ResponsiveLoad Limited

The Edge Debate
Responsive Technologies

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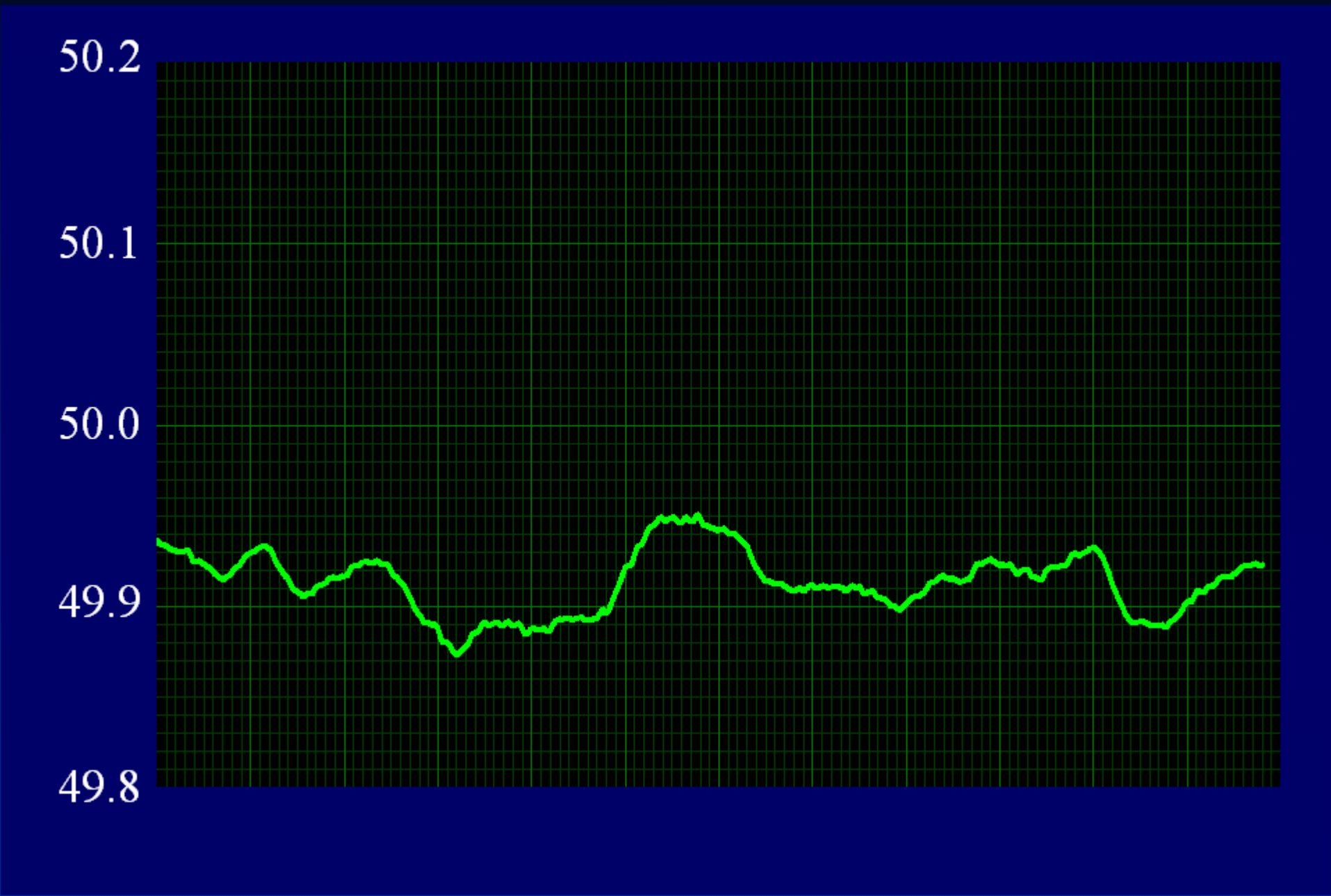
London 25th April 2005 - ICE

System frequency (Hz) Stavanger 10/6/4



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Response

- Response is capacity for Generators to change output quickly (seconds - minutes) when frequency shows imbalance
- System Operators buy Response (UK ~ £190m p.a.), but it is often mixed up with Energy & Reactive Load
  - Need to buy “head-room”, so less efficient running
  - Monoposony Market

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ResponsiveLoad

- Population of smaller, duty cycle, loads – such as fridges & air conditioners – Respond to frequency signal (when this has negligible consequence to user)
- Automatic, fast, reliable (and pure) Response always available
- Greater Grid stability, reliability and frequency control
- Lower Control Costs

