

BESS Protection Engineering: Grid Stability, Fault Behaviour, and EMT Simulation

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Introduction – Presenter

Hanane Oudli

- Senior Electrical Engineer. Founder & CEO, Hanane Global Advisory Inc. — an independent technical consulting firm based in Calgary, Alberta, Canada, specializing in Battery Energy Storage Systems (BESS), AI data center power infrastructure, DER integration, grid modernization, and power system protection
- University Technical Degree in Electrical Engineering, Moulay Ismail University, Morocco; BSEE from the Engineering Institute of Technology (EIT), Australia
- 10+ years of international engineering experience across Morocco, the USA, Canada, Southeast Asia, and Australia — including HV/MV transmission work at ONEE (Morocco) and offshore BESS projects in the USA (750 kWh / 1.8 MW system in partnership with GE Power Conversion)
- Currently completing a Master of Engineering (Electrical Systems) at EIT Australia, developing continuous grid-forming BESS control for resilient AI data center power (expected completion December 2026)
- Lecturer in Electrical Engineering at EIT Australia; Official Global Brand Ambassador & Strategic Partner for EMTP®; recognized as a LinkedIn Top Voice with 30,000+ followers



Agenda

1	Welcome and Introduction
2	Meet the Presenter
3	BESS as a Grid Stability Solution
4	Protection Challenges of Grid-Connected BESS
5	EMT Simulation – Seeing the Split Second
6	AI Data Centers – The High-Stakes Case Study
7	Key Takeaways, Summary, and Q&A



Webinar Overview

THE CENTRAL STORY

The Problem: BESS is often seen as a big battery, yet it connects through power electronics whose fault behaviour differs fundamentally from synchronous machines.

The Solution: Treat BESS as a grid stability resource, and design protection and controls around inverter-based fault behaviour.

The Result: EMT simulation lets engineers see and fix problems in the split second a fault occurs, long before it happens for real.

The Stakes: AI data centres are large, sensitive loads that show why getting this right matters.

A battery stabilises the grid only if its protection is engineered for the first few milliseconds.

3. BESS as a Grid Stability Solution

BESS: More Than a Big Battery

- **Traditional view:** an energy container that shifts energy from one time to another
- **Grid view:** a fast, controllable resource that actively holds voltage and frequency steady
- Power electronics make this possible, and they also change how faults behave



