storage ~0.5€/Wp, EV charging infrastructure
• Fighting against grid limitations by reducing prices!!
Thank You for your Attention

Download University website: www.zhaw.ch/~bauf

see also journal publication: Progress of Photovoltaics, 2010
Online ISSN: 1099-159X; http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1099-159X/homepage/custom_copy.htm