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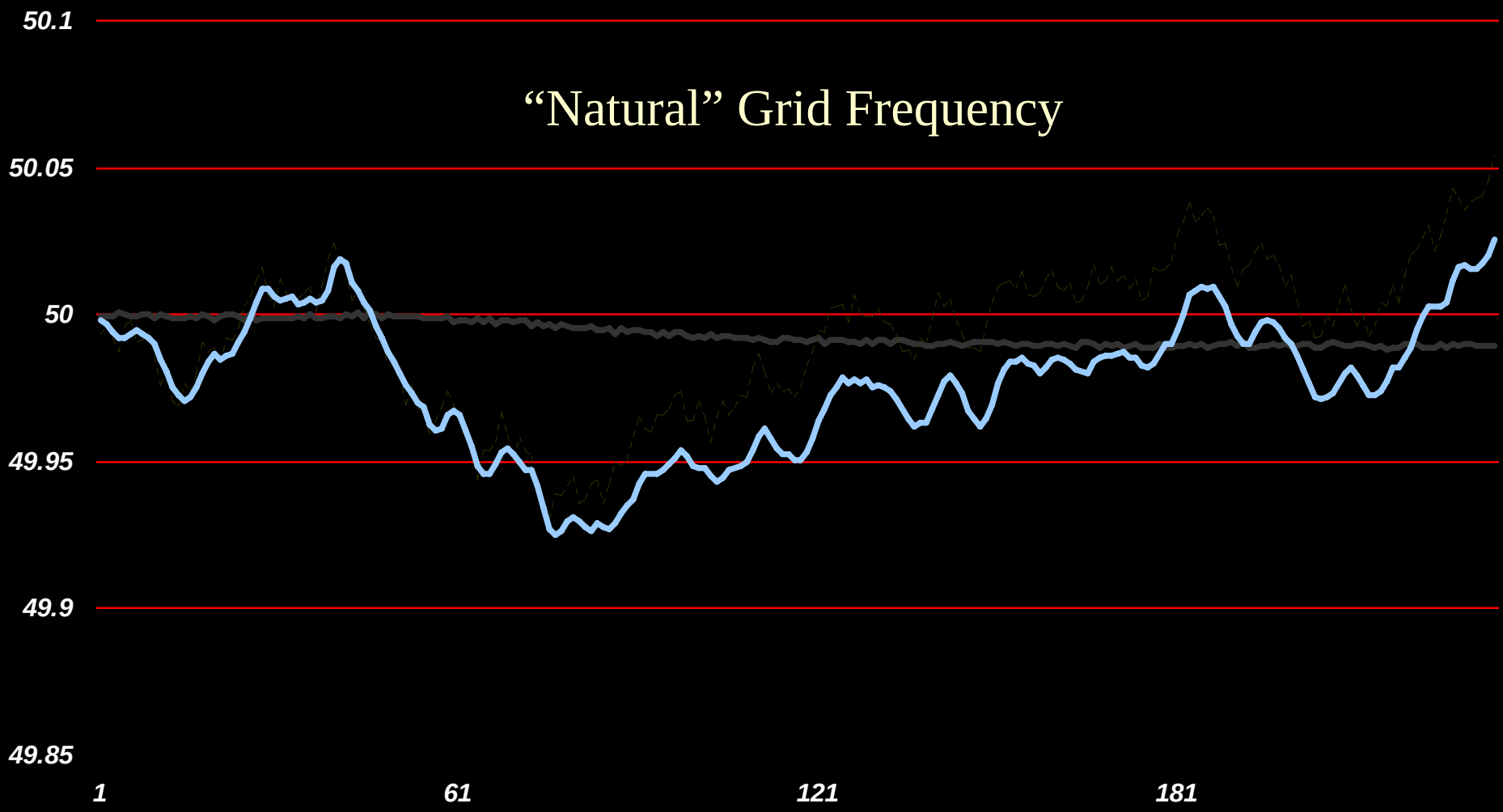
Responsive System Frequency



