IMPACT OF HARMONICS ON FUTURE CONVERTER DOMINATED POWER SYSTEM

Joint MIGRATE & PROMOTioN workshop

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WHY IS POWER QUALITY A CENTRAL ISSUE TO SUCCEED IN MASSIVE POWER ELECTRONIC INTEGRATION?

EU Energy policy & goals

⇩

Integration of RES (PE)

⇩

Costumers to have same quality of supply

⇩

Reliability of the system shouldn‘t be endangered

⇩

Developing PQ mitigation options

⇧

MIGRATE WP5

WP5 – Power quality in transmission networks with high PE penetration

Task	Description	Deliverable
T5.1	• Evaluation of PQ related to PE dominated grid	D5.1
T5.2	• Developing numerical simulation models of PE devices for PQ studies	D5.2
T5.3	• Propagation of PQ disturbances through power networks	D5.3
T5.4	• Evaluation of PQ level in future PE rich power networks	D5.4
T5.5	• Mitigation options for keeping PQ levels within affordable levels	

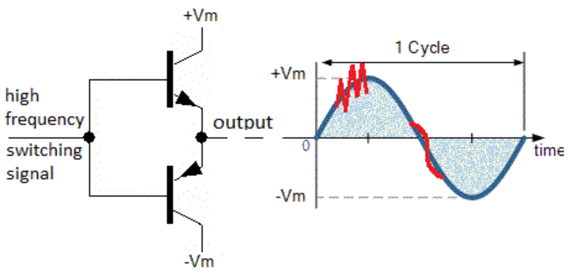
All Publically available:
https://www.h2020-migrate.eu/downloads.html

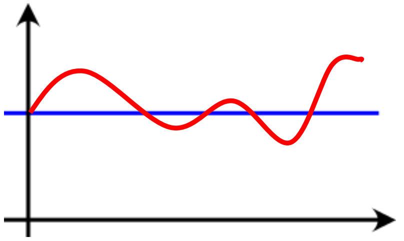
Partners: UNIMAN, TUB, UL, EIMV, TalTech, ELES, TenneT, EIRGRID, SPEN, ELERING

POWER QUALITY PHENOMENA RELATED TO PE

- Voltage dips and Temporary Over-Voltage
- Harmonic distortion (PE harmonic injections, device susceptibility to voltage harmonics, grid resonance, poor controllers performance causing excessive harmonic distortion)
- Supraharmonics
- Flicker and voltage fluctuation
- Harmonic resonance
- Voltage Unbalance
- Voltage variation
- Frequency variation
- Frequency fluctuations

Main focus of WP5



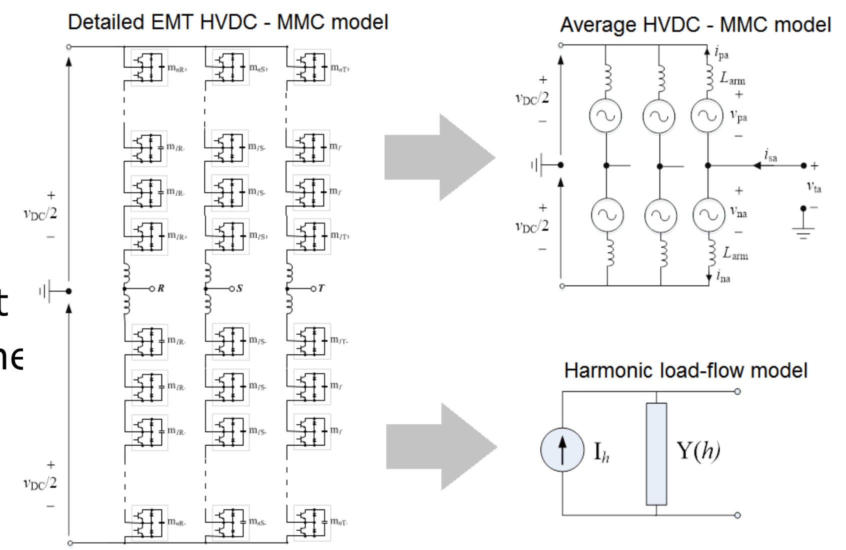


PE DEVICES EMT MODELS

Models developed for:

+ High voltage direct current system (**HVDC**),
+ Static compensator (**STATCOM**),
+ Static-var compensator (**SVC**),
+ Wind-turbine generators (**WTG type 3 and 4**),
+ Solar photovoltaics (**PV**) and
+ Battery storages (**BS**).