Frequency Response



Voltage Support



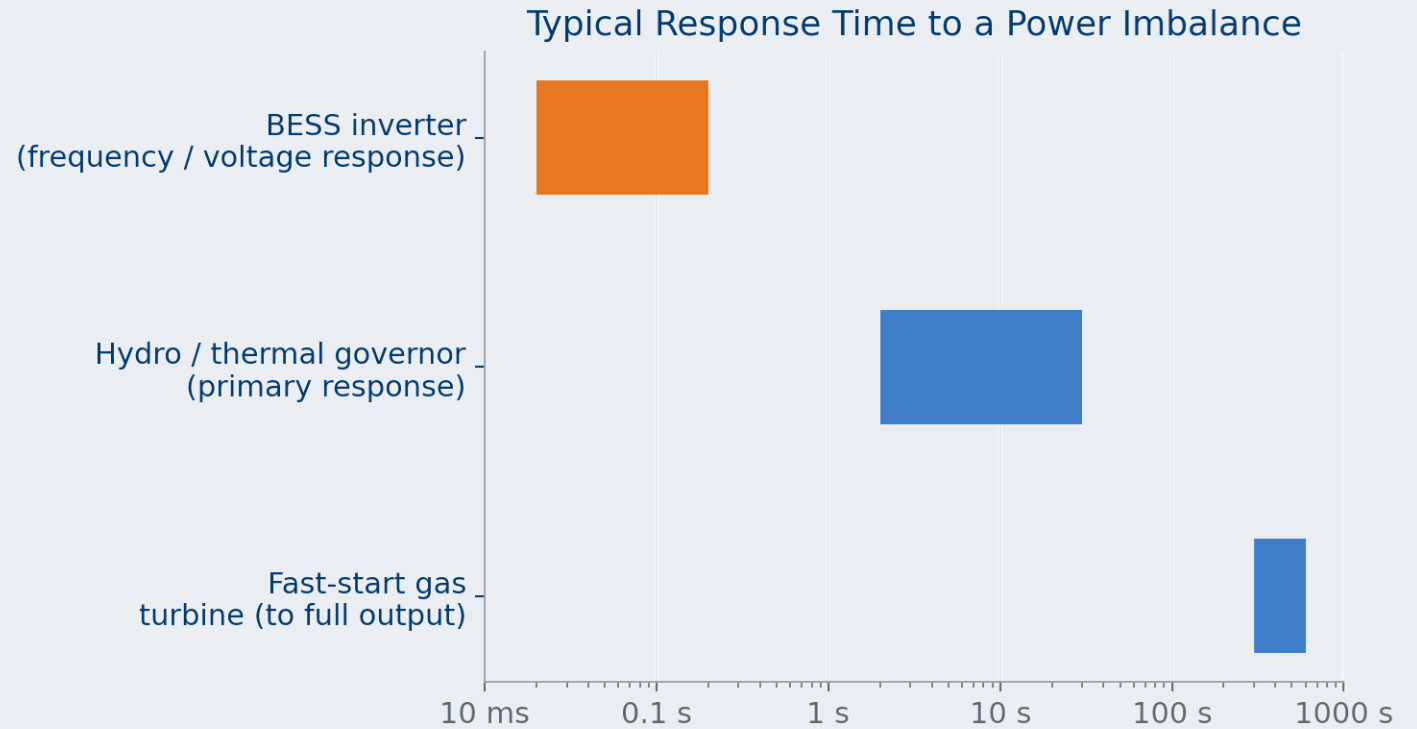
Fault Ride-Through



Black Start & Resilience

BESS Responds Faster Than Conventional Plant

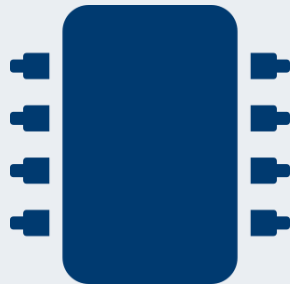
- Inverter controls act in milliseconds; governors act in seconds
- That speed helps arrest frequency decline and stabilize voltage
- But the same fast controls decide how the BESS behaves during a fault



Order-of-magnitude ranges, illustrative; actual values are design and grid-code dependent

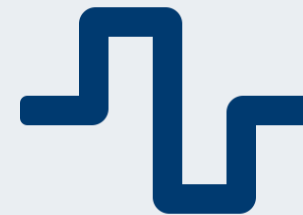
Grid-Following vs Grid-Forming Control

- Grid-following inverters act as controlled current sources and rely on a PLL to track the grid
- In weak grids or low-inertia conditions, PLL-based control can become unstable
- Grid-forming inverters act as voltage sources and set voltage and frequency themselves
- Both are current-limited during faults, which is what matters for protection



Grid-Following
Current source, tracks the grid

VS



Grid-Forming
Voltage source, sets the grid

Your Turn: What Should BESS Do for Your Grid?

Which role of BESS matters most on your network?

- A. Frequency response and inertia-like support
- B. Voltage support and fault ride-through
- C. Black start and resilience
- D. Energy shifting only



