The Meaning of Photovoltaics to Future Grid Stability

Gunnar Kaestle, Institute of Electrical Power Engineering

Berlin, 2011-01-24
Agenda

- What Does System Stability Mean?
- Grid-friendly Connection Requirements
- Active Power Frequency Response
- Synthetic Inertia
- Economics of Learning Curves
Stability Aspects

- A simplified view on the stability of interconnected systems demands
  - sufficient voltage stability margins
  - sufficient rotor angle stability margins
  - sufficient frequency stability margins
  - sufficient transmission capacity margins
  - sufficient economical margins

- This presentation will focus on frequency issues.
Agenda

- What Does System Stability Mean?
- Grid-friendly Connection Requirements
- Active Power Frequency Response
- Synthetic Inertia
- Economics of Learning Curves
Requirements for the Connection to the Grid

- Photovoltaics has become system relevant
- Ca. 80% of PV power is connected to the LV grid
- LV feed-in was regarded as „noise generator“
- In case of minor disturbances, LV feedings had to disconnect

- This is now a harmful setting, see over frequency tripping at
  - VDE 0126-1-1: 50.2 Hz
  - EN 50438: 51 Hz
  - IEEE 1547: 60.5 Hz
A Worst Case Scenario

- Over frequency incident due to a loss of load (5 GW, eg. export to Italy)
- 10 GW of low voltage PV disconnects and reconnects ~ 30s later
- Yo-yo effect until sunset?
Better Ideas for Over Frequency Situations

- droop controlled power reduction
- known principle from TransmissionCode 2007 and the MV guideline
- ENTSO-E drafted requirements for all generators (size class A: 400 W-100 kW)
- Forum network technology / network operation (FNN) is moderating the new requirements for LV generators
Agenda

- What Does System Stability Mean?
- Grid-friendly Connection Requirements
- Active Power Frequency Response
- Synthetic Inertia
- Economics of Learning Curves
Active Power Frequency Response

- Similar to Delta Control @ Danish wind parks
- Also known as primary control power
- Option to substitute „must run“ thermal power plants
- Reduced energy harvest is small

- BNetzA plans to allow pooling of primary balancing power

Loss of energy yield by reducing max. output
Agenda

- What Does System Stability Mean?
- Grid-friendly Connection Requirements
- Active Power Frequency Response
- Synthetic Inertia
- Economics of Learning Curves
Why Synthetic Inertia?

- Inertia keeps ROCOF (Rate of Change of Frequency) low in case of active power imbalances
- Provides a short term energy storage: „instantaneous reserve power“
- In-built, passive security feature

- but: communicating energy storages may cause oscillations
  - inter-area oscillations
  - power system stabilisers (feature of future PV systems?)

[T. Weißbach 2009]
Who cares?

- Smaller Interconnections such as the synchronous zone of Hydro Québec’s TransÉnergie
- Islanded power systems such as Ireland and Great Britain
- ENTSO-E about the long term integration of wind power (and solar power?)
- Energy storage needed for inertia emulation:
  1 MWs per MW$_p$ @ $T_\alpha = 10$s
Agenda

- What Does System Stability Mean?
- Grid-friendly Connection Requirements
- Active Power Frequency Response
- Synthetic Inertia
- Economics of Learning Curves
Learning Investment for Small and Large Scale PV-Systems

- Assumptions: turn-key installation price & learning target
  - 3000 €/kWp (S) ⇒ 2000 €/kWp
  - 2000 €/kWp (XXL) ⇒ 500 €/kWp
- \( P_{\text{cum}}(t_0) = 20 \text{ GWp (e.g. Jan 2010), progress ratio 80\%} \)

- Turn tariff parity into sustainable business models!
Questions?

Please meet me during the coffee break.

Isocost curve sweep for the US residential sector in 2012

[Breyer et al 2009]