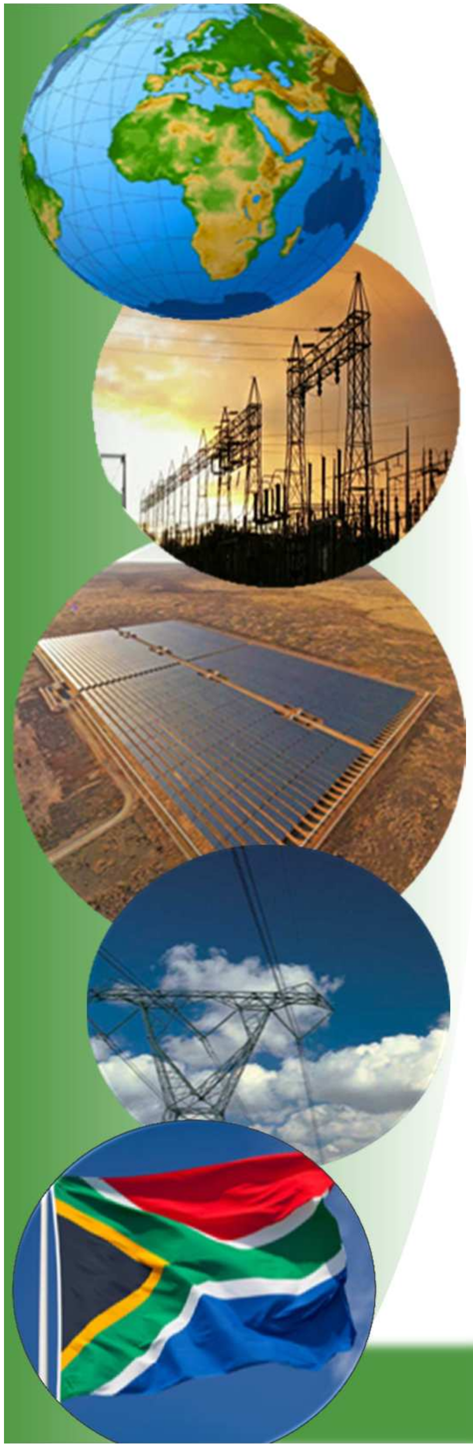

Methodology for Assessing the Impact of Intermittent Generation on Utilities

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Introduction

- The Issue
- Approach
- Intermittency and Diversity
- System State Limitations
- Dynamic Assessment and Inertia
- Cost Implications
- Dispatch Optimisation

The Issue

- “Cheap” renewable energy is intermittent and non-synchronous
- Impact on reliability and operation of “Supplier of Last Resort”
- Goes beyond simple “Plant-level” Grid Code Compliance
- Cost/Reliability balance

Approach

- By how much and how fast does it change? – System Wide Requirement
- How big can the plant(s) be? – Localised system restriction
- What is the dynamic capability? – System wide restriction
- How much money?

Intermittency and Diversity (1/4)

