# Concerning the efficient connection of VLS-PV to national grid systems

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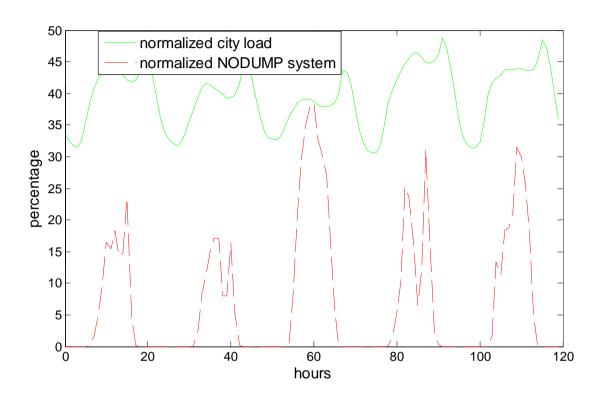
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#### The Problem



A large PV system may instantaneously provide more energy than the grid can absorb

## Address problem in 4 stages

- 100% "Flexible: Grid (all solar acceptable)
- More realistic flexibility (some acceptable)
- The real world (ehh!)
- Storage to the rescue

Caution: We only have hourly data

# Flexibility

- Qualitatively: The ability of the grid to turn down its generators in order to accommodate large PV input
- Quantitatively: 1 Ratio of minimum to maximum levels of generation
- Obscuring factor: Economic issues (ignored in this study)

#### IEC Statistics for 2006

- Total generating capacity = 10.5 GW
- Total electricity production = 50.3 TWh
- Min hourly prod/Max hourly prod = 0.64

## For 100% Flexibility

Q: What is maximum size of no-dump PV?

A:  $5.4 \text{ GWp} \Rightarrow 8.75 \text{ TWh}$ = 17.4% of total requirements

# What if we allow some dumping?

System size	% annual needs provided by PV	% of PV dumped
ND	17.4	0
2xND	31.6	9.0
3×ND	37.2	28.7
4xND	39.9	42.6
5×ND	41.7	52.0

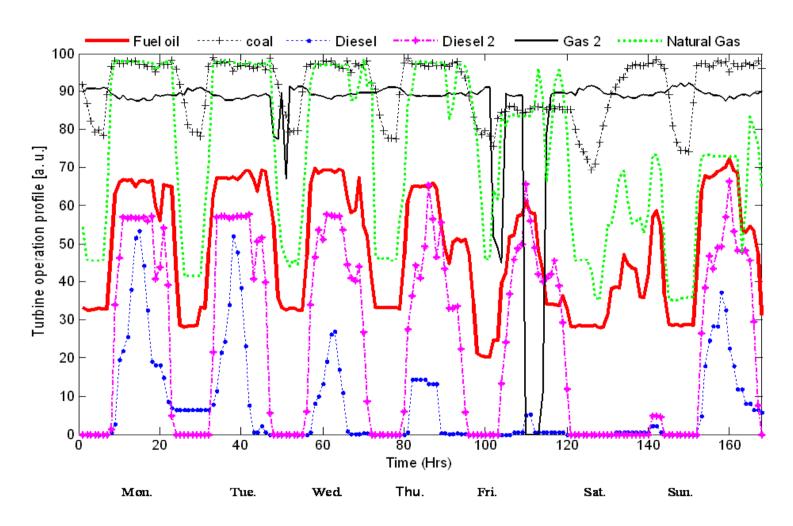
## What if flexibility is < 100%?

