Electricity Transmission

Power Quality Harmonic requirements for the GB Transmission Grid

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Presentation Overview

- Landscape – Energy transition towards Net Zero
- Power Quality – Harmonic issues and management
- Setting and meeting Harmonic Specification for connections
- Challenges – Tools and Monitoring

Landscape – Energy transition towards Net Zero

What is this about in terms Power Quality?

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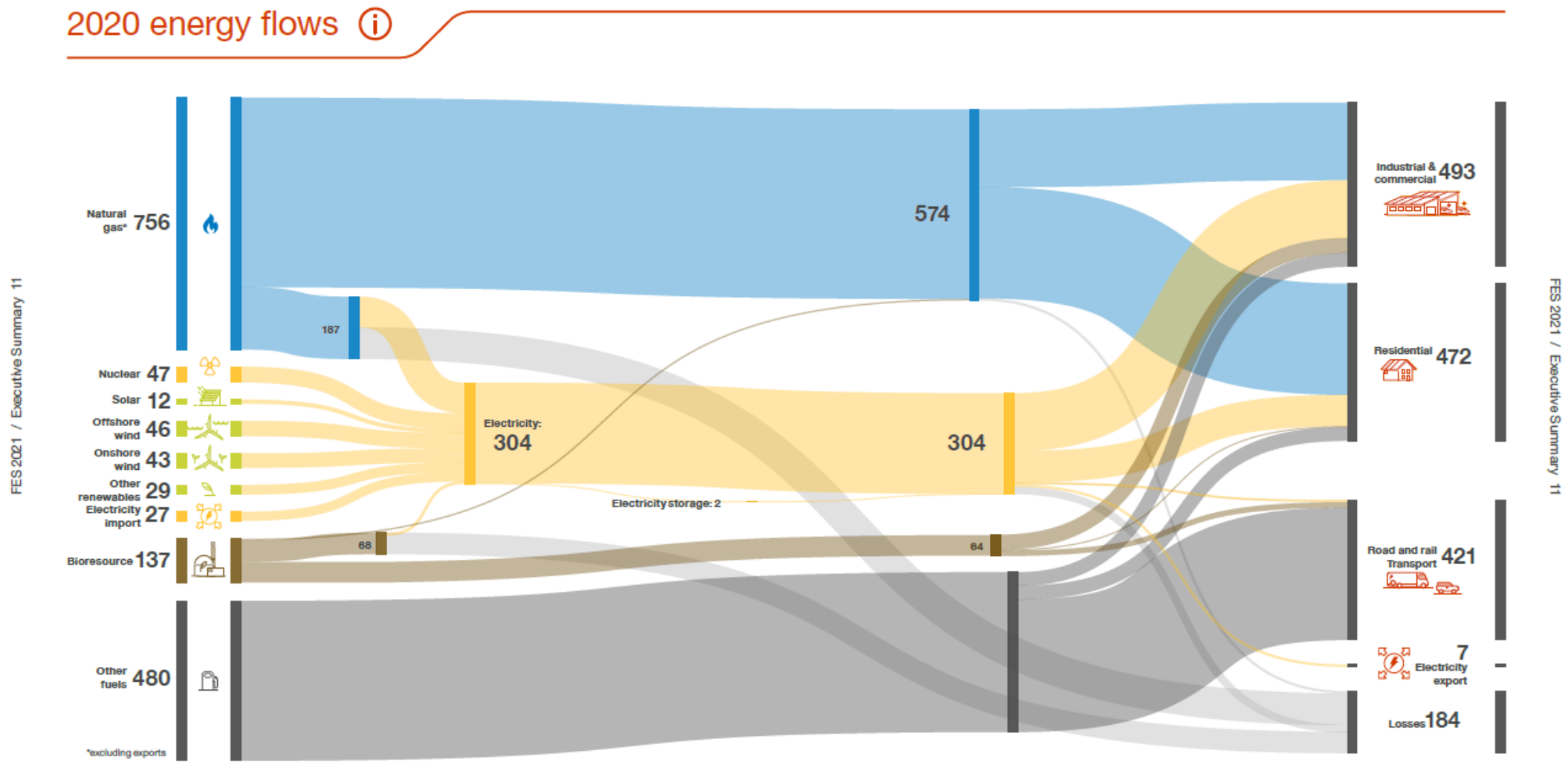
Current energy flows (Based on 2020 information):



