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

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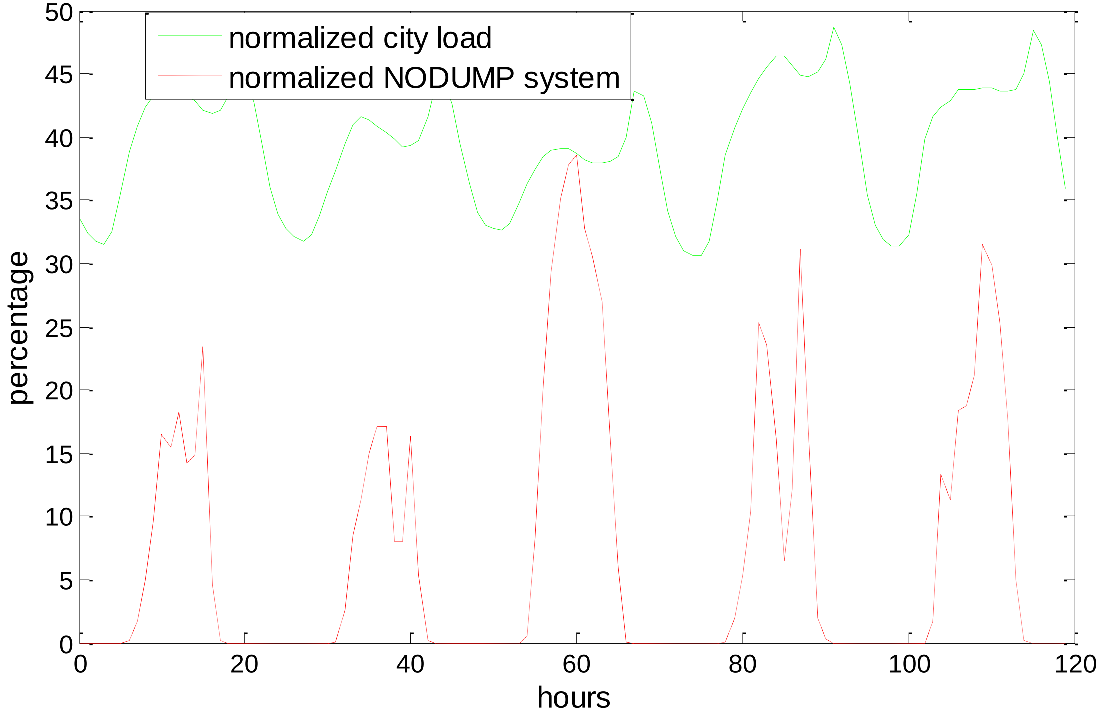
# The Problem




**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 GWp $\Rightarrow$ 8.75 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 |
| 3xND | 37.2 | 28.7 |
| 4xND | 39.9 | 42.6 |
| 5xND | 41.7 | 52.0 |

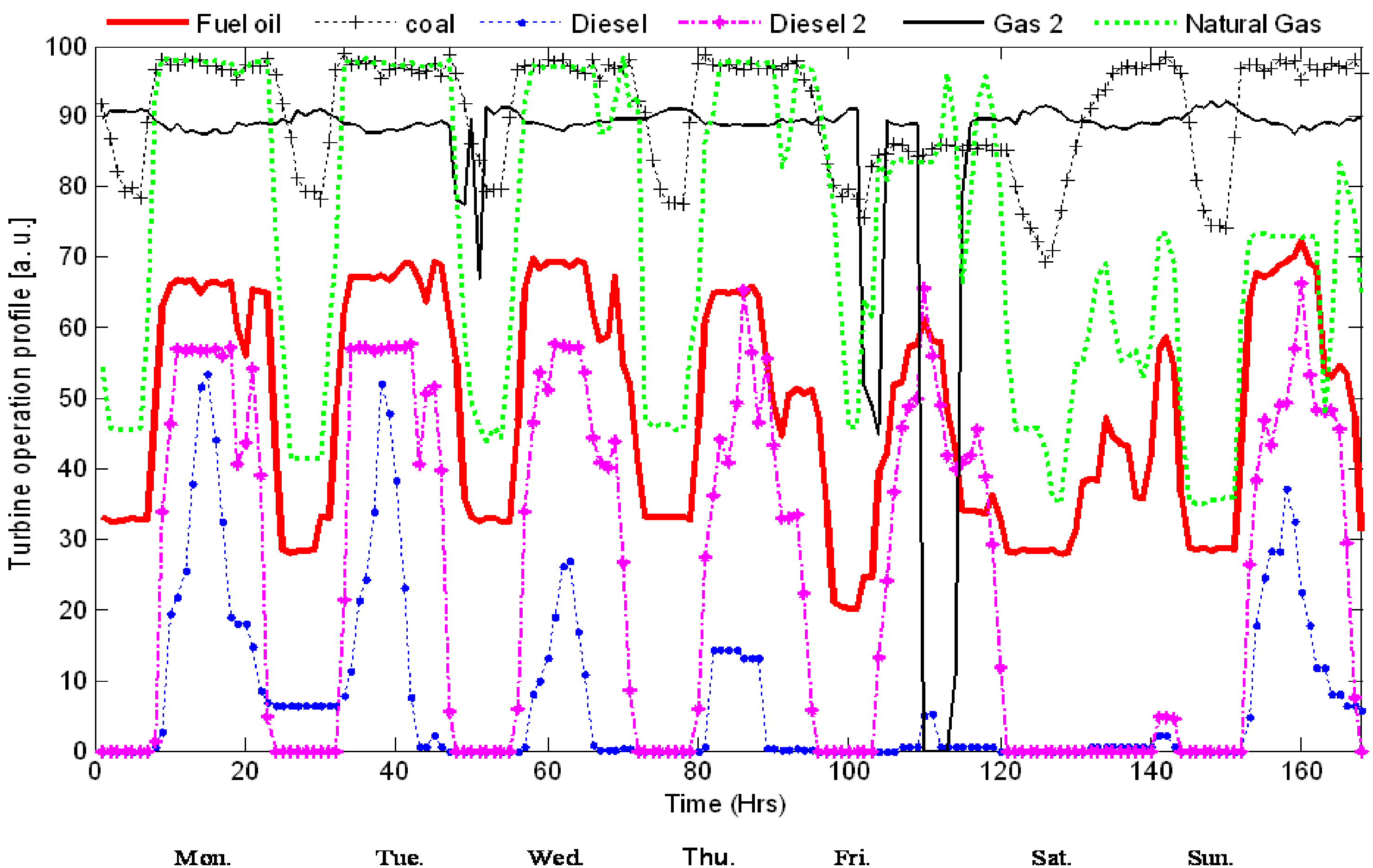
# What if flexibility is < 100% ?