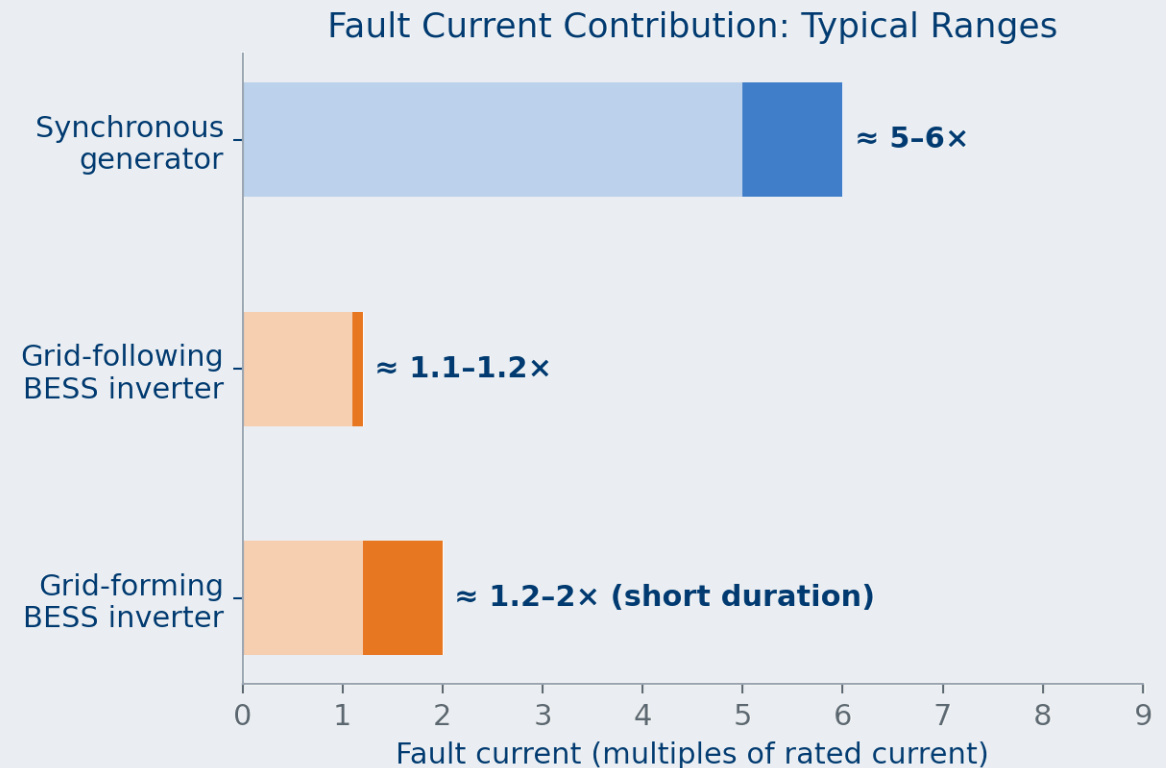
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4. Protection Challenges of Grid-Connected BESS

The Problem: Fault Current Is Different

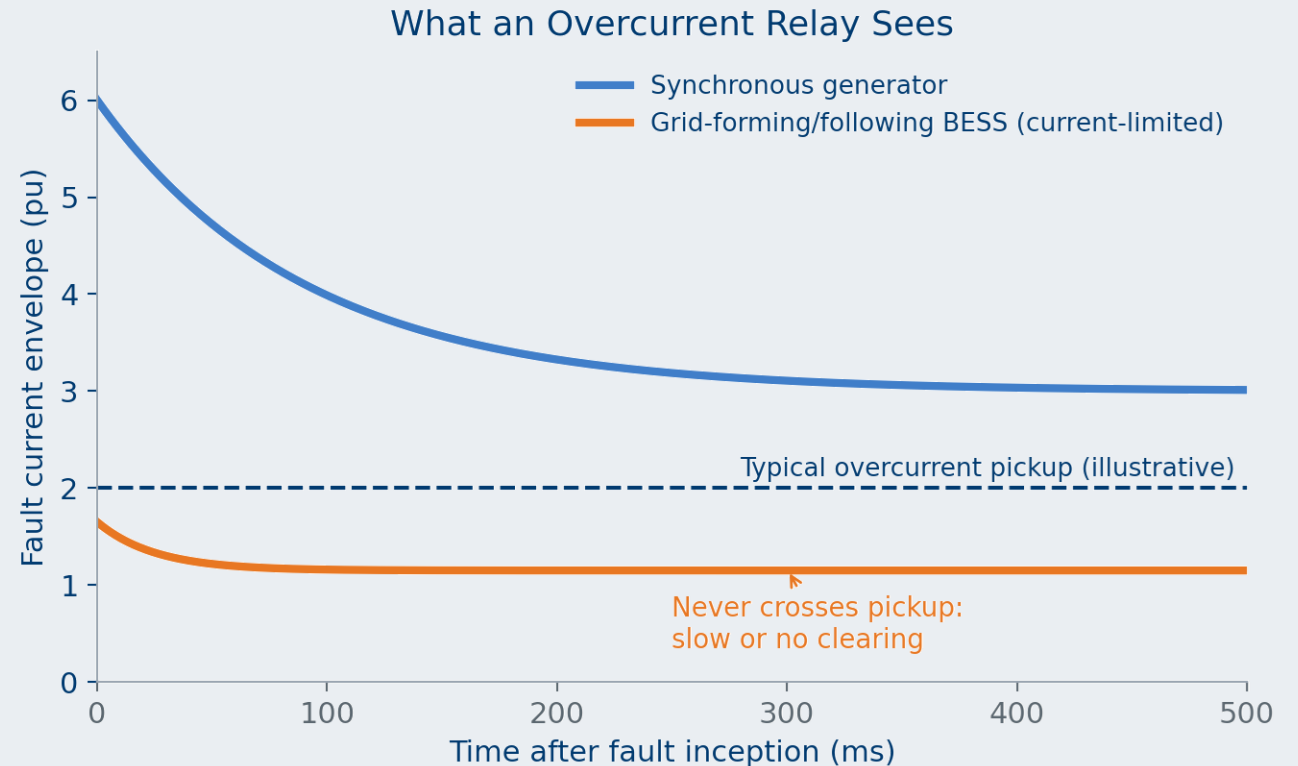
- A synchronous generator can deliver roughly 5–6× rated current into a fault
- A BESS inverter limits itself to about 1.1–2× to protect its power electronics
- Fault current is a controlled output, not a physical property