*Source - https://www.nationalgrideso.com/document/199871/download

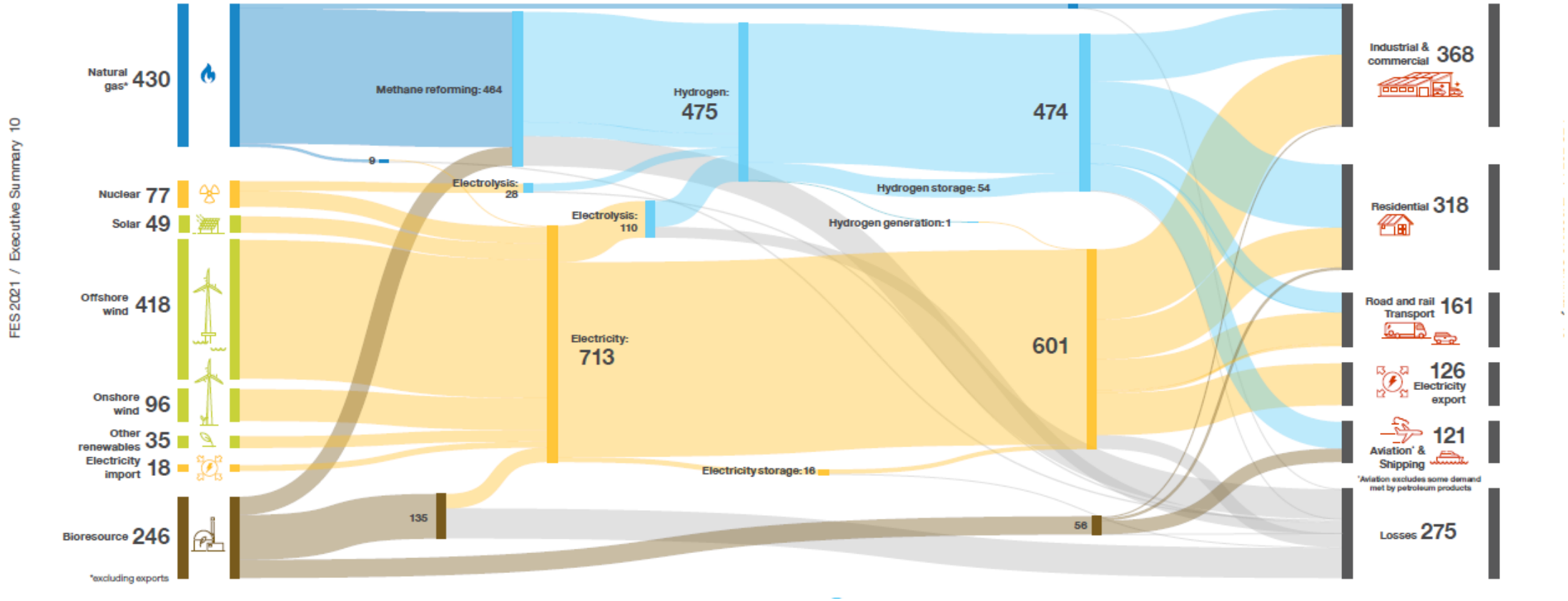
Transition To

Achieving Net Zero energy flows by 2050 – Scenario of System Transformation:

2050 energy flows

System Transformation: energy demand and supply (TWh)

- Highest proportion of hydrogen with widespread use for home heating, industry and HGVs
- Hydrogen produced in the UK, mainly through methane reforming, with large requirement for natural gas with CCUS
- Some negative emissions from hydrogen production from bioresources with CCUS
- Highest level of bioresource use, particularly for BECCS in the power sector



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Some key questions as progressing to Net Zero:

- How is this goal when transitioning towards net zero in terms – striking the right balance on ensuring security standards while achieving this aim? i.e. Carbon capture , carbon trading, technology and network changes necessary to ensure successful transition etc..

- What are the changes/challenges imposed on transmission system?