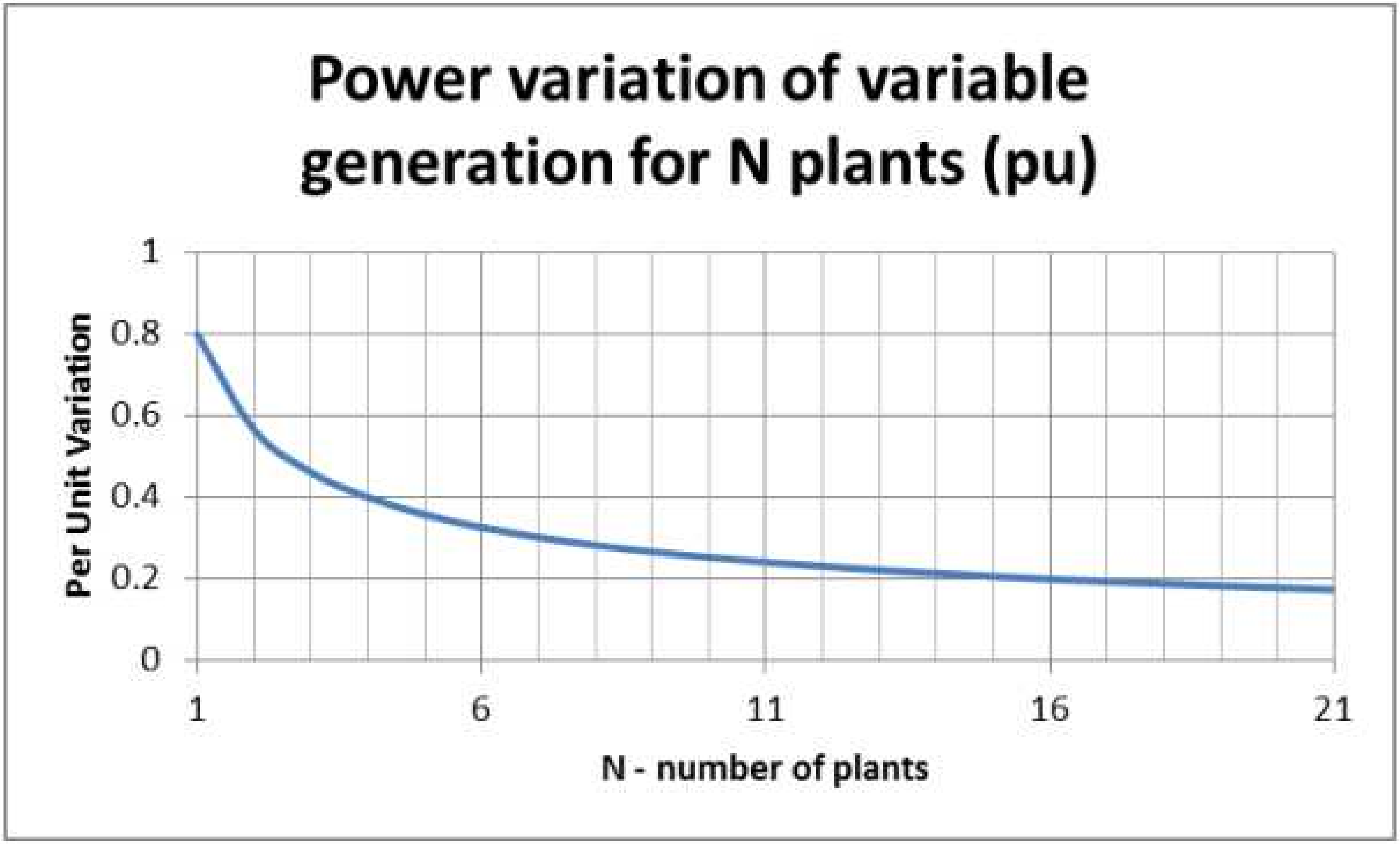
- PV can vary in output up to 80% in 1 minute
- Geographical diversity to reduce impact
  - Unlikely a cloud will impact plants “far away”
- For *N* plants mutually and sufficiently separated

$$r \propto \frac{1}{\sqrt{N}}$$

- Typically reasonable for separations of 20km or more
- Good approximation when data is unavailable

“Implications of Wide Area Geographic Diversity for Short-Term Variability of Solar Power”, A. Mills and R. Wiser, 2010

Intermittency and Diversity (2/4)

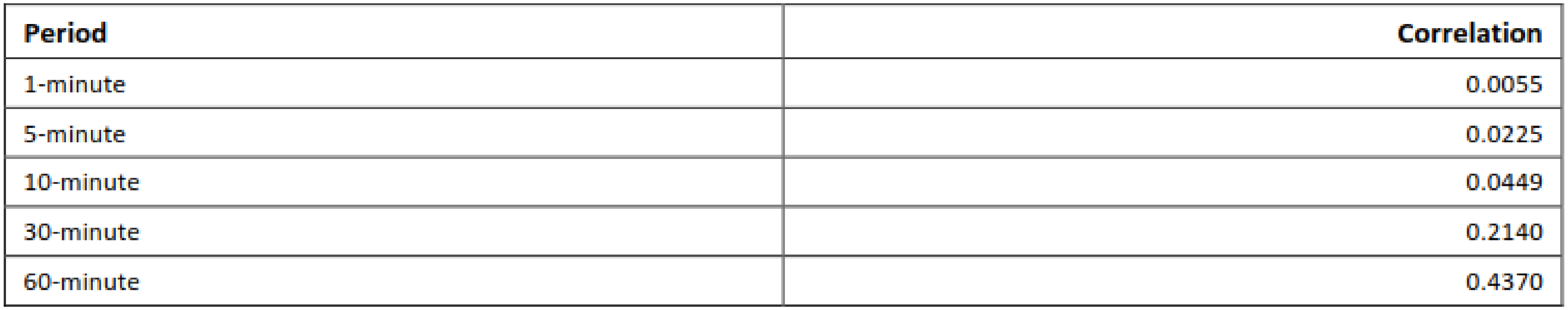


Intermittency and Diversity (3/4)

