3 MWp vertical E-W oriented system in Germany

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Advantages of vertical PV

Three main advantages:

• #1 - gaining yield: 10% typical, 15% possible, both on grassland
• #2 - gaining market value: +7% (nowadays, in Germany)
• #3 - lowering footprint: „no“ ground coverage, agricultural usage of plant area
#1 yield gain

• The yield of a vertical system depends strongly on bifaciality compared to a common (monofacial) system:
  → with BF < 80%: same or lower yield
  → with BF 85-90%: ~10% more yield
  → with BF 95-100%: ~15% more yield

• this is valid for typical conditions in Germany (albedo ~20%)
  → lower gain for lower latitudes (unless with higher albedo!)
  → larger gain for higher latitudes

• in our configuration (10m row spacing / 2m active height), mutual row shading still causes 5-10% loss
The cost of electricity is one side of the medal - its value is the other one.

Nearby any PV installation worldwide has its production peak at (sun-) noontime.

In a system with low share of PV, this is very useful, as it meets demand!

But in a system with high share of PV, it becomes a disadvantage.

→ What does high share mean?
Germany today: approx. 7% PV (annual average)
→ Is this a high share?
#2 produce & forget?

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→ At least it’s enough to drive down the wholesale price at noon as low as it has only been at midnight for many decades!
#2 LCOE vs. „LVOE“

- German electricity wholesale price in Q2+Q3 2016 (average):
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#2 LCOE vs. „LVOE“

- German electricity wholesale price in Q2+Q3 2016 (average):
- production of a vertical bifacial PV plant comes mainly...
#3 Agriculture

- Large distances between rows are needed due to mutual shadowing.
- Resulting in 10-15m spacing, allowing the usage of common agricultural machines on grassland.
- Even several crops could be cultivated – but is it meaningful?

Module row, height 3m approx.

Grass swathe after mowing with common agricultural mower (10m) → to be harvested commonly

Remaining green area (~1m)
Test site

- installed in May 2015
- total capacity **28 kW**
- 96 modules in 3 rows, 12 strings
- customized 66-cell module with n-type bifacial cells, BF = 87%
- three years of gathering data & experience

- annual energy gain +10% (real, not „up to“)
- average price gain (based on EEX prices) +7%
Test site
Test site
Specific yield

Reference (monofacial south)
vertical East-West

Januar  Februar  März  April  Mai  Juni  Juli  August  September  Oktober  November  Dezember

0.0  50.0  100.0  150.0  200.0

08:00  10:00  12:00  14:00  16:00  18:00  20:00
5 kw  10 kw  15 kw  20 kw  25 kw  30 kw
Next step: Demonstration plant

- Site: Dirmingen, Saarland (south-west Germany)
- Size: 10 hectares (module area)
- Power: **3 MW (full size) / 2 MW (first phase)**
  → 300 kW per ha, compared to 800 kW per ha for conventional plants
- Yield estimate: **1.080 kWh/kW**
  → compared to 980 kWh/kW on the same site for a conventional plant
  → global irradiation: 1.090 kWh/kW
- Commissioning in **Q1-2018**
Site map
Installation scheme

row spacing: 10m
Installation scheme

- Active height: 2m
- Distance from ground: 0.6-1.0m
- Total height: 3m
Components

- Modules

Finding a suitable module is still challenging, so...

Christmas is coming close – here’s our wishlist for module manufacturers supplying Santa Claus:
module requirements: junction boxes

not good: X% coverage of one single cell means same percentage of loss for the whole rear side!

good: split junction boxes or "pencil type" junction boxes without any coverage of cell area
module requirements: cables

necessary:
Cables long enough to interconnect modules in landscape orientation without shadowing the rear side
module requirements:
cell/electrical design

preferred: standard 3-substring design (mutual row shadowing)

preferred: large, full-size cells (shadowing from the racking)

less preferred: half-cut cells (lower shadowing tolerance)

most important: high bifaciality!
module requirements:
module design

bifacial modules for vertical installation means:
completely symmetrical design

double glass is needed to be weatherproof

if AR coating makes sense for the „front“ side, then it makes sense for the „rear“ side too
Components

• Inverters

State-of-the-art inverters can be used, with some restrictions:

- mpp-tracking with „global peak“ algorithm
  (surprisingly for us, this is not a given)
- at least 2 mpp-trackers
- decentral

Sizing is similar to monofacial south oriented plants
(here: ~80% of nominal DC power)
Components

• **Racking**

No state-of-the-art products available → proprietary development

- high wind load on a cantilever system
  → challenging mechanics
- low shadowing
- quick fastening and mounting solutions
- patent pending

• **Cabling**

less challenging, but some issues to be considered:

- longer distances
- avoiding shading on the rear side
- durable fixation over spacings
Conclusion

• vertical E-W PV plants are nothing crazy, but a real choice
• in grid systems with high share of PV, the East-West component becomes essential
  → vertical bifacial can deliver this cheaply
• gain in yield & proceeds is proven
• improvements in module & plant design to be done

→ only small steps are necessary to make vertical bifacial a real business case in many markets!
Thank you for your attention!

Questions ... ?

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