Flexibility	ND size [GWp]	% annual needs provided by PV
100%	5.4	17.4
90%	4.2	13.7
80%	3.1	9.8
70%	1.7	5.5
65%	0.83	2.7
60%	0.68	0.2
50%	0.05	0.02

## Provisional "good" news

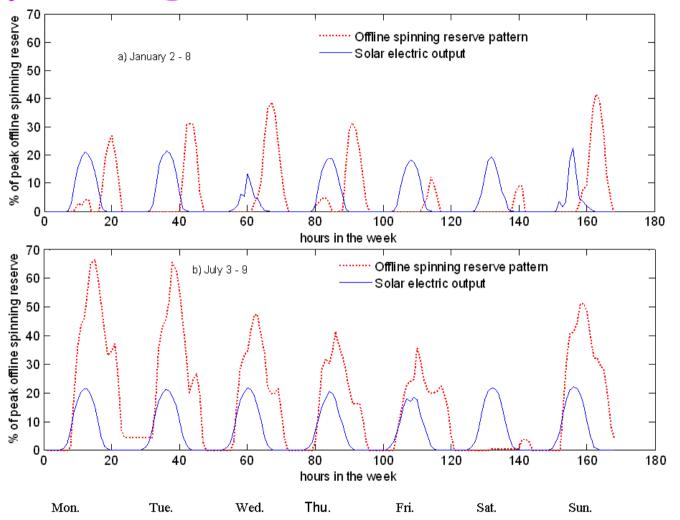
- If the Israeli grid is really 65% flexible:
- No-Dump PV system size is 830 MWp
- Provides 2.7% of annual requirements

#### The real world!



Only spinning reserve is readily "solarizable"

## Spinning reserve vs. solar



No such thing as a no-dump system !!!

# A 830 MWp PV system in reality

- Not "No-dump"
- Dumps 43% of its annual production
- Replaces only 28% of spinning reserve
- Provides only 1.5% of annual needs

### Storage to the rescue

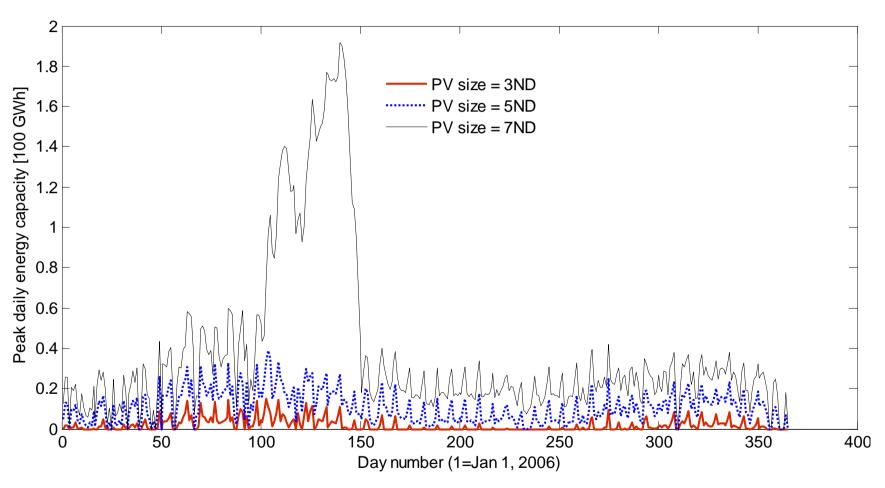
Assume: 75% round-trip storage efficiency and grid flexibility ff = 0.70

Strategy 1: Fix storage size at *nominal* value 100 GWh and dump any excess generation

Result: 25% of annual needs provide by solar, only 10.4% of PV generation lost (storage inefficiency)

Bonus: 42% provide by solar if we allow total PV loss of 20% (dumping plus storage inefficiency)

## Alternative Strategy



Ramp down baseload plants for 50 days in spring

# Results of spring ramp-down

- 1. Increases solarizable part of load
- 2. Enables direct grid-injection of more PV

Baseload reduction from 30% to 25% enables PV to supply 44.4% of annual load.

Grid operation at ff = 0.80 raises annual PV penetration to 59%

#### Additional results

Spreading PV systems around the Negev does not improve grid penetration substantially

Sun-tracking slightly improves situation

Seasonal re-scheduling of base-load plants via storage massively improves grid penetration

IEC should prefer gas to coal (or nuclear) in future - to keep system flexibility high

#### Conclusions

- Storage plus baseload re-scheduling can allow massive solar penetration
- · Need more actual plant data
- Hourly data are probably too coarse
- · Need to quantify storage efficiency
- Need to include economic constraints
- Need to keep grids as flexible as possible

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