"Natural" Grid Frequency

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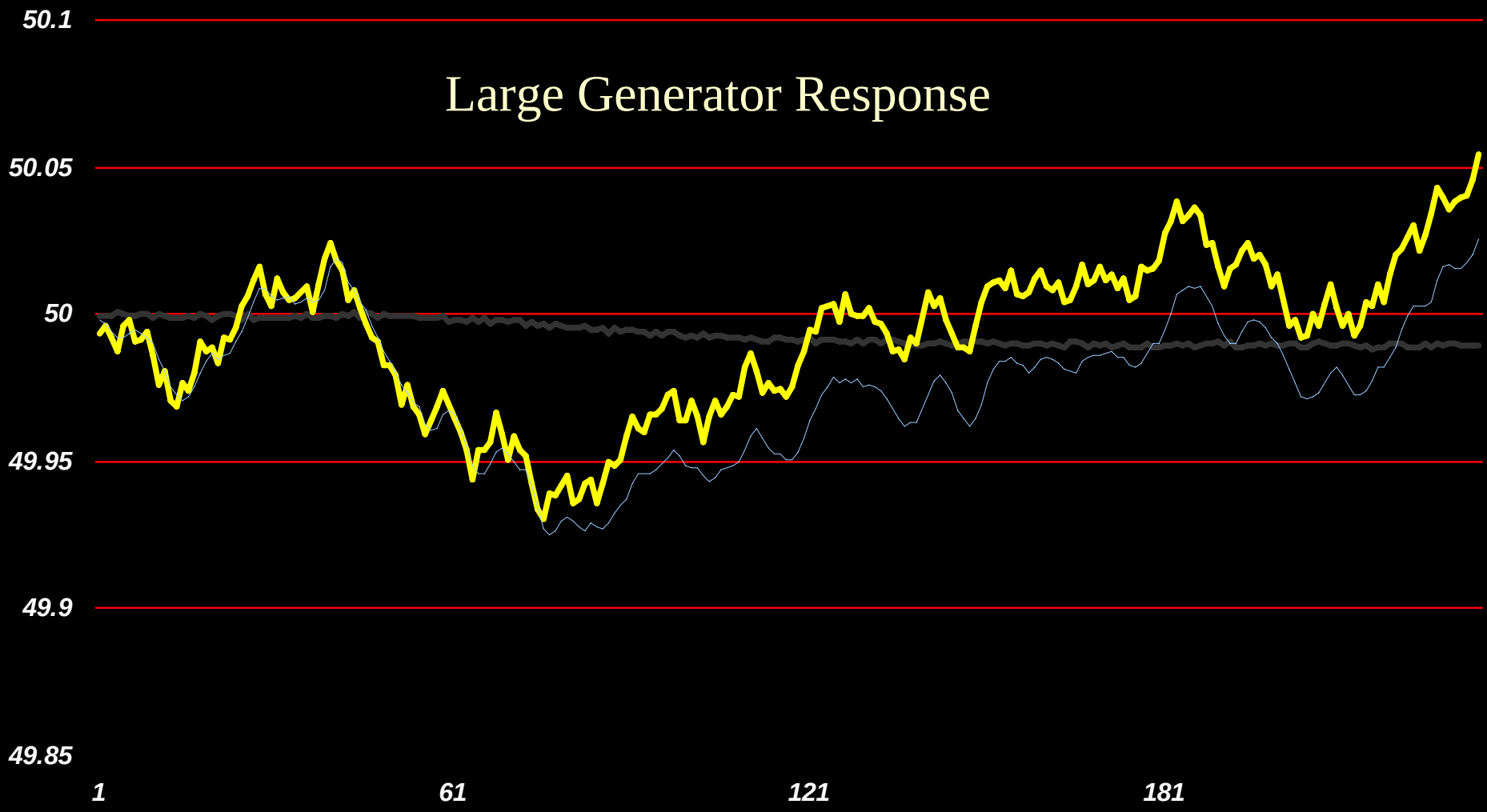
Responsive System Frequency



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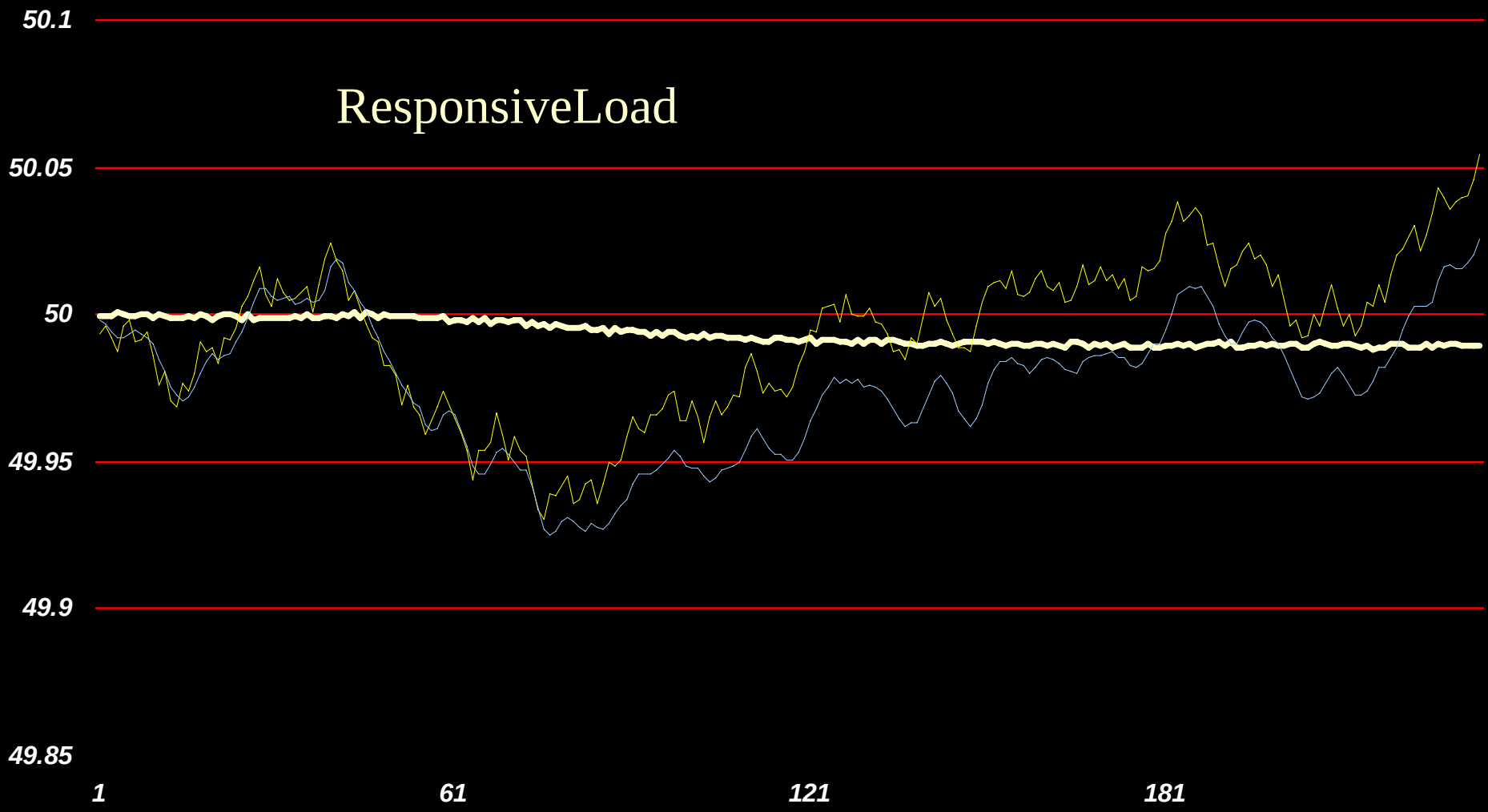
Responsive System Frequency