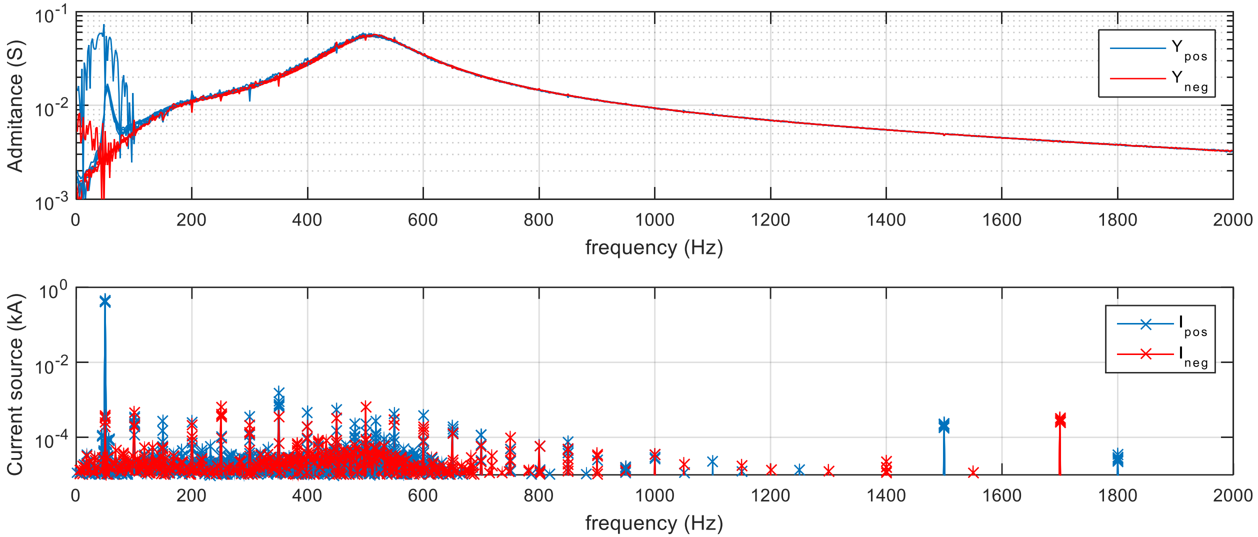
– For each device, three types of models with different level of detail and complexity have been developed: the electromagnetic transient (**EMT**) model, the **average RMS** model and the **harmonic load-flow** model (frequency domain).



PE DEVICES EMT MODELS

A **representative topology** for each PE device (amongst a wide variety of different topologies and implementations currently available) has been selected. This approach has been adopted in order to provide a **generic**, yet **representative**, model and more importantly, to **propose a methodology** for EMT modelling of PE devices for PQ studies.

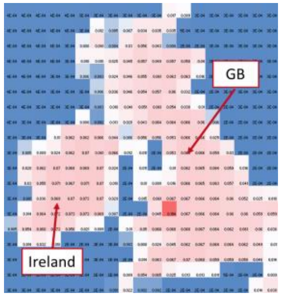
Harmonic loadflow models developed by “scanning” the EMT models in various operating points.



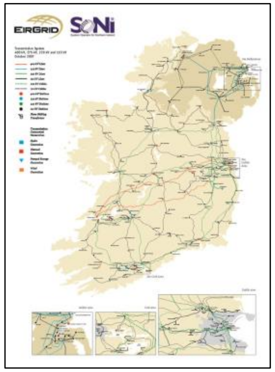
PROPAGATION OF PQ DISTURBANCES IN THE GRID

TYPE:	Frequency variations	Harmonic distortion
DEVICE MODEL:	Average RMS model	Harmonic Load Flow model

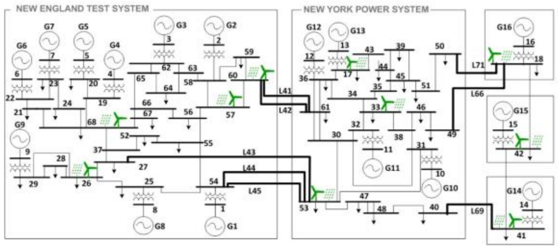
TESTING NETWORK:



MERRA wind data

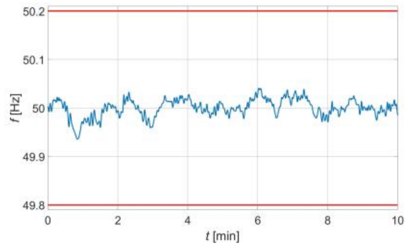


Irish grid



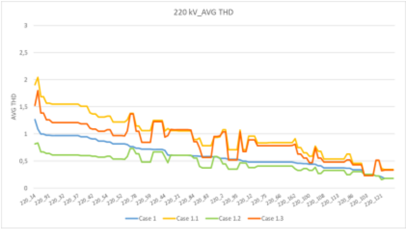
IEEE 68 bus network

METHOD:



10 minutes simulation with wind data in DIgSILENT PowerFactory

Varying SNSP from 60% to 90%



Harmonic load flow based on Monte Carlo simulation of harmonic emissions

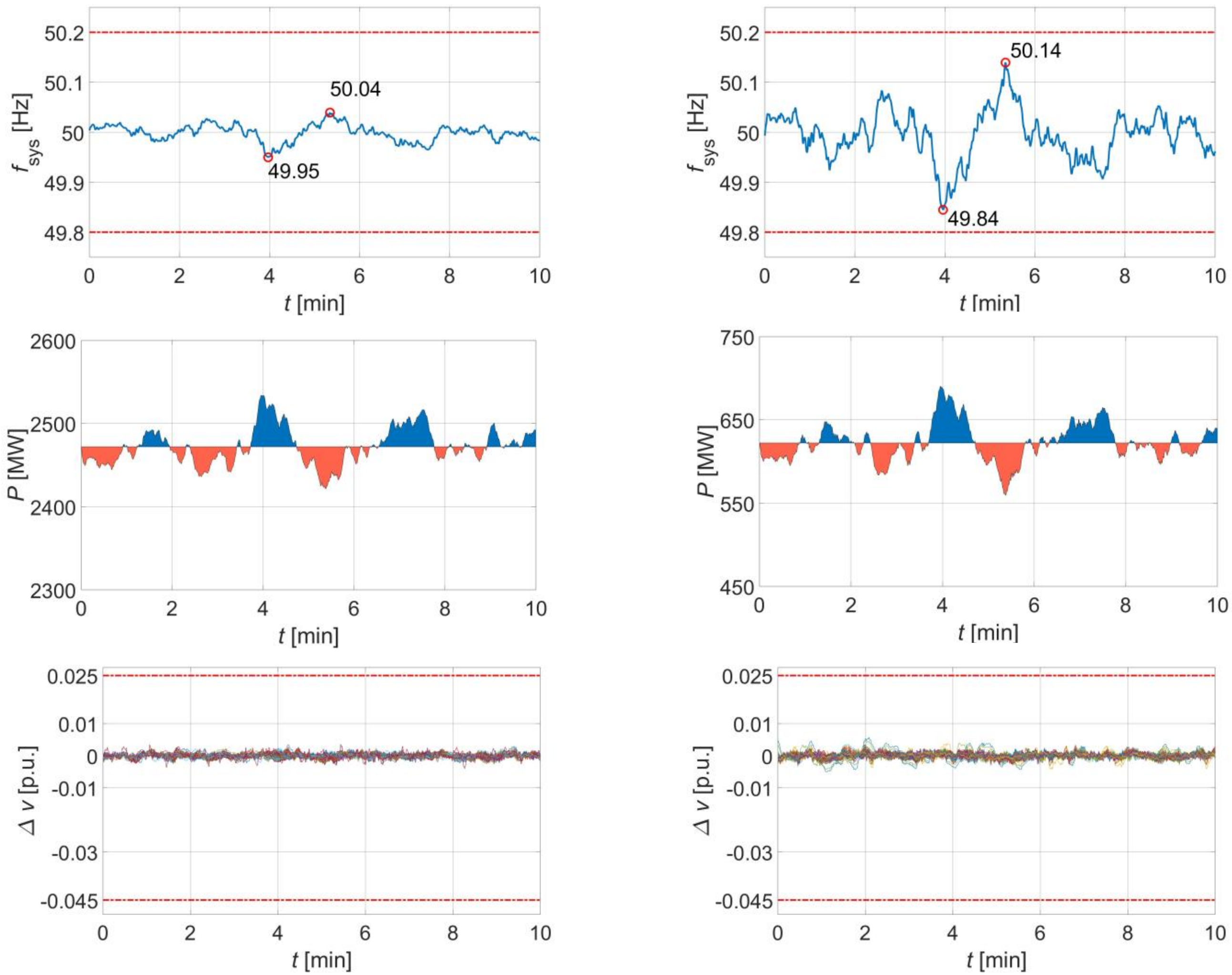
FREQUENCY VARIATIONS RESEARCH

60% SNSP | 90% SNSP

Frequency:

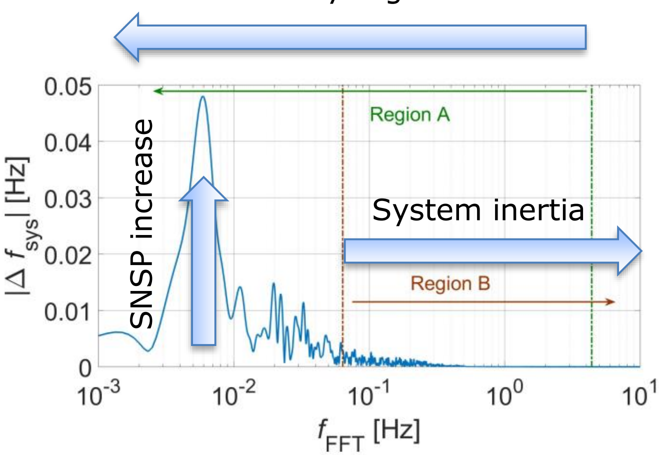