Illustrative; depends on vendor, control mode and grid code

When the Relay Sees No Fault

- Overcurrent relays (50/51) rely on high fault current to pick up quickly
- A current-limited inverter can stay below pickup, so clearing is slow or does not occur
- Weak fault current does not mean a harmless fault: voltage stays depressed



Illustrative envelope curves, not project data

Where Protection Schemes Struggle

- Relay principles assume large, sinusoidal, mostly symmetrical fault current
- Inverter controls shape magnitude, phase angle and sequence content during faults
- Grid codes such as IEEE 2800 expect the BESS to ride through many faults rather than trip



Overcurrent Pickup



Directional & Negative-Sequence



Distance Elements



Ride-Through vs Trip

Inside the Battery: DC-Side Protection

- DC faults have no natural current zero crossing, so interruption needs DC-rated fuses and breakers
- Rack and module faults can drive very high short-circuit current from many parallel strings
- Thermal runaway can propagate between cells and modules, so detection and isolation must be fast
- Arc-flash hazards in DC enclosures affect maintenance, labelling and design
- Protection must coordinate across DC, converter, AC collector and grid-interface layers

Your Turn: Your Biggest Protection Concern?

Which BESS protection concern worries you most?

- A. Detecting low fault current
- B. Coordination with existing relays
- C. DC-side and thermal events
- D. Ride-through vs trip requirements



Type your answer in the chat — we will review responses live

The Solution: Layered BESS Protection

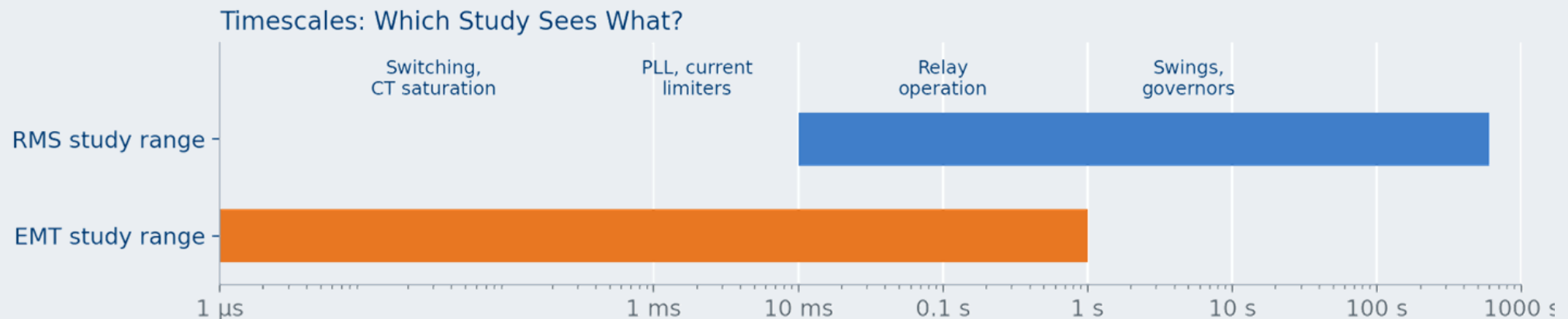
- **Layer 1, Battery & DC:** cell and rack monitoring (BMS), DC fuses and breakers, thermal and gas detection
- **Layer 2, Converter:** fast internal current limiting, DC-link and power-electronics protection, controlled fault response
- **Layer 3, Plant AC:** differential (87), voltage-restrained overcurrent (51V), undervoltage (27) and frequency (81) functions
- **Layer 4, Grid Interface:** ride-through settings per grid code, and communications-assisted schemes where fault current is weak
- Settings come from studies, not rules of thumb, which brings us to EMT simulation