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Emergent Properties

- ResponsiveLoad is effectively highly efficient electricity storage
  - zero energy loss
- Borrowing (or lending) energy of ResponsiveLoad devices damps frequency variations (without the control lag of large gensets)
- Integration performed by system frequency exposes a fast, reliable, shared and co-ordinating signal to all participants
- Frequency tells you whether grid is long or short
  - Frequency error => W imbalance
  - Clock change => Wh imbalance

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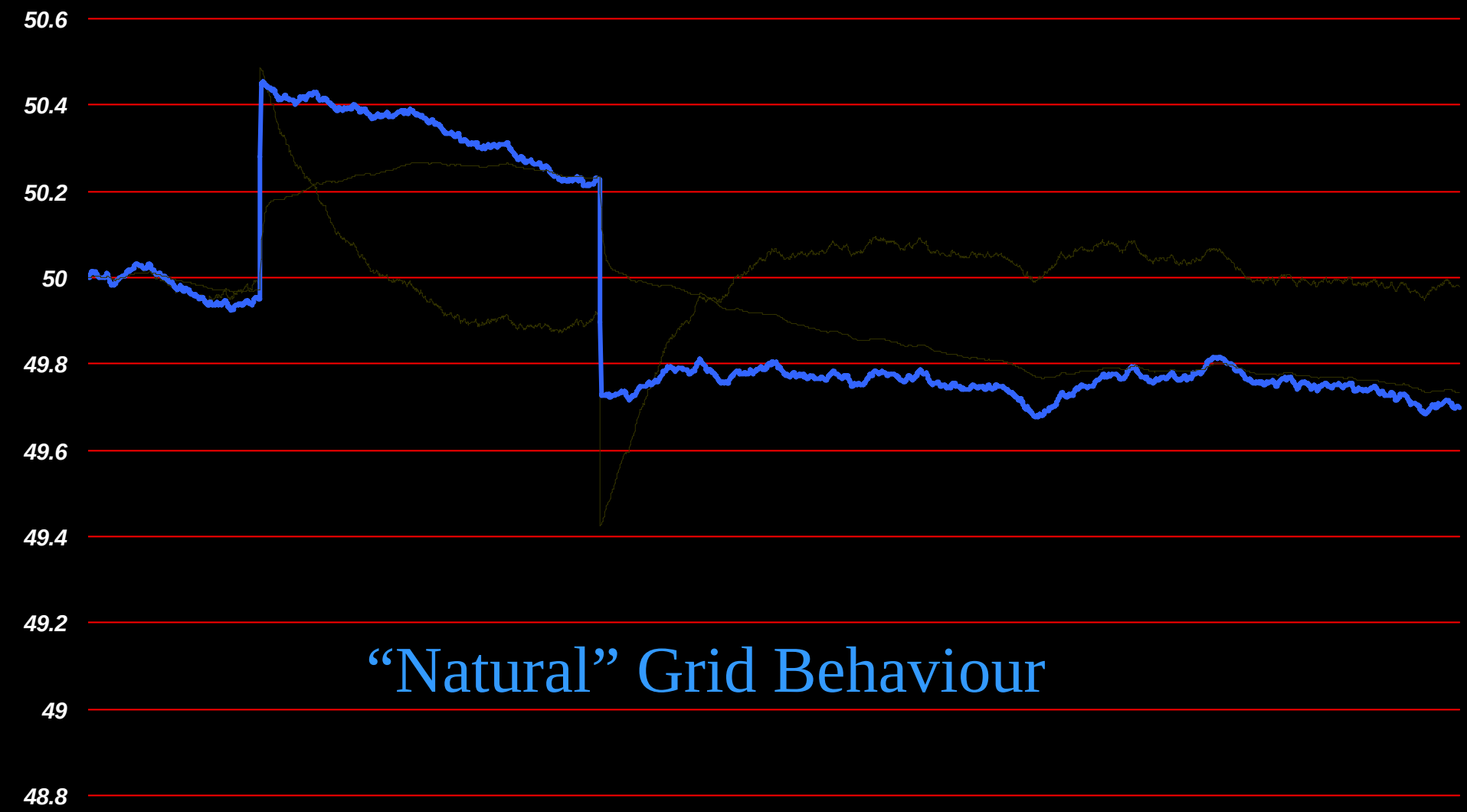
Grid Perturbations & Storage