- When data is available:

$$\sigma_{\Delta P}^{t} = \sqrt{var(\Delta P^{t})} = \sqrt{\sum \sum Cov(\Delta P_i^t, \Delta P_j^t)}$$

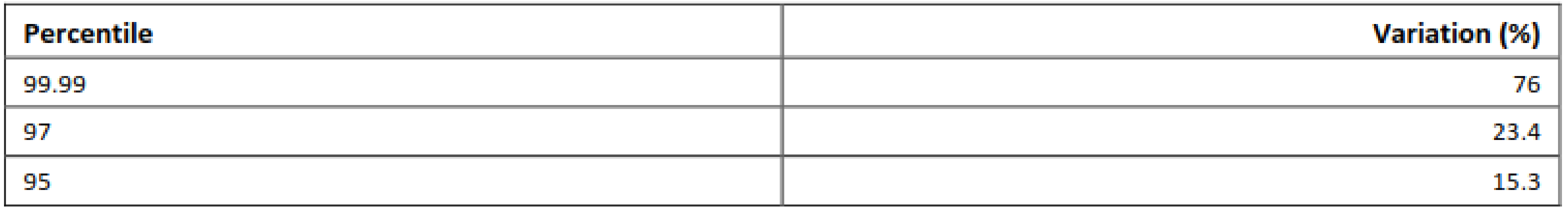
- As time periods increase, correlation between plants increases – the sun moves



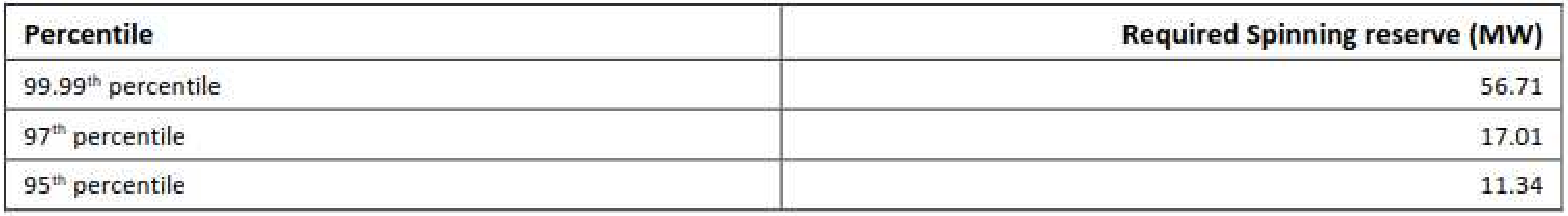
Period	Correlation
1-minute	0.0055
5-minute	0.0225
10-minute	0.0449
30-minute	0.2140
60-minute	0.4370

Intermittency and Diversity (4/4)

- Short-term variability affects spinning reserve requirements
- “Choosing” lower variability = increased risk of exceedance



Percentile	Variation (%)
99.99	76
97	23.4
95	15.3



Percentile	Required Spinning reserve (MW)
99.99th percentile	56.71
97th percentile	17.01
95th percentile	11.34

Steady State Limitations (1/2)

- Aim to assess how distributed renewables affect conventional system operation
- Individual plant sizes limited by locations and surrounding infrastructure
  - Natural tension between "prime mover" availability and evacuation capability
- Generation may exceed local load – results in back-feed into bulk transmission network
  - New protection considerations

Steady State Limitations (2/2)

- Lines become de-loaded and raise system voltages
  - Is there sufficient reactive compensation to mitigate?
- E.g. Solar power transition from afternoon to evening
  - Quick reduction in (local) generation + Quick increase in (local) load = possible low voltages
- Fault levels will end up decreasing due to (economic) re-dispatch of generation assets
  - Less synchronous generation online
  - Asynchronous fault level 1 tp 1.5 nominal current