5. EMT Simulation – Seeing the Split Second

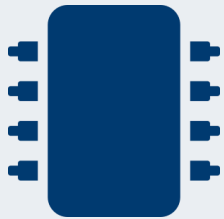
Why RMS Studies Are Not Enough

- RMS (phasor) studies use steps of about 5–10 ms and assume sinusoidal quantities
- Converter controls, PLLs, current limiters and relays interact in microseconds to milliseconds
- EMT models solve the actual waveforms, typically in steps of 10–50 μs

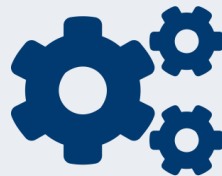


What EMT Simulation Captures

- EMT models reproduce the physics that decide whether protection works
- They show how converter control, network and relays respond together
- Faults too dangerous or costly to test on site can be studied safely



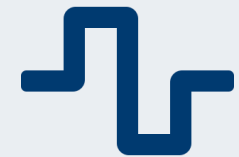
Converter Controls



Transformers & CTs



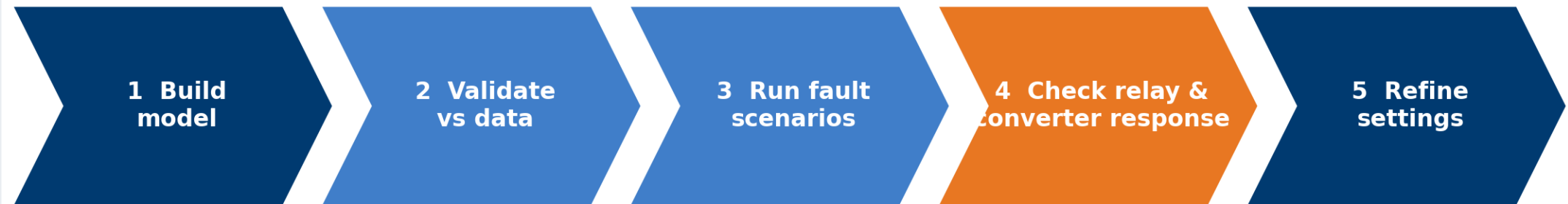
Relay Behaviour



Switching & Harmonics

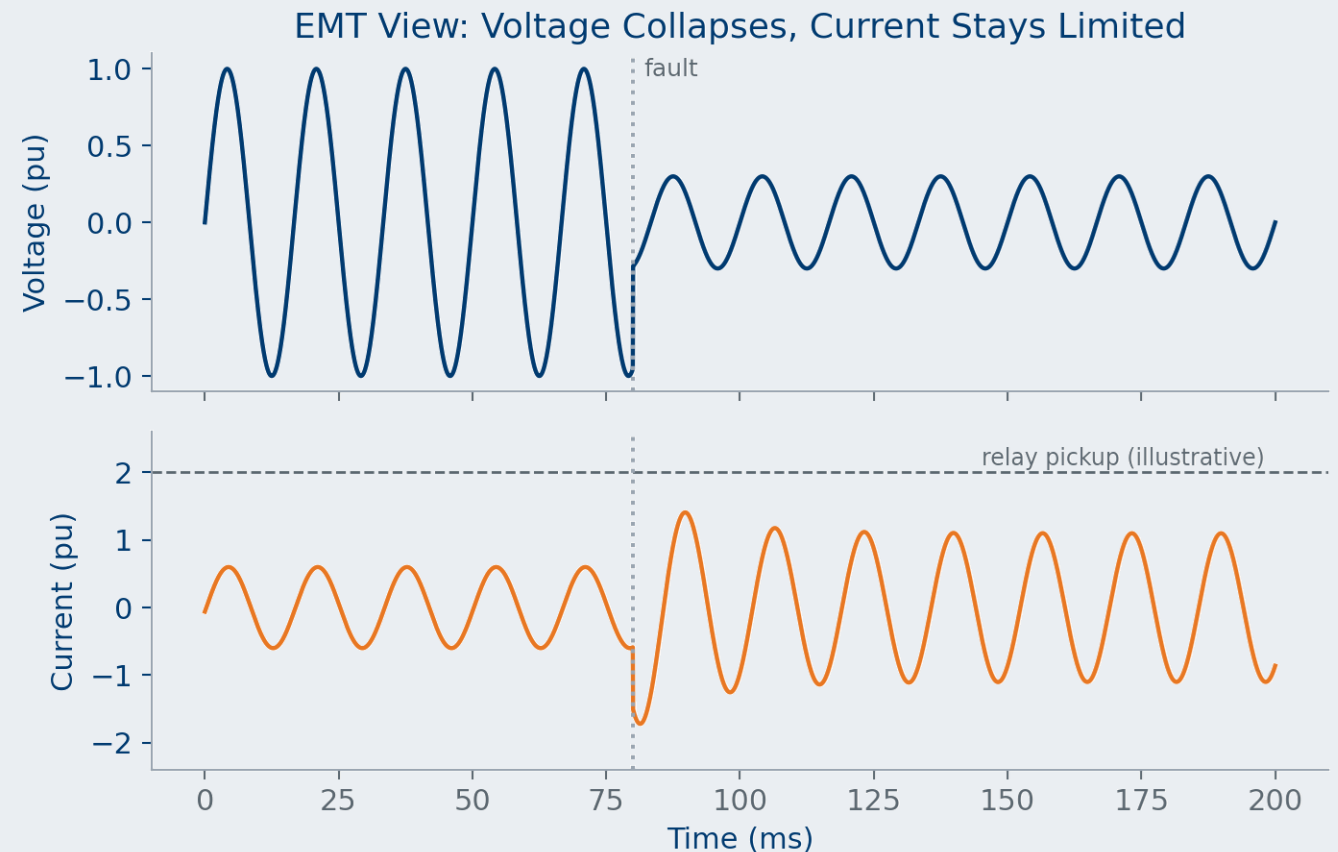
Using EMT to Test Protection Safely