  - Energy exchange – interconnectors, storage systems (battery standalone, as part of renewable wind, solar due to intermittency etc.) introduces more complexity in managing security, reliability and resilience in system

  - Network infrastructure changes in order to accommodate the unprecedented increase in generation in specific areas of network – new transmission lines, increased cable connections, increased compensation devices

  - Many connections in same area at similar time scales – difficult to solve power quality issues like harmonics

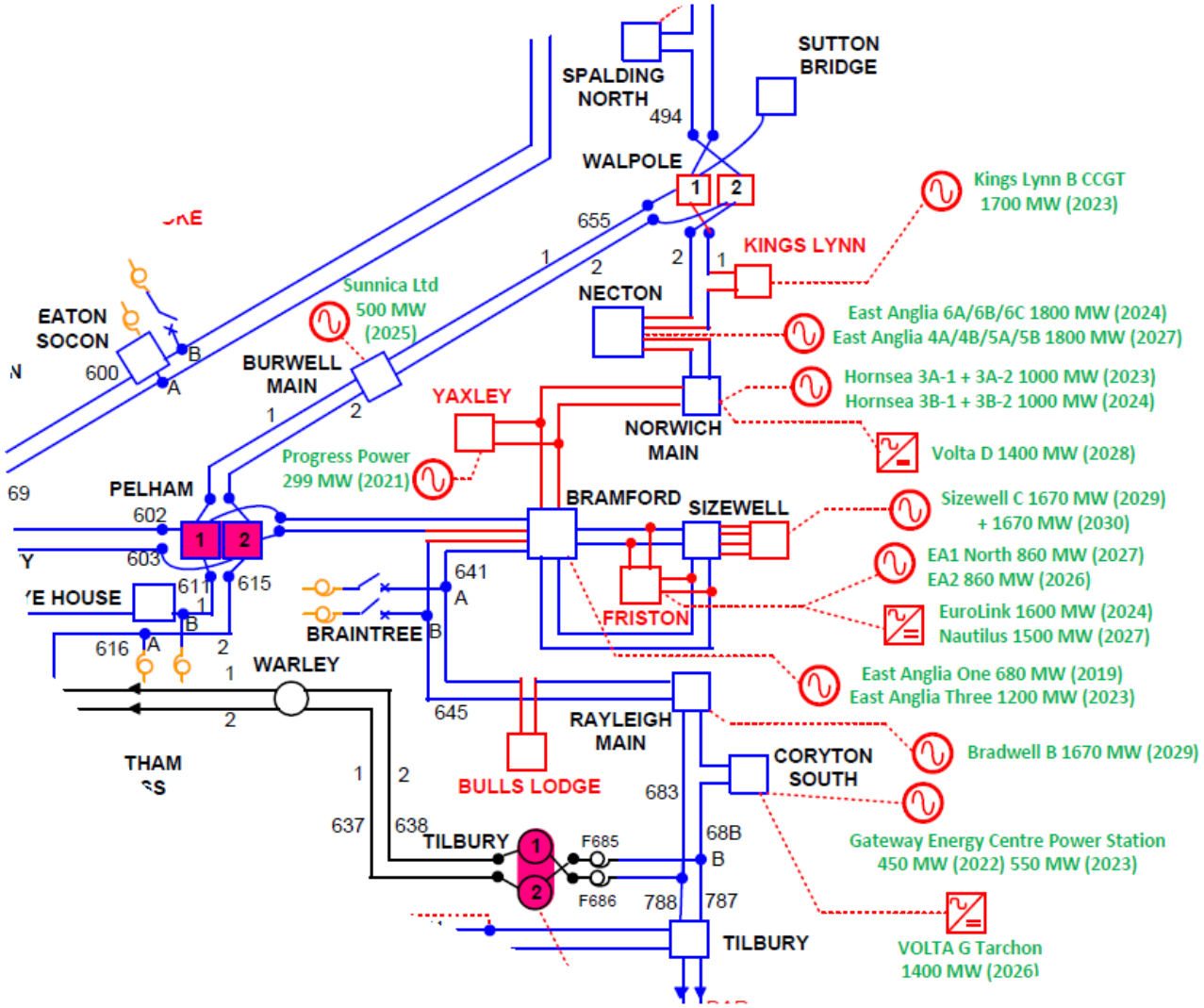
- **Hopefully will provide some answers from Power Quality perspective !!!!**

Changes to Energy sources and demand types:

- **LESS** of Conventional generation – fossil fuelled power stations
- **MORE** of Power Electronic based generation connected to transmission systems:
  - Offshore and Onshore Wind Farms, Solar PVs
- **MORE** interconnectors for import/export across boundaries:
  - Countries and between transmission companies
- **Demand side** – through transmission SGT tertiaries and directly:
  - Electric vehicle charging, energy storage

What this means to the transmission network?

