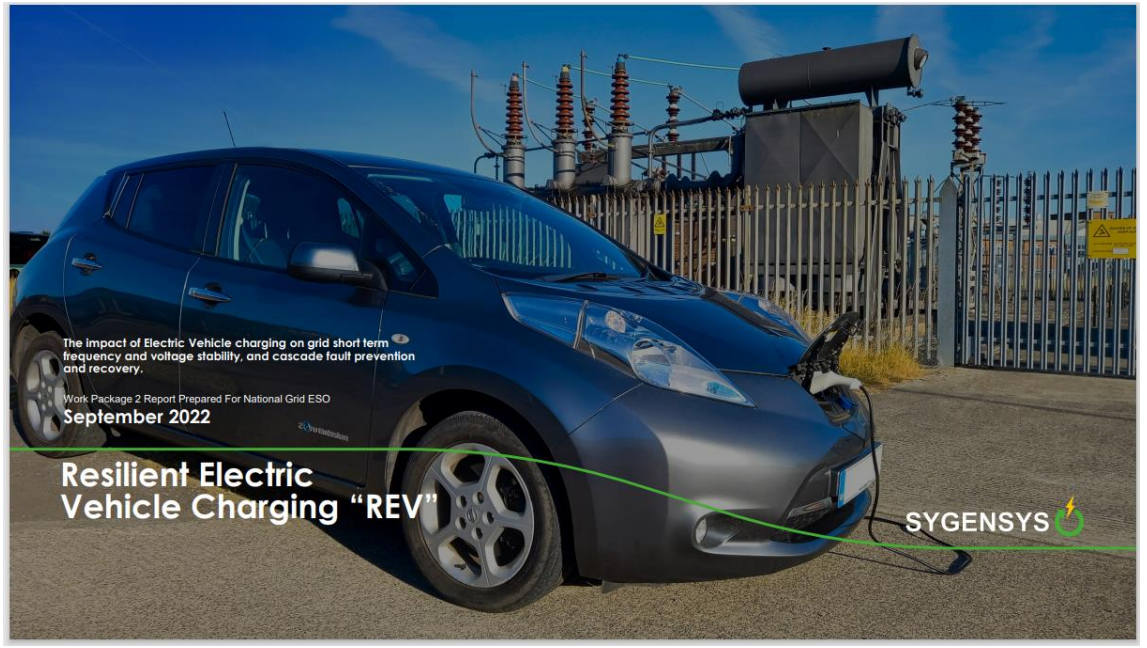
Fault ride-through of converter-based loads

Andrew Larkins

CEO Sygensys

Does Load Fault Ride-Through matter?

Looking to the mid 2030s, on some summer nights EV charging is forecast to be up to 50% of the total load on the GB grid.