Balancing power of synchronous generators:

Voltage:

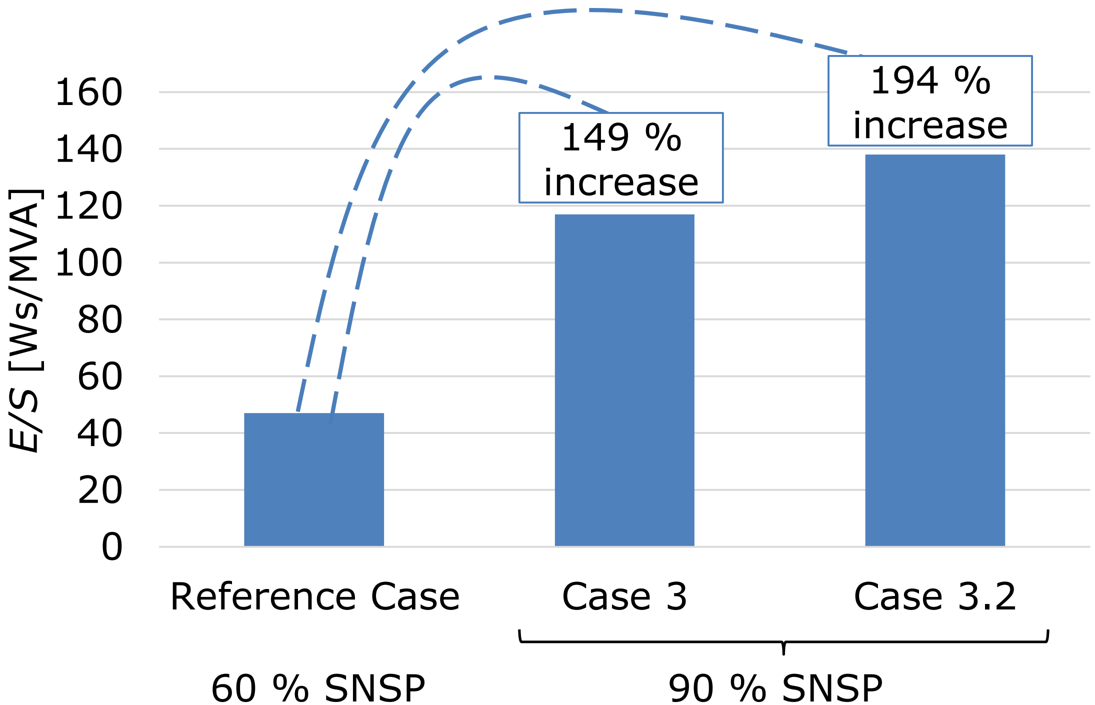


FREQUENCY VARIATIONS RESEARCH

- Fourier analysis of frequency variations due to intermittent supply of wind farms indicates that the main impact is on primary regulation, not inertia of the system.
- Primary regulation balancing energy almost doubles going from 60% to 90% SNSP
- Voltage variations minimum due to voltage control functionality in PE converters