- Build detailed models of the BESS, converter controls, transformer, network and relays
- Validate against vendor data and factory or commissioning tests
- Run fault, switching and ride-through scenarios, then check relay and control response
- Refine settings and controls before anything is energised



The Result: Seeing the Split Second

- Voltage collapses within a cycle while current stays limited
- Waveform detail shows exactly when, and whether, a relay would operate
- Insights like this guide settings, controls and equipment choices



Illustrative waveforms, not project data

Your Turn: Have You Used EMT Studies?

Have you used EMT studies on inverter-based projects?

- A. Routinely
- B. Occasionally, through a consultant
- C. Not yet, but we need to
- D. New to EMT



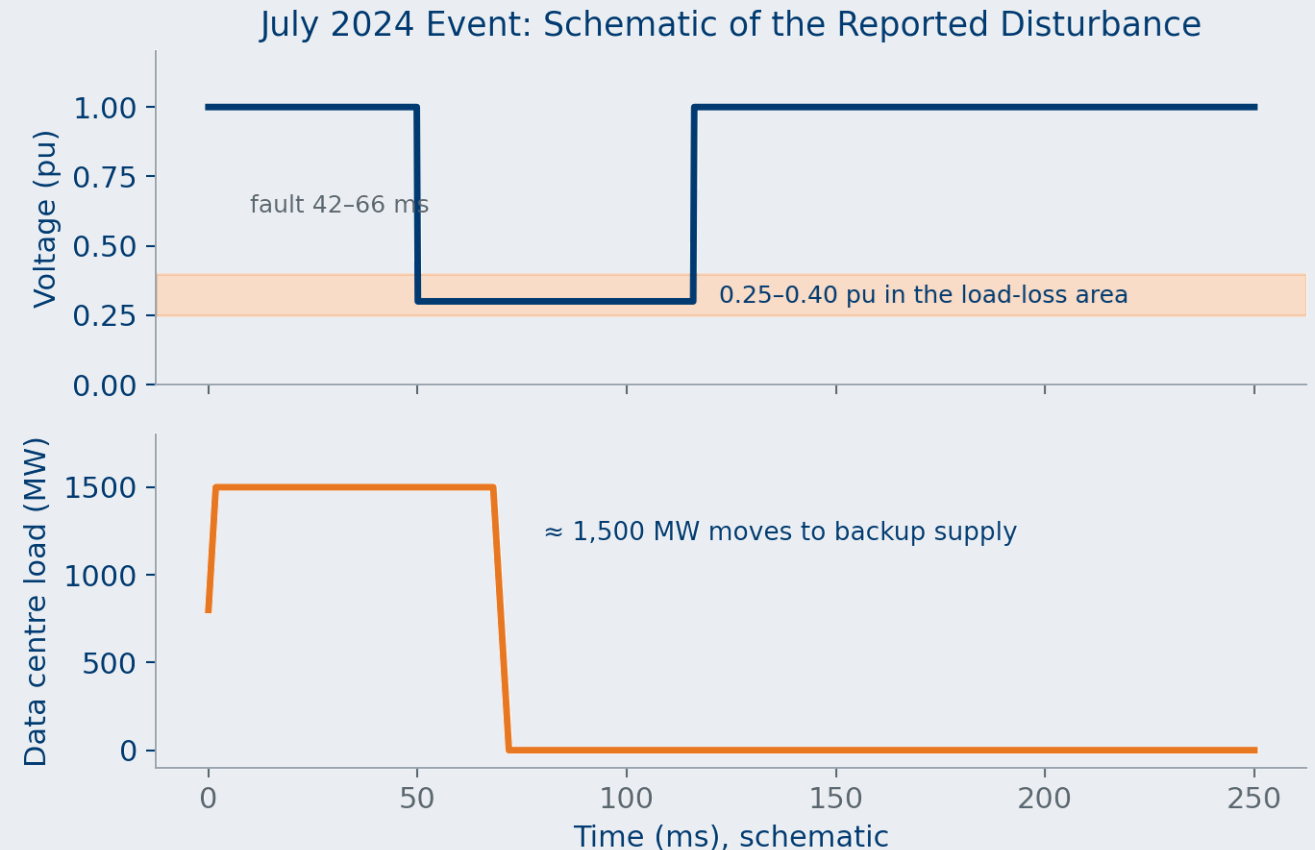
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6. AI Data Centers – The High-Stakes Case Study