| 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

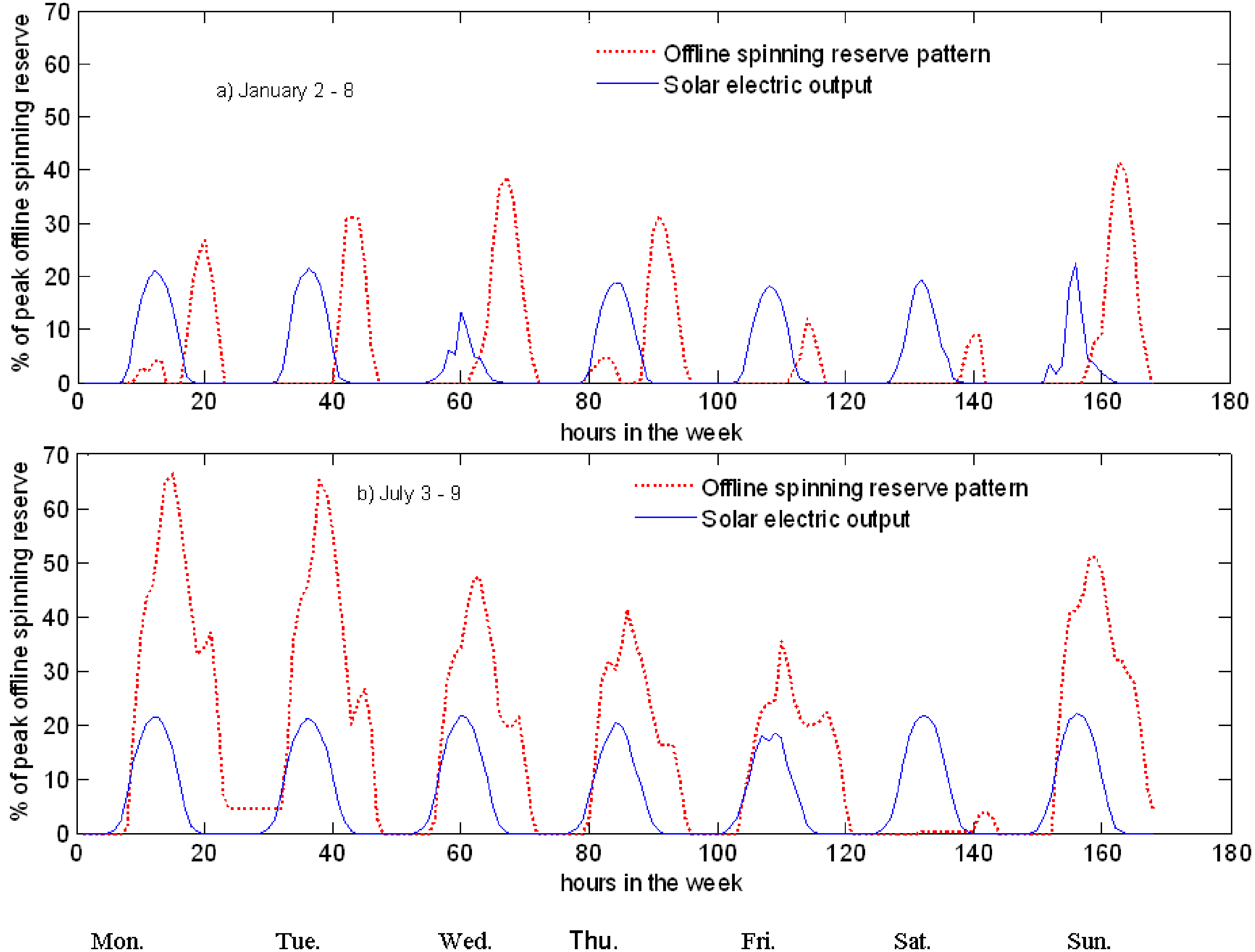
- *If* the Israeli grid is really 65% flexible:
- No-Dump PV system size is 830 MWp
- Provides 2.7% of annual requirements