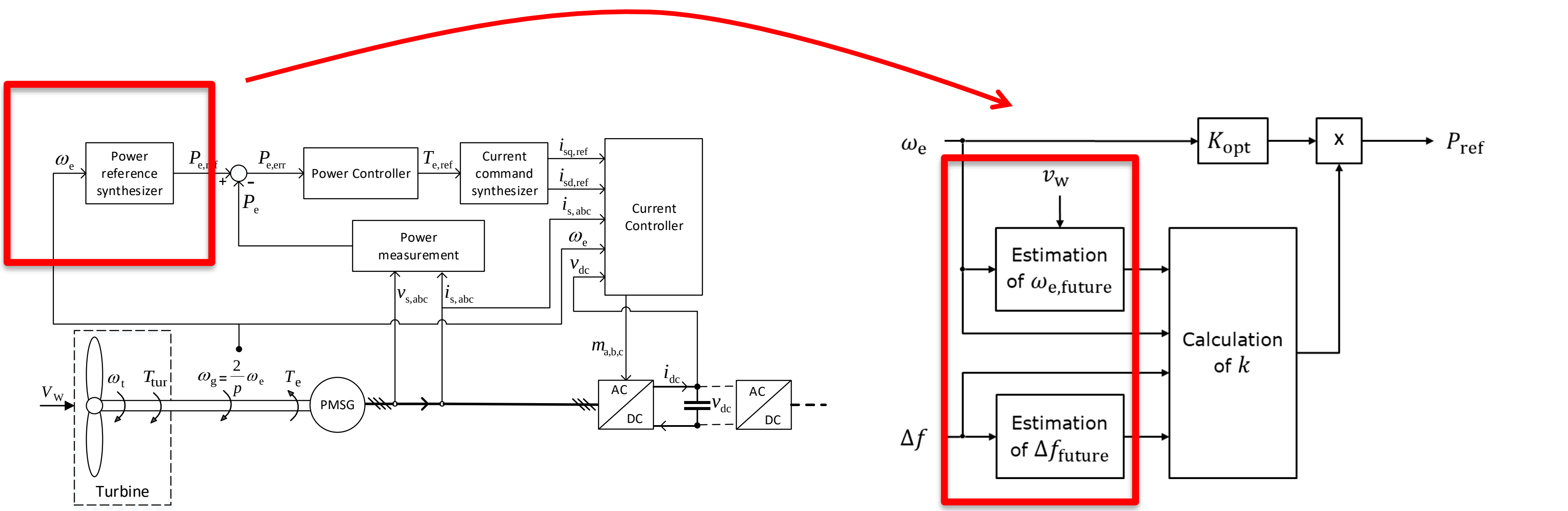


Fourier analysis of system frequency deviation



Primary regulation balancing energy needed

- Focus is on smoothing the frequency pattern by preserving as much renewable energy generation as possible
- Modularity of design (N-1, independent as well as coordinated operation)
- Applying a modified power reference synthesizer block in wind turbine control
- Adding short term wind speed as well as frequency forecast (up to 1 minute)