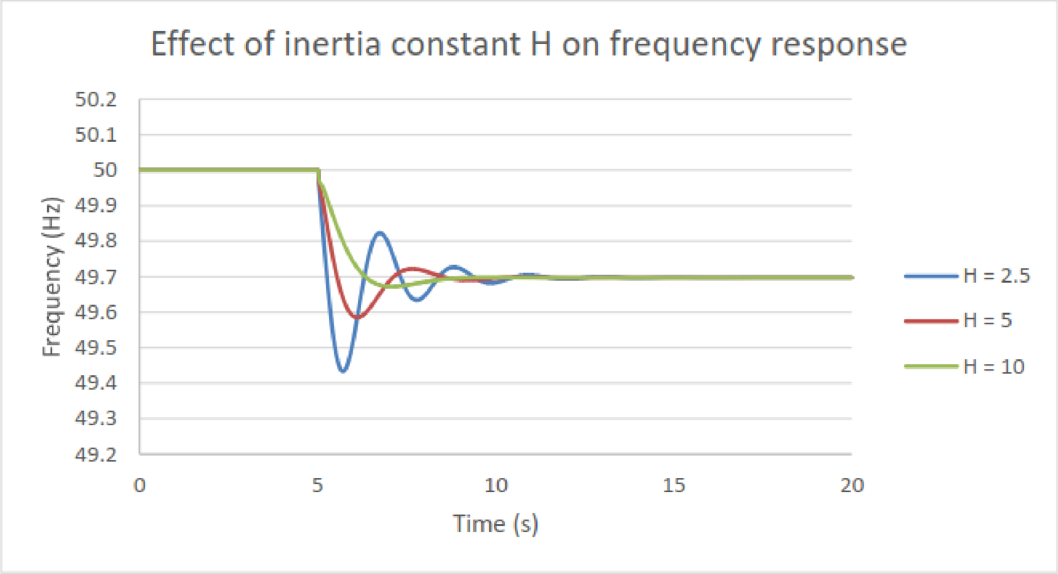
Dynamics and Inertia (1/3)

- Increased "cheap" resources leads to switching off of conventional generation
- System must be robust against natural intermittency, and unplanned generation outages
- Spinning Reserve = ability to recover
  - Loss must be less than available reserves
  - In principle only, ignores frequency protection
  - Frequency may drop below UFLS settings

Dynamics and Inertia (2/3)

- Frequency nadir function of :
  - System inertia (how fast frequency drops)
  - Governing capability (how fast power is restored)

$$H_{sys} = \frac{J_{sys}}{S_{nom_{sys}}}$$



Dynamics and Inertia (3/3)