The Event: 1,500 MW Gone in Milliseconds

- 10 July 2024: a 230 kV line fault in Northern Virginia
- Fault durations of 42–66 ms; voltage in the area dropped to 0.25–0.40 pu
- About 1,500 MW of data centre load switched to backup supply
- Frequency and voltage rose as that load disappeared

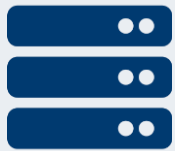


Schematic built from NERC-reported ranges; not a measured record

Source: NERC, Incident Review – Considering Simultaneous Voltage-Sensitive Load Reductions

Why AI Data Centres Raise the Stakes

- Gigawatt-scale campuses, concentrated at a few substations
- Power electronics and UPS systems that react to voltage dips in milliseconds
- AI training creates rapid load swings; sudden load loss is as challenging as sudden load gain



Enormous Scale



Voltage Sensitive



Rapid Swings



No Interruption Allowed

How BESS and EMT Change the Outcome

- Grid-forming BESS can support voltage and frequency at the point of connection during disturbances
- Co-located storage can buffer fast data centre load swings and absorb sudden load loss
- Protection must handle both current-limited faults and the new large-load behaviour
- EMT studies of the combined BESS, data centre and grid system reveal interactions before commissioning
- My M.Eng. research: continuous grid-forming BESS control without mode switching for resilient AI data centre power

Your Turn: What Will You Check First?

Which check will you add to your next BESS project?

- A. Fault current under all control modes
- B. Relay response to current-limited faults
- C. Ride-through vs trip settings
- D. Scope for an EMT study



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Key Takeaways from This Webinar

- Why battery storage is really a grid stability tool, not just an energy container
- The protection challenges that come with connecting large battery systems to the grid
- How EMT simulation helps engineers safely test and predict fault behaviour before it happens for real

Summary

- BESS is a grid stability resource: fast, controllable and increasingly grid-forming
- Inverter fault current is low and controlled, so protection built for synchronous machines can fail to detect or coordinate
- Inside the battery, DC faults, thermal runaway and arc flash need dedicated protection
- EMT simulation reveals converter and relay interactions that RMS studies cannot see
- AI data centers show the stakes: sensitive loads can disappear in milliseconds
- Looking ahead: Session 4, 18 November 2026 “Battery Storage Safety and Digital Substations: Standards for the Modern Grid”

BESS STABILISES THE GRID. EMT PROVES IT.

Thank You!

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Bachelor of Engineering (Honours) in Electrical Engineering	February 2027
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Master of Science (Industrial Automation and Instrumentation Control)	October 2026, February 2027

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