"Natural" Grid Behaviour

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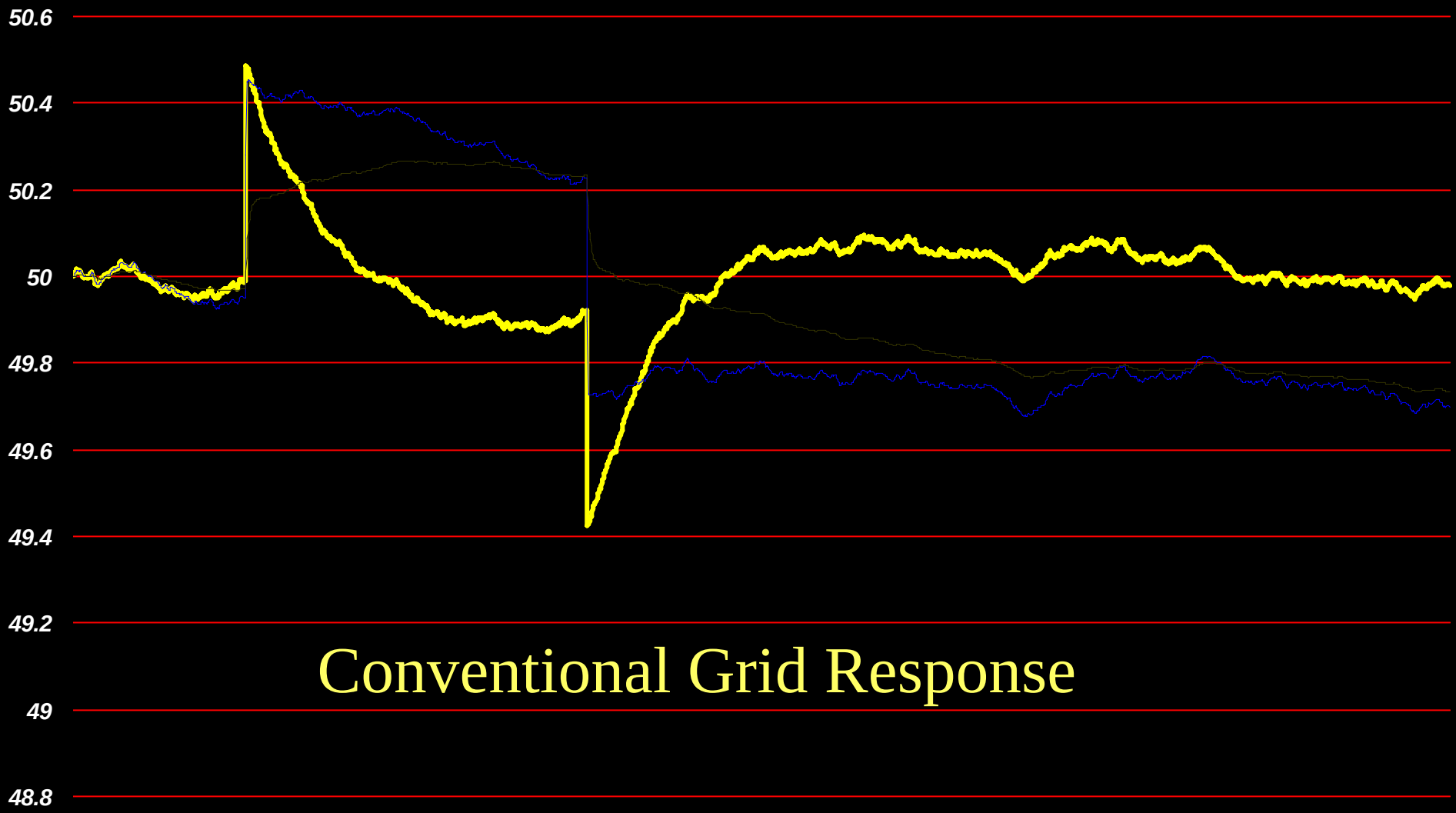
Grid Perturbations & Storage