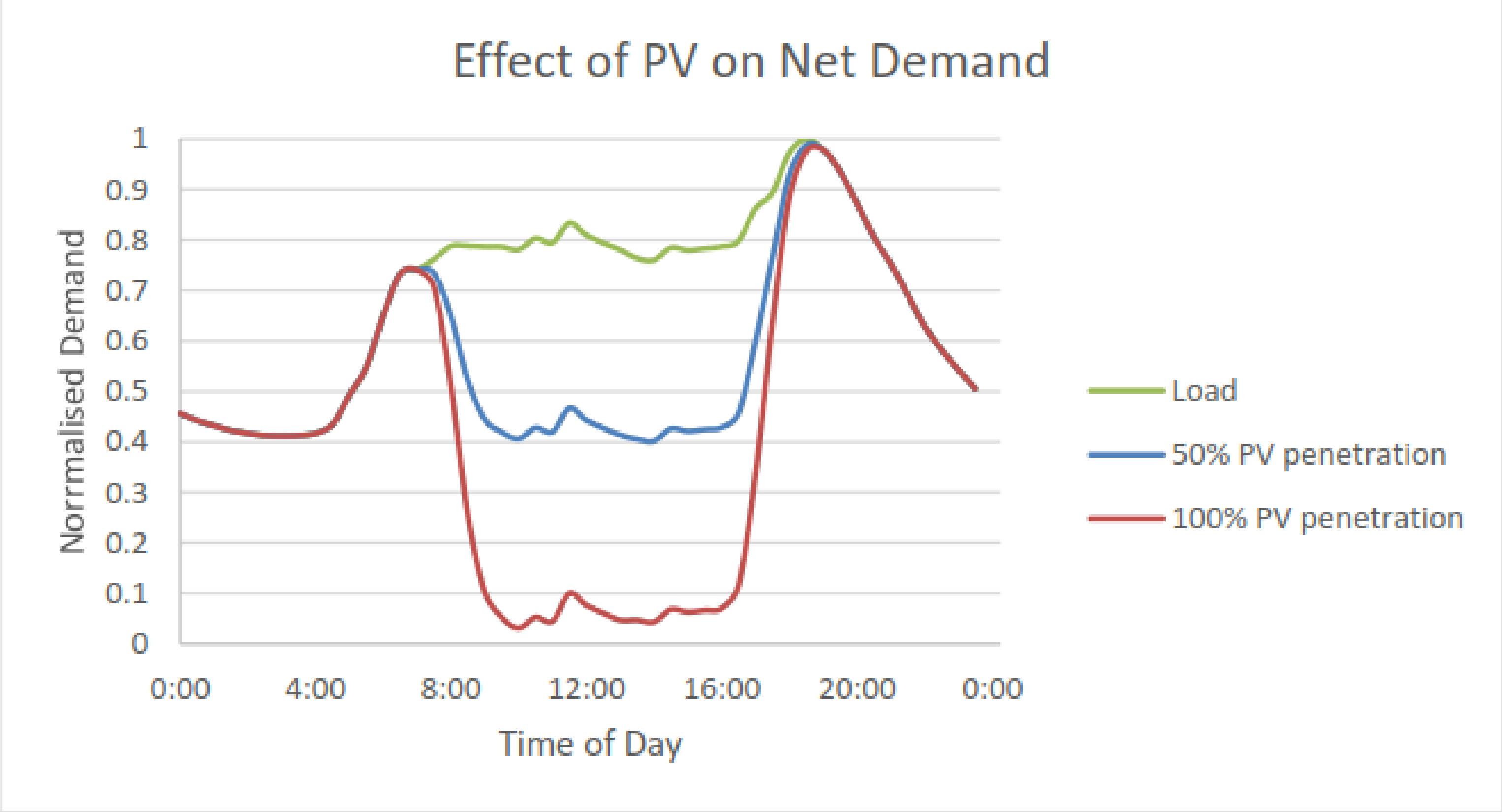
- Dynamic simulation can assist in determining a minimum inertia – hard limit
- To be assessed in conjunction with reserve requirements
- Combine inertia requirements with machine minimum dispatch levels (foot room and head room) gives a limit on penetration levels
  - Increased penetration = increased offline conventional generation = reduced inertia
- Technical limitation to penetration

Cost Implications (1/4)

- “Behind the meter” Embedded Generation
  - Reduce energy sales
  - Under-recovery on tariffs
  - Difficult to predict
- Utility Scale
  - No reduction in energy sales
  - However does affect supply costs
    - Sub-optimal dispatch of existing generation resulting from technical analysis and requirements
    - Some IPPs are more expensive than existing generation