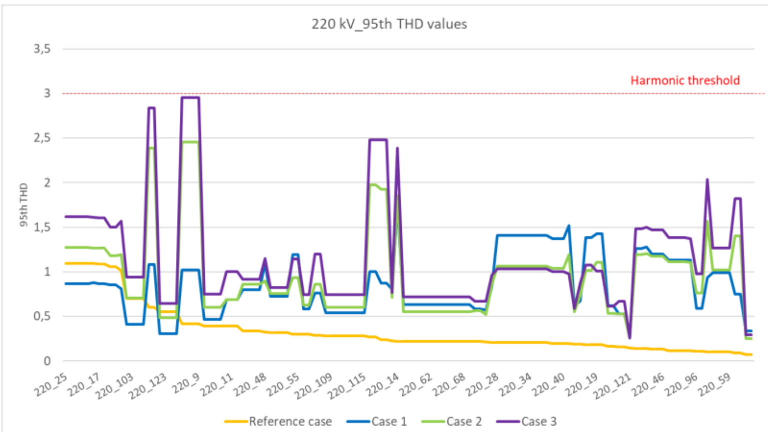


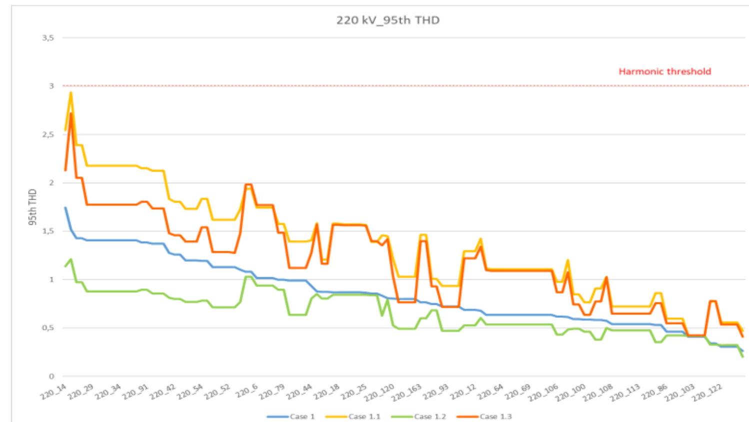
HARMONICS DISTORTION RESEARCH

60% - 90% SNSP

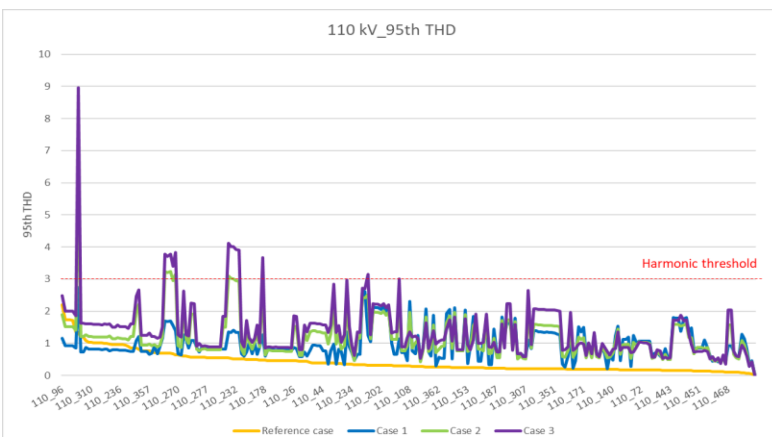
4 load (non)linearity cases

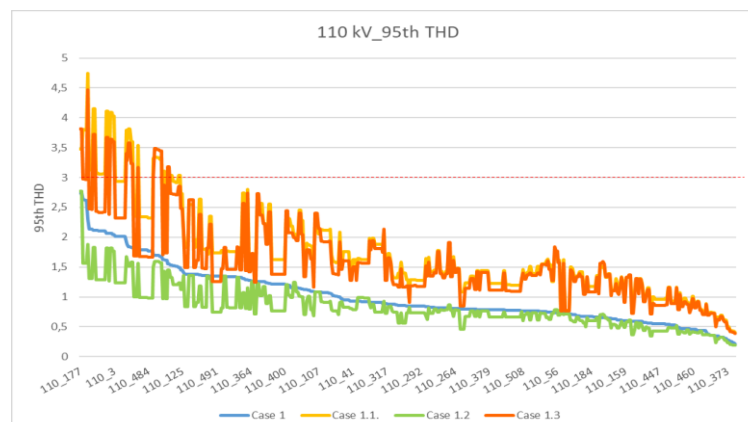
THD: (220 kV)