Conventional Grid Response

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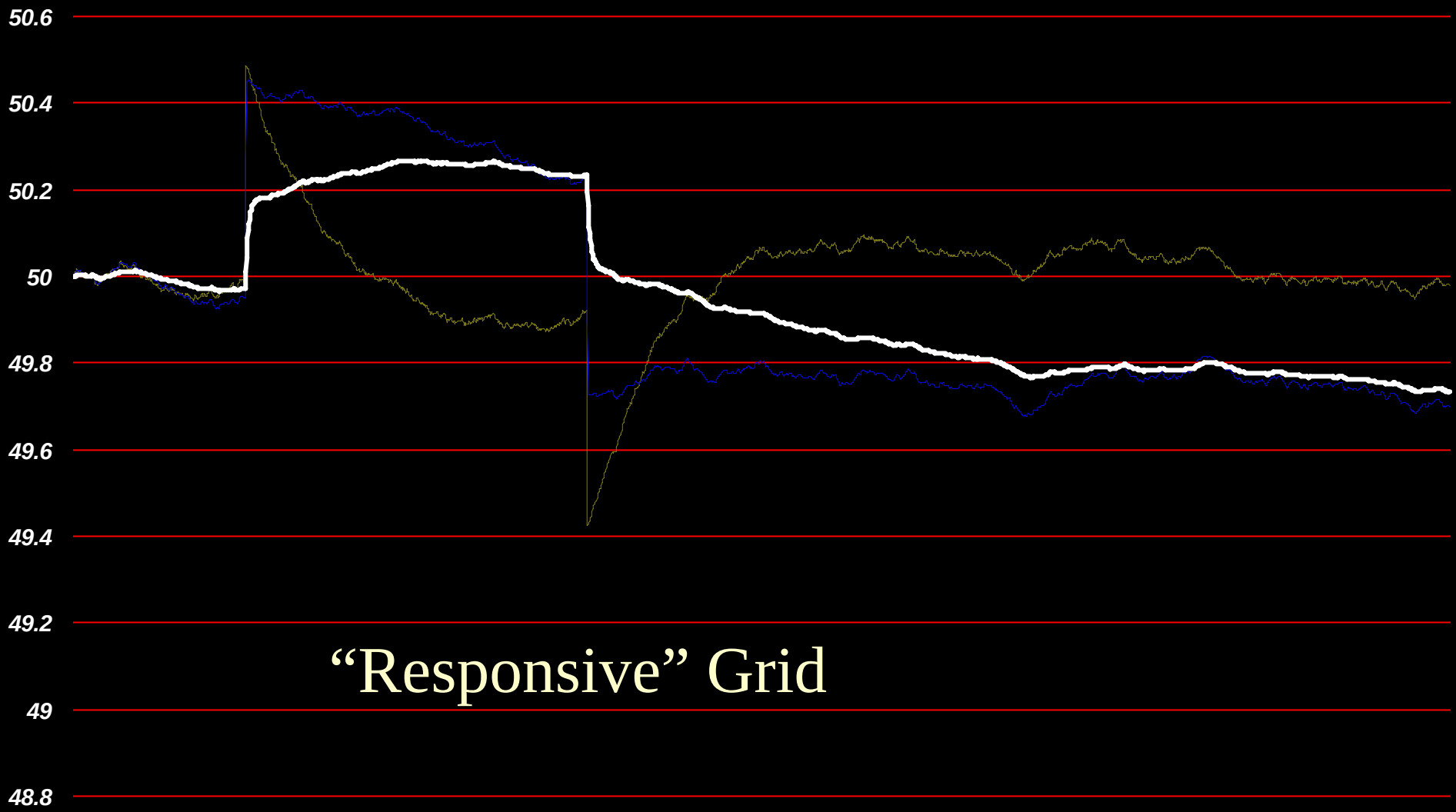
Grid Perturbations & Storage



"Responsive" Grid

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Markets & Prices

- Normally: Price ⟶ Market Imbalance
  - But we know Imbalance from Frequency
- So: Market Imbalance ⟶ Price?
  - Contingency Prices set in Advance?
  - Offers Real Time Price of Electricity?
  - Readily Available to All Devices?
- So automatic real-time demand side market participation?
  - Price Sensitive Appliances?
  - Do your Laundry When the Wind is Blowing!