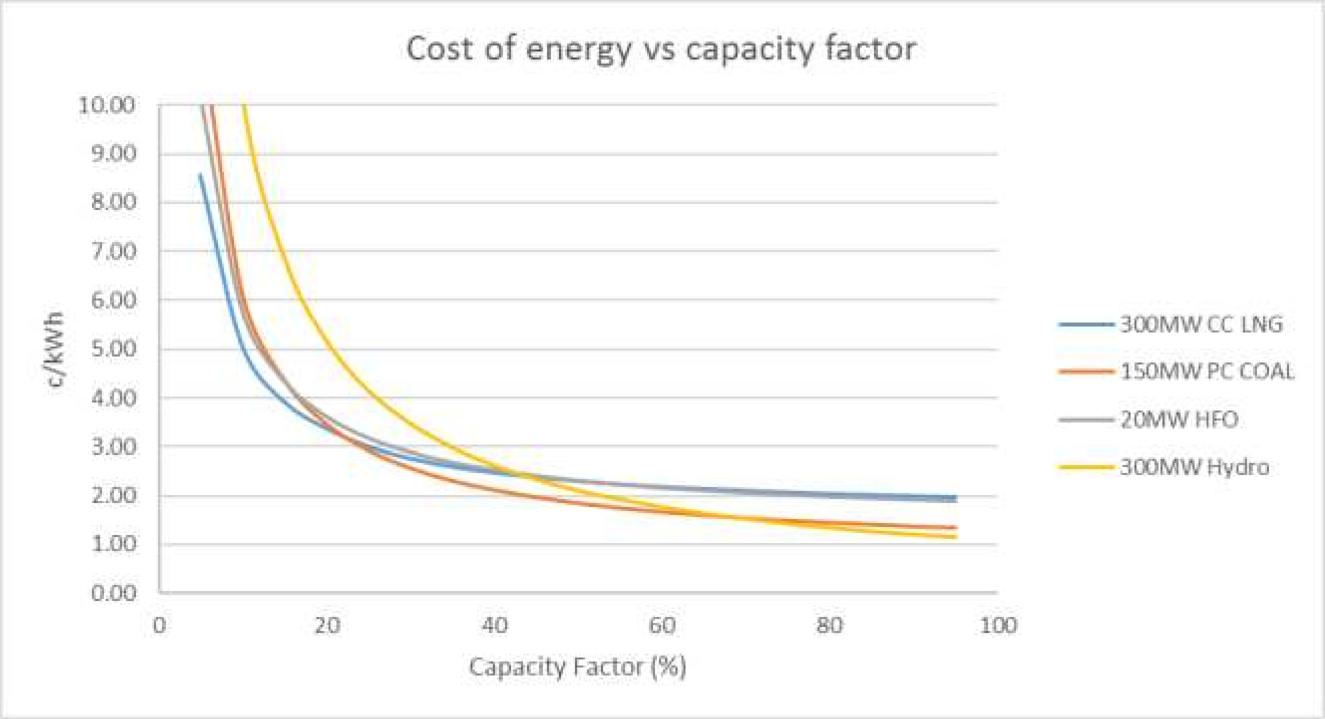
Cost Implications (2/4)

- Effect of PV on net demand (example)



Cost Implications (3/4)

- Penetration above 50% decreases existing plant capacity factor = increase in cost of energy

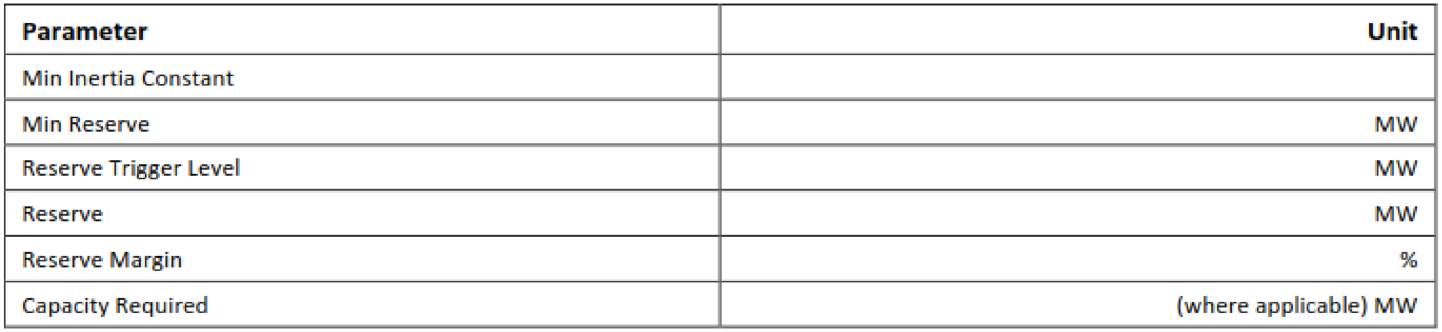


Cost Implications (4/4)

- Not just a simple matter of reducing instantaneous apparent costs of energy
- Wholistic approach required
- 50% penetration of previous example is not indicative of a “general answer”

Dispatch Optimisation

- Dispatch must be optimised to find an economical restriction subject to the constraints determined previously (e.g. PLEXOS or other specialist software)



Parameter	**Unit**
Min Inertia Constant	
Min Reserve	MW
Reserve Trigger Level	MW
Reserve	MW
Reserve Margin	%
Capacity Required	(where applicable) MW

Conclusions

- Determination of intermittency has been provided
- Technical limitations have been discussed
  - Interplay between System inertia, spinning reserve, and dispatch
- Effects on system costs and optimisation thereof presented
- While storage has not been explicitly considered, the effect would be to change the limits, not the approach to determining them