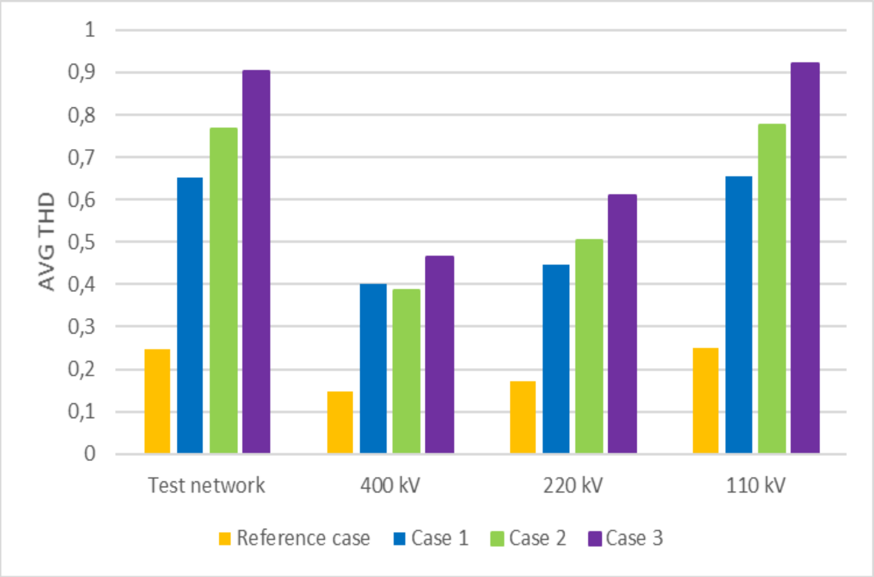
THD: (110 kV)