Frequency Tells Price

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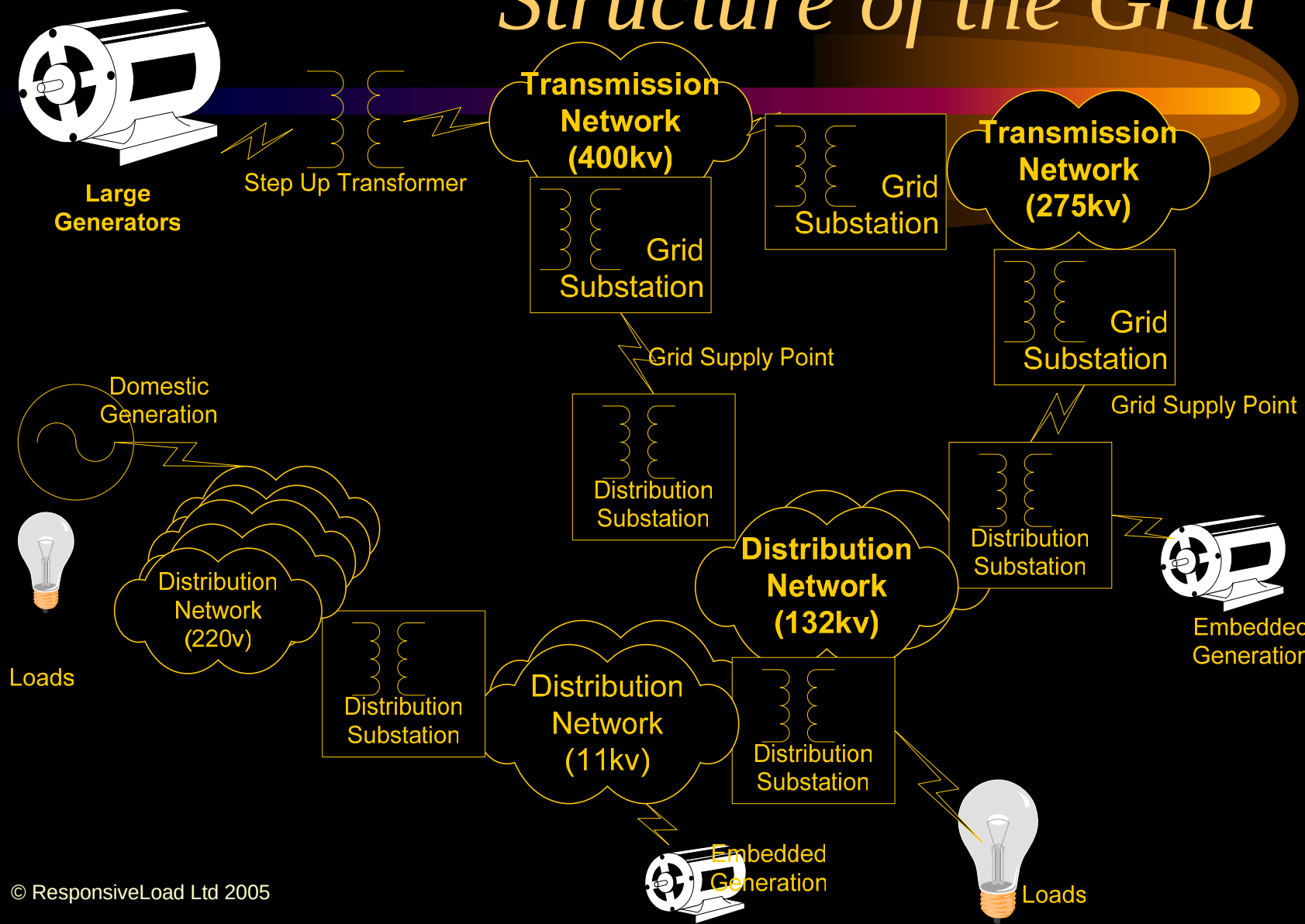
Structure of the Grid



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Blackouts

- Electricity Grids are fundamentally unstable
  - Large Blackouts inevitable (occasionally)
  - 14th August 2003 US NE
  - 18th September 2003 Italy (all of it)
  - 23rd September 2003 Sweden and Eastern Denmark
  - July 1999 Taiwan
  - Great NE Blackout 9th November 1965
- Stability Services cost ~2% of retail electricity sales
  - UK over £200m p.a.
  - Global ~$6billion + p.a.