Numerous non-linear connections – wind farms, HVDCs etc.



**Source – NGET based 2019 Picasso*

Power Quality – Harmonic issues and management

Impact of more Power Electronic type-based devices on Power Quality?

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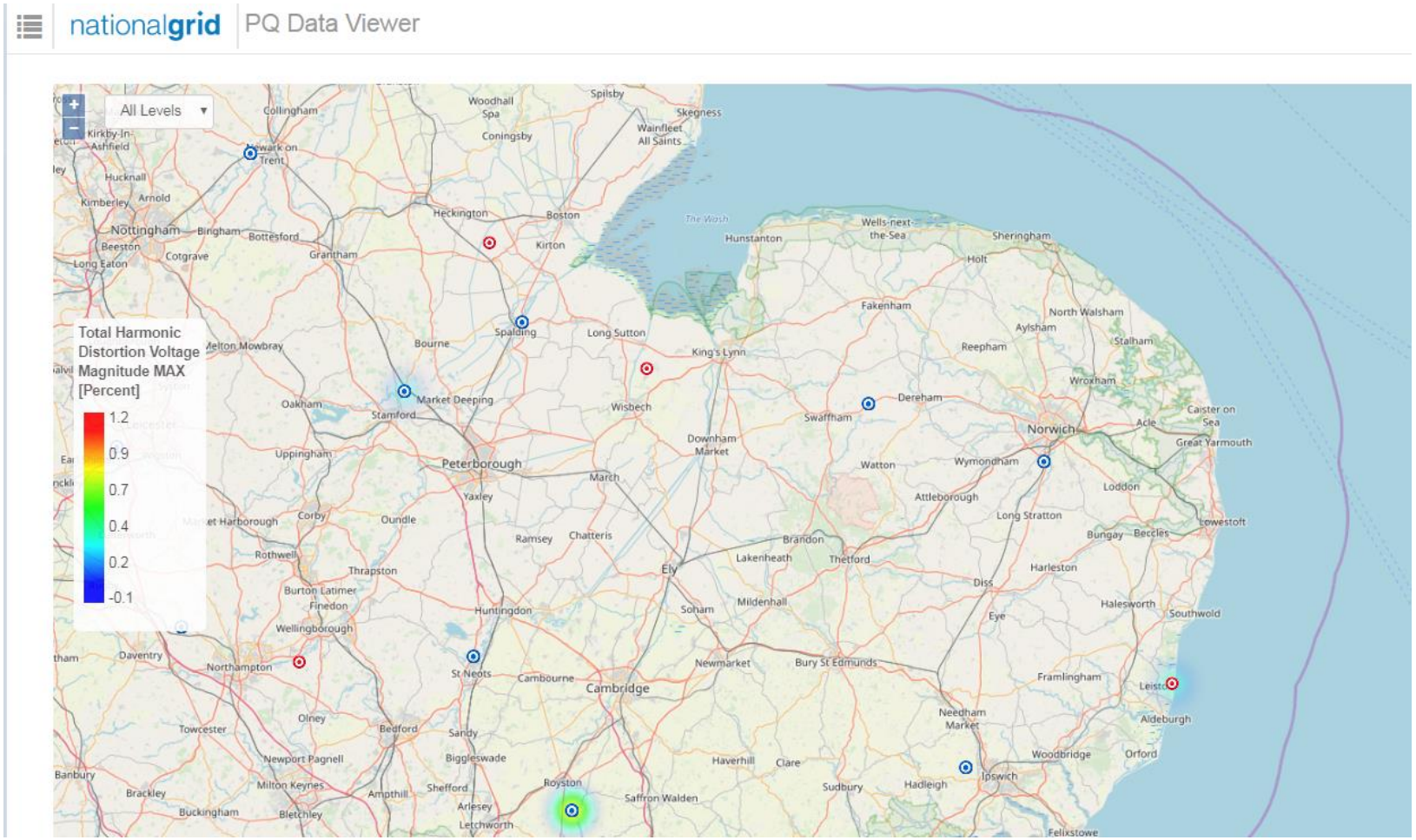
Some key terms and definitions:

- TIP – Transmission Interface Point
- PCC – Point of Common Coupling is point where the new user is nearest to public supply system
- TO – Transmission Owner or Transmission Operator
- BCA – Bilateral connection agreement between TO and customer

Harmonic monitoring at key connection sites



**Source – National Grid PQMS system*

Grid code, standards and BCAs:

- **In the UK, Engineering Recommendation G5 is the reference for assessing harmonic limits.**
  - Stage 3 requirement – applies to all connections at transmission level and is the most detailed.
- What is in the BCA – connection agreement and technical requirements for TO and customer?
  - This is contractual agreement between transmission owner and the connection customer which contains the technical requirements
  - This specifies table of harmonic limits and the network conditions that applies at the Transmission Interface Point (TIP).

Harmonic assessments to transmission systems required for Non Linear Polluting loads:

- Offshore wind farms
- Onshore wind farms
- Interconnectors
- PV connections
- Battery connections
- Data centres
- Traction Loads
- FACTs devices
- Resonant plants (e.g. cables, reactors)

Setting and meeting Harmonic Specification for connections

Applying harmonic limits and demonstrating compliance

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Harmonic Limits - parameters:

- Voltage harmonic limits calculated according to ENA E5 Stage 3 for:
  - Individual integral harmonic order
  - THD (Total Harmonic Distortion)
- Frequency range up to 5 KHz (or 100th harmonic)
- Impedance information as series of customized impedance envelopes at TIP

Harmonic Limits – consists of background, incremental and total at TIP:

- Background (measured existing or adjusted)
- Incremental harmonic limits
- Total harmonic Limits

Calculation of incremental limit according to G5/5

- **The incremental limit taking into effect also of remote nodes**

$$V_{h\_limit\_inc} = M \times \min(H_{h\ n\ PCC}, H_{h\ PCC})$$

Where:

Vh_limit_inc is the incremental harmonic voltage limit (% h=1) at the PCC;

M is the apportionment multiplier

$H_{h\ PCC}$ ***is the harmonic voltage headroom at PCC***

$H_{h\ n\ PCC}$ ***is the harmonic voltage headroom at remote nodes***

Calculation of total harmonic voltage limit according to G5/5

$$V_{h\ Limit\ Total} = \sqrt[\alpha]{(MV_{h\ PL})^{\alpha} + \left((1 - M^{\alpha})\left(V_{h\ bg\ PCC}\right)^{\alpha}\right)}$$

- **Where:**
- ***M is the apportionment multiplier***
- $V_{h\ PL}$ ***is the planning level for the harmonic order h as per ENA G5***
- $V_{h\ bg\ PCC}$ ***is the measured/adjusted background level for the harmonic order h at the PCC***