Sygensys reports [1] [2] for National Grid ESO

[1] Project REV WP1
[2] Project REV WP2

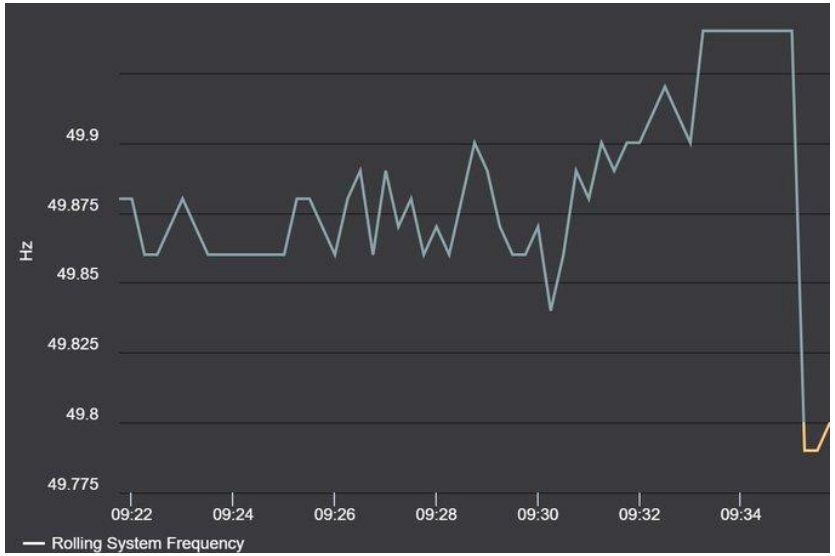
Converter-based loads

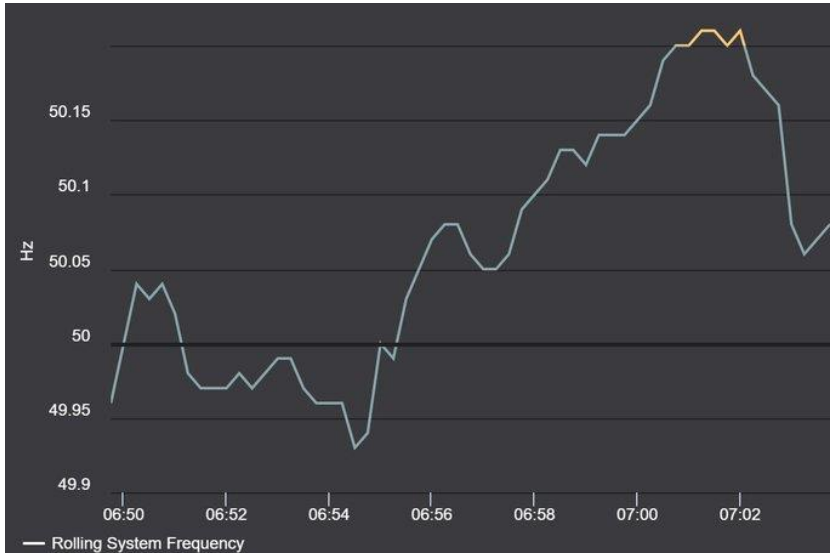
- Historic load types:
  - From resistive
  - To synchronous motors
    - Poor power factor
    - Stall – Fault-induced delayed voltage recovery
  - Load response and fault ride-through based on the physics of the device

- From LED lights to data centers, loads are increasingly converter-connected
  - EV chargers, heat pumps and air con with variable speed drive
- Converter loads:
  - Unity power factor
  - Constant power for small frequency and voltage excursions
  - Response to fault, large frequency and voltage excursions best described as complicated!

Does load FRT matter?

- GB grid decarbonising rapidly
- Jan to March 2023 wind overtook gas
  - was largest source of energy
- GB grid operators consider +/- 0.5 Hz as ‘normal’
  - Briefly exceed +/- 0.2 Hz daily
  - Include high, not just low frequency
- **Loss of load is a concern**
  - Especially coincident tripping of load
- Grid-scale bidirectional plants have FRT requirements
  - Lower risk synchronous: Pump storage
  - Higher risk: HVDC interconnectors and battery storage
  - Grid Code FRT requirements are currently being clarified [1]





Enact (@LcpEnergy) / Twitter
May 12, 2023

[1] GC0155: Clarification of Fault Ride Through Technical Requirements | ESO (nationalgrideso.com)

SYGENSYS

Inverter-based load growth

- GB: Sale of all fossil fuel cars banned from 2030 and trucks from 2035
- No new gas heating installations from 2035
  - currently gas is around 70% of all space heating
- New 650 MW data center planned for London [1]
  - 50 to 150MW typical now
- Doubling of GB energy demand in next 20 or so years

- How will 50% load from EVs in 2030s impact grid operability and security?
- What impact will time-shifted load have?
  - Peak demand is reduced by smart charging, shifting demand to off-peak periods
  - Risk of post-fault increased load?

[1] London Data Freeport Project

Fault ride-through of converter-based generation and bidirectional assets

Potential Issues

- Protection, anti-islanding
- AC over-voltage
- RoCoF
- Momentary cessation
- PLL, Phase jumps
- DC link
- Frequency
- Misconfiguration

Controls

- FRT defined in regulatory codes
  - IEEE 1547, P2800,
  - Regularly updated
- Fault recorders for large generators
- Post incident investigation
  - NERC Level 2 alert March 14 2023
- Analysis of small distribution-connected resources
  - See AEMO roof-top solar ”shake off”

Fault ride-through of converter-based loads

Have you thought about it before today?

Fault ride-through of converter-based loads

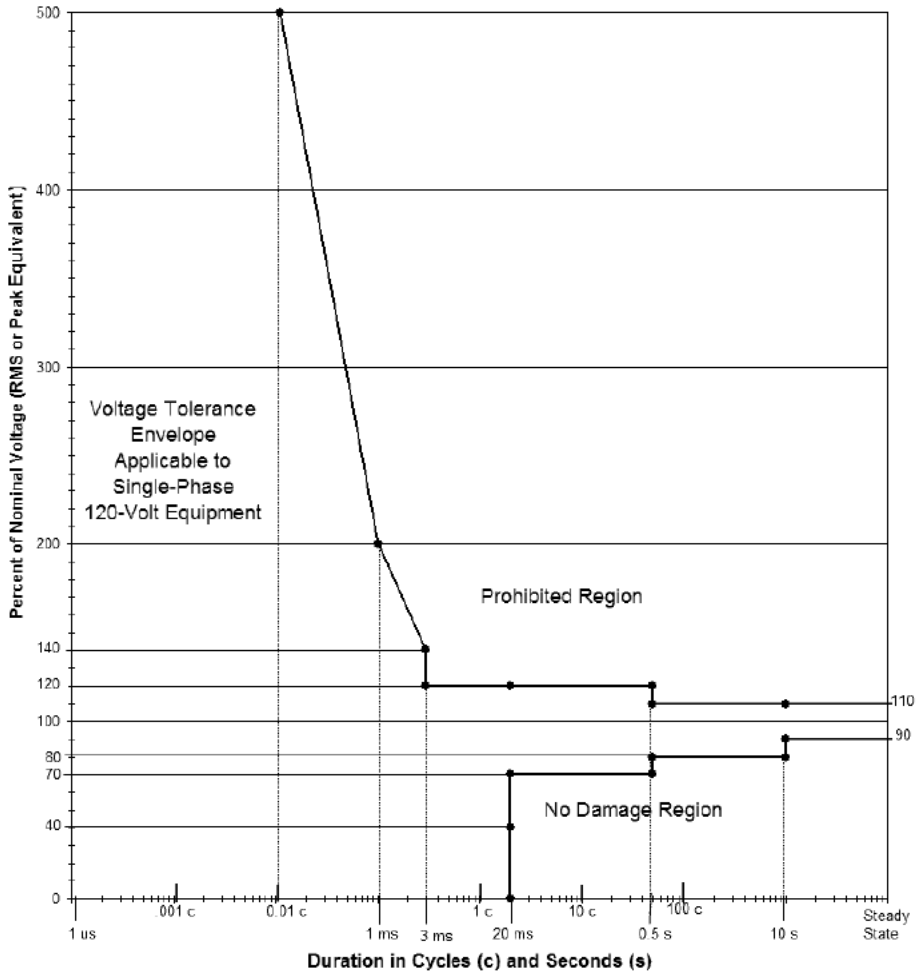
- **Potential Issues**
- Protection, ~~**anti-islanding**~~
- Ac over-voltage
- RoCoF
- Momentary cessation
- PLL, Phase jumps
- DC link
- Frequency
- Misconfiguration