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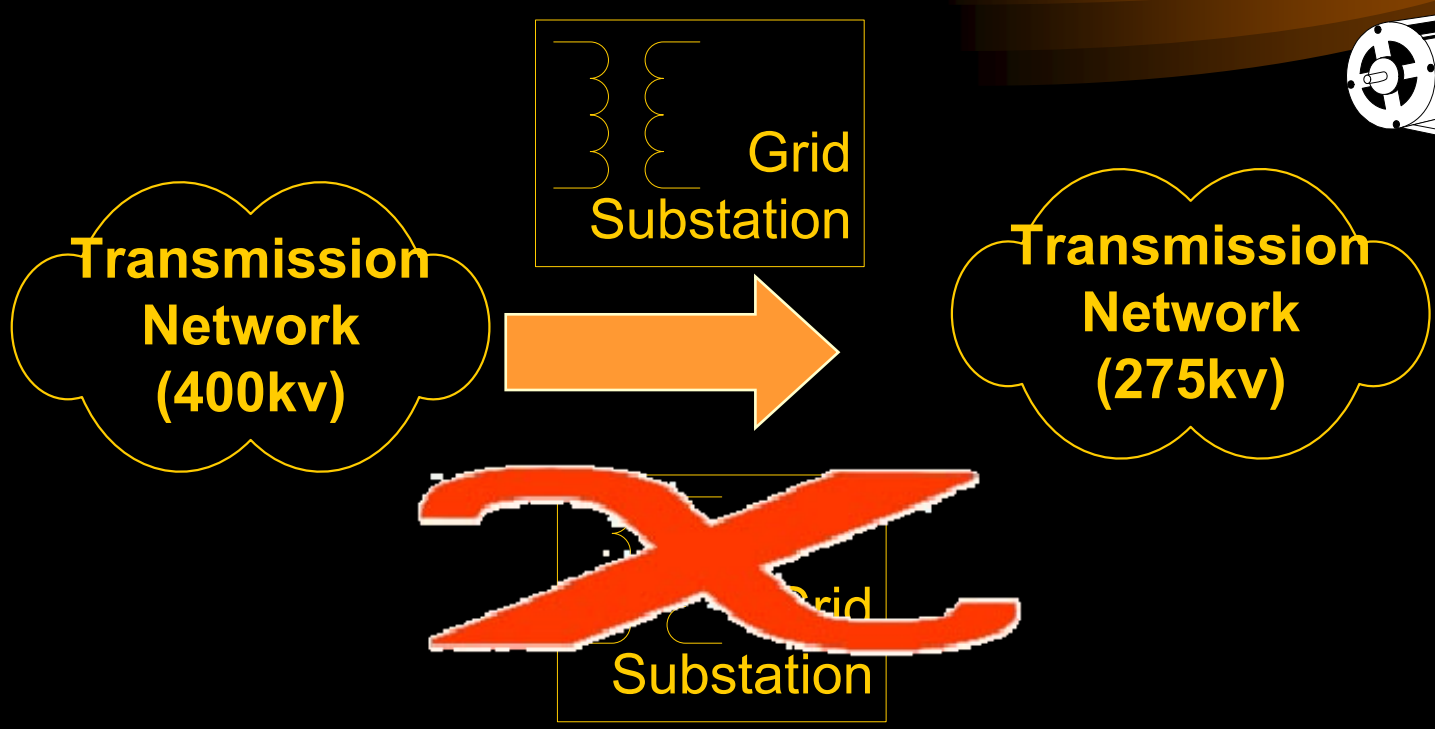
Linked Networks



Surviving Substation must carry all the flow

Embedded Generation sees no change

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AC DC AC Power Converters

- Also known as Back to Back DC links
- DC used for long distance
  - Has other capacity & efficiency benefits
- Controlled Flow of electricity between independent Grids
- **NOT** subject to uncontrolled changes when failure strikes within the Grids

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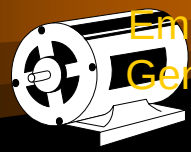
Linked ResponsiveGrids



Embedded Generation

Grid Responsive Substation

Transmission Grid (400kv)

Transmission Grid (275kv)

Grid A (Long) Frequency Rises

Grid B (Short) Frequency Falls

Substation

Surviving Substation increases “exports”

Embedded Generation increases generation

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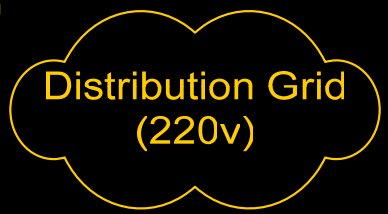
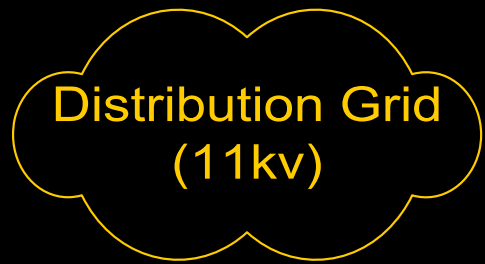
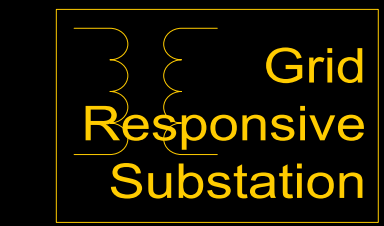
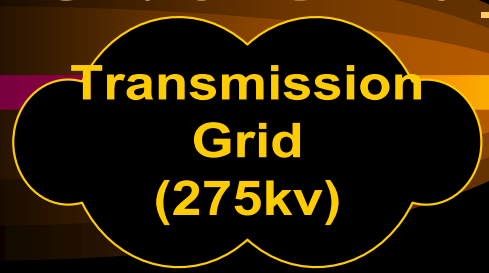
Responsive Grids

- Preset Flows & Predefined Prices (via Internet)
- ResponsiveSubstations adjust imports / exports
- Price Sensitive Appliances see Frequency of Neighbourhood Grid
- Run (or not) according to price
- **Domestic ResponsiveSubstation feeds DC in home?**

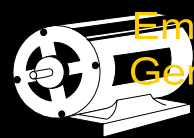








Price Sensitive Appliances



Embedded Generation

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The Domestic Opportunity

- LEDS offer step change in lighting efficiency
  - Without Compromise to controllability
  - And (perhaps) adding colour change
- Distributed Generation does it in DC
  - Photovoltaic create DC
  - CHP Fuel Cells create DC
  - Wind has Power Electronics with DC
- Information & Entertainment Appliances (PC & TV)
  - Prefer DC (how many chargers / converters in your house?)
  - Avoid Parasitic Losses
- Low Voltage DC is safe

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The Ultimate Question?

- What Voltage DC?

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www.responsiveload.com