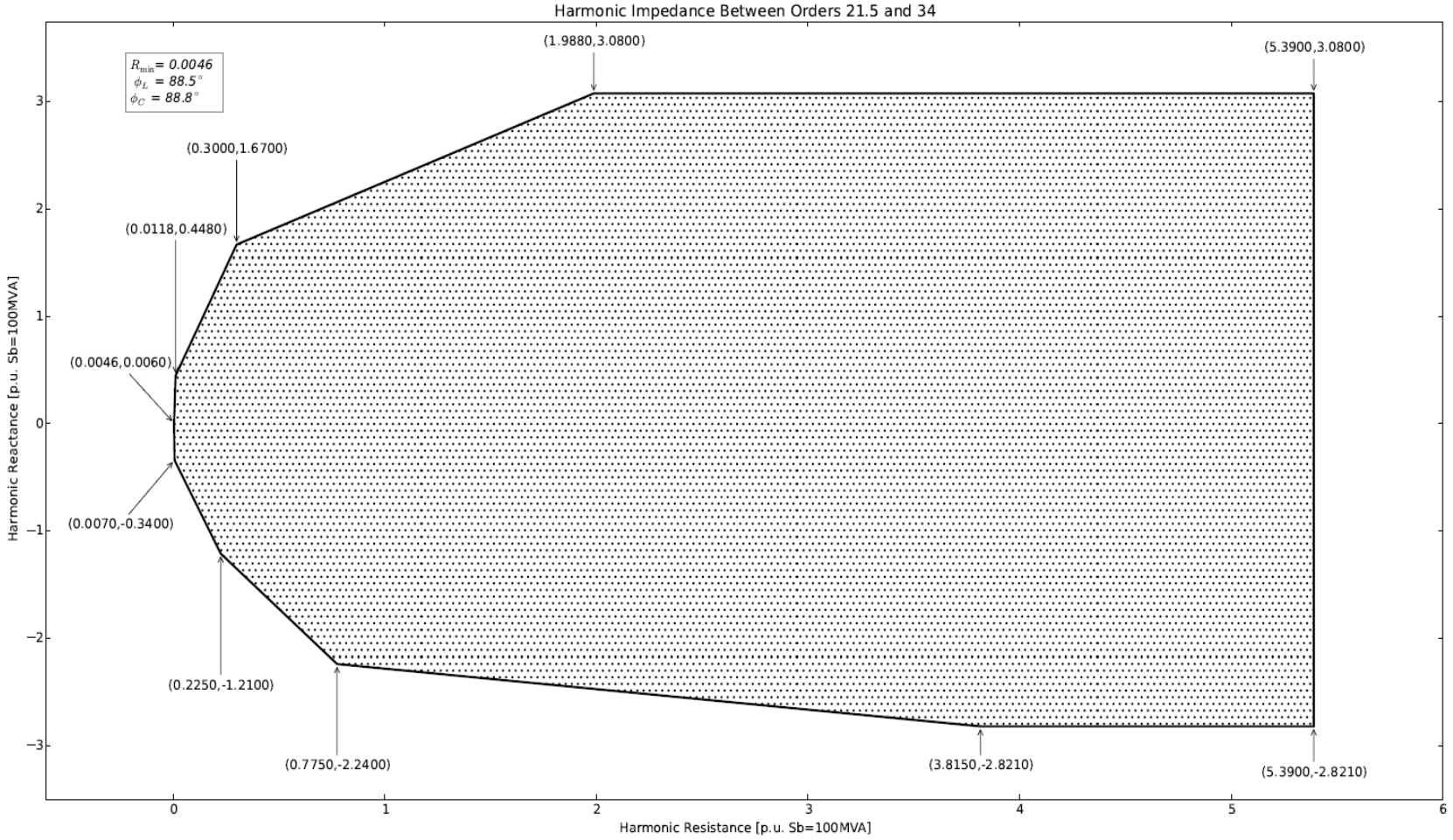
Final harmonic voltage limit table

Harmonic order (*h*)	Background harmonic level [1)] % *h=1*	Incremental harmonic voltage limit [2)] % *h=1*	Total harmonic voltage limit % *h=1*
2			
3			
4			
...	...	...	...
...	...	...	...
NOTE: All values apply at the PCC.			
[1)] Prior to connection of the new user's plant and equipment. [2)] Due to harmonic emission of the new user's plant and equipment.			

Example limits in a table forming part of a harmonic specification

Source – ENA Engineering Recommendation G5 document

Impedance Loci



Meeting harmonic limits at TIP:

- Customer equipment uses harmonic limits and loci to:

1) In conjunction with the model of their equipment
2) Effect of their passive equipment
3) Effect of their active equipment harmonic emission
4) All transmission network conditions as defined by loci for (2) and (3)

Challenges – Tools and Monitoring

Study models and compliance measurements

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Harmonic mitigation?

- Better coordinated filter solutions for many connections.
- Controllers to actively manage harmonic emissions within connection.

Harmonic monitoring system?

- Shift in harmonic frequencies could be problematic at higher frequencies.
- This needs to be closely monitored coming months/years with good records for analysis.

Study tools?

- Challenges will keep coming – models validity for conducting studies constantly need reviewing to ensure accuracy.

Thank you

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