# 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

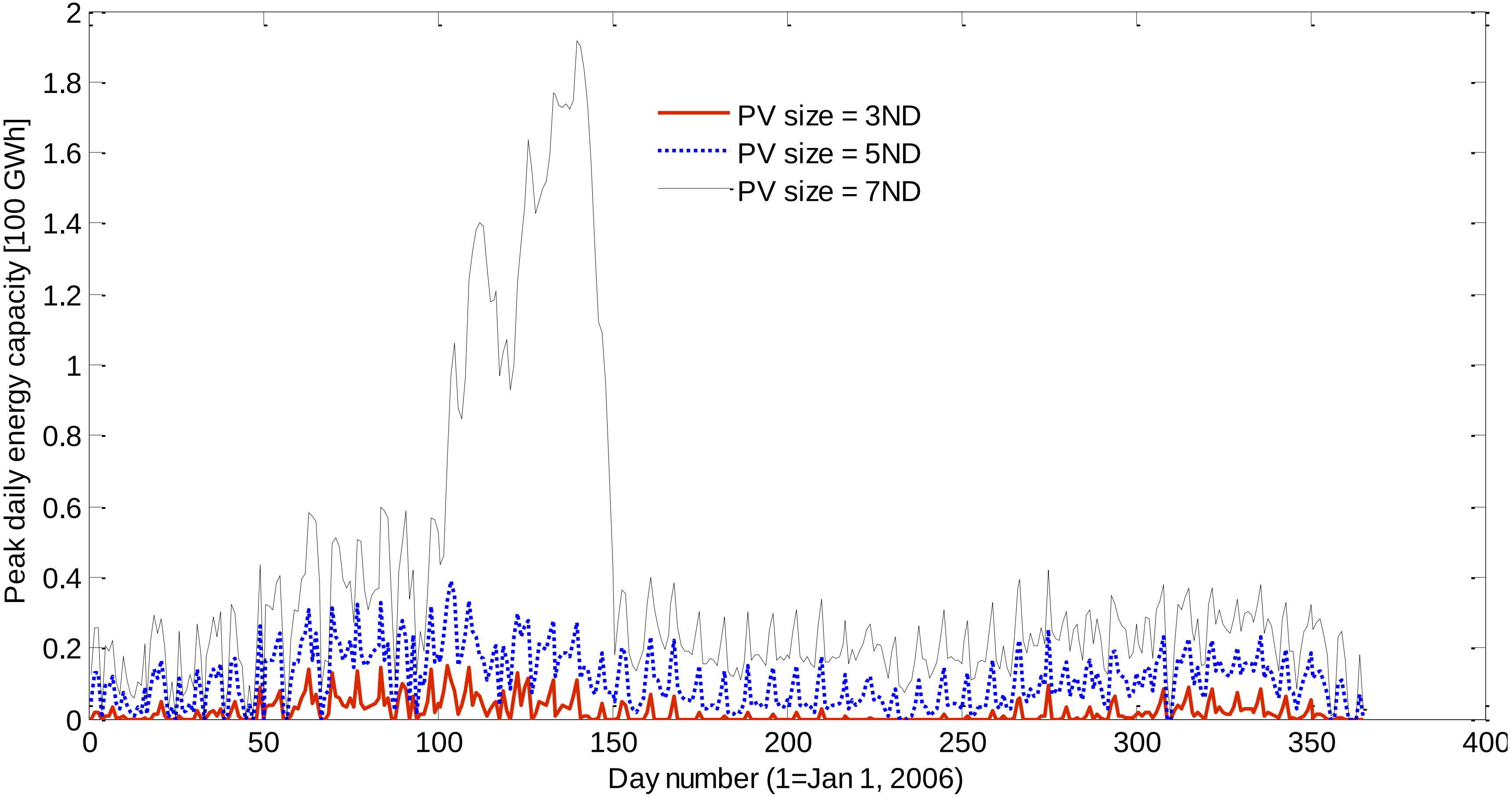
Assume: 75% round-trip storage efficiency
and grid flexibility *ff* = 0.70

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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