- **Controls**
- Regulations ??????

Converter based FRT considerations are much like converter based generation except anti-islanding.

Information Technology Industry Council (ITIC) curves

- Voltage ride-through curves date back to 1970s.
- **Developed based on the requirements to deliver reasonable experience for consumer/business for typical small loads in the kW region.**
- Now being applied to use cases which were never envisaged [1]
  - Transmission connected 100 MW+ data centres
  - GWs of EV chargers and motors with VSD
- Other global load FRT regulations are similarly consumer experience focused.



ITIC Curve – Voltage Disturbance

[1] Data Center Modeling for Transmission Planning WECC MVS - Parag Mitra EPRI

Existing load regulations to protect the grid

- Power factor
- Harmonics
- Inrush
- …..
- GB: Cyber security for load controllers of >300MW
- GB: Foreign ownership restrictions for >1GW load control

- No Fault Ride-Through aimed specifically at grid stability?
  - There is some incompatibility: Recloser Violates ITIC Curve

- We employ system-level design
- **Load FRT should be closely related to generator FRT**

"Unfortunately the ITIC curve isn't compatible with normal recloser operation."

"If the breakpoint at 70% retained voltage were moved from 20 ms to possibly 120 ms, and the upper voltage range of 110% went to 115%, much greater compatibility would be achieved between delivered voltage and equipment designed to the ITIC minimums."

Load FRT guidelines/regulations

- Now
  - Low regulatory control
  - Not even good advice for designers and installer
- Future: Grid-friendly loads
- Cascade prevention
  - Load relief
  - Over-voltage load trips after generation
  - Under-voltage load trips before generation
  - Rapid return, no momentary cessation
  - ……
- Publicly known response
- Models that represent aggregated loads of the future

NERC NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION CMC CALIFORNIA MOBILITY CENTER WECC

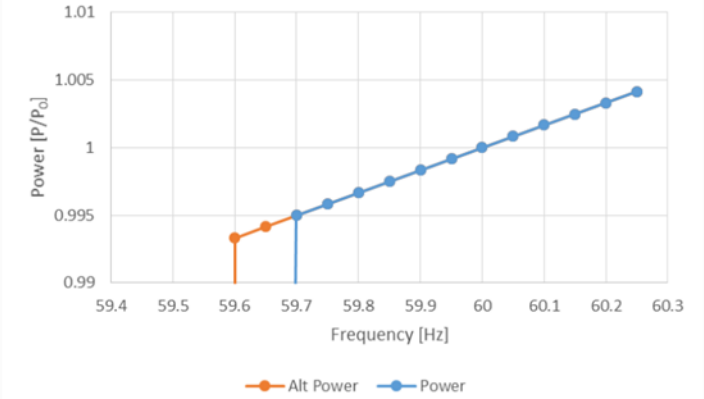


Figure 3: Simplified Example of EV Charger Load Frequency Droop Characteristic [Source: Quint, et al.][23]

https://www.nerc.com/comm/RSTC/Documents/Grid_Friendly_EV_Charging_Recommendations.pdf

Suggestions for a way forward

- Raise awareness, and assess scale of potential issue.

Assuming issue is considered significant:

- Engage converter suppliers and industry-wide international collaboration, especially for high-growth load types such as EVs and datacentres
- Obtain FRT characteristics for existing installed base of converter-connected loads.
- Define harmonised load and generation FRT characteristics which support high uptake rates and work globally.
- Adopt new FRT characteristics into regulations as appropriate.
- Identify any new processes or capabilities needed to identify issues caused by load FRT behaviour.
- Develop updated load models as appropriate. Similar to AEMO roof-top solar PV ”shake off”?