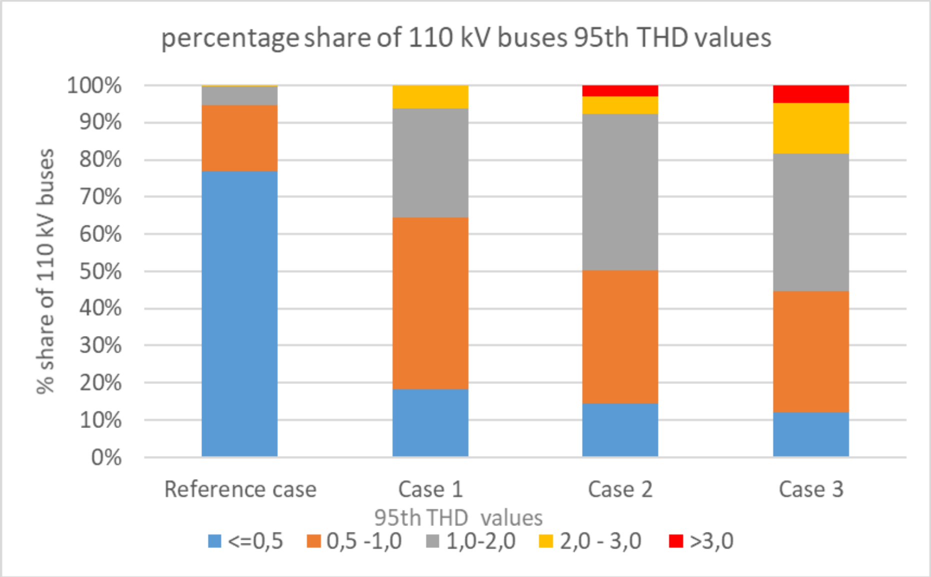




HARMONICS DISTORTION RESEARCH

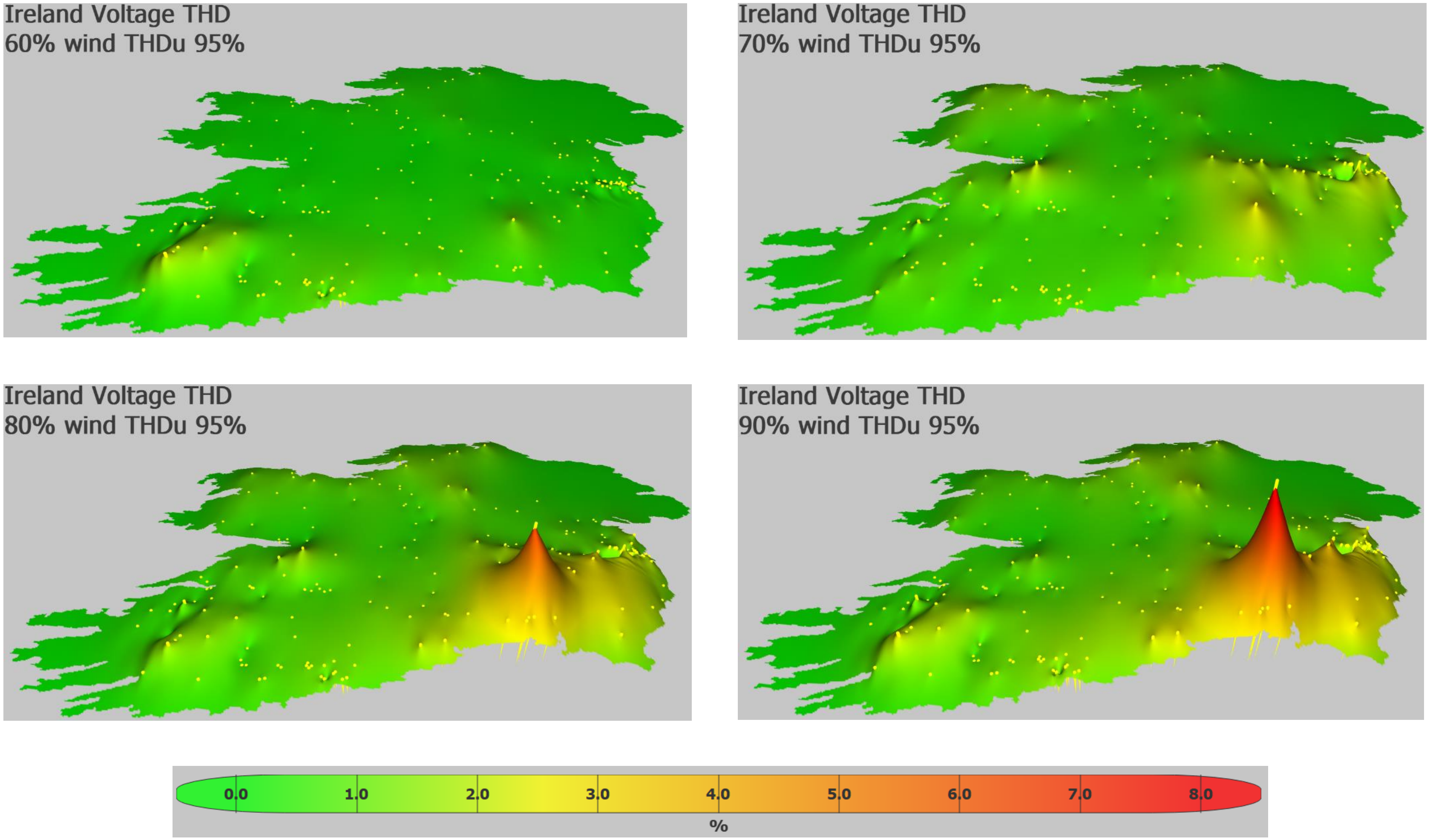
- Approximately three time increase of average THD from 60% to 90% PE.
- 110 kV is affected the most – in 90% PE, almost 5% of busses exceeds 3% 95th THD
- Load (non)linearity has great impact on harmonics – for the case of 70% SNSP, increasing the share for non-linear load of distribution networks from 20% to 50% leads to doubling the average THD.





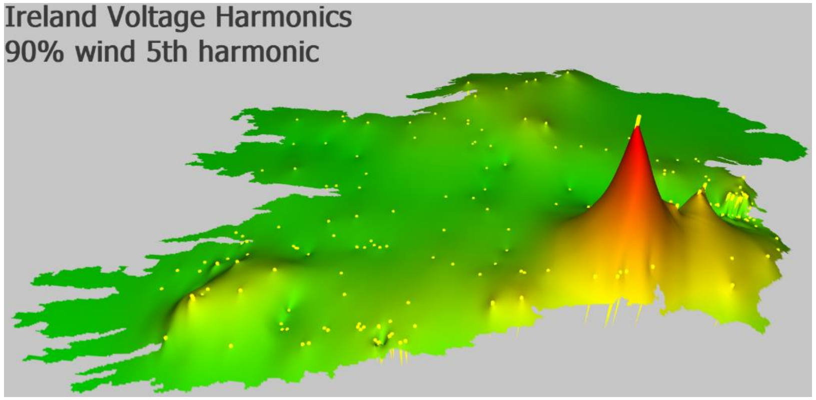
- Cases: Ref., 1,2,3 -> 60%, 70%, 80,%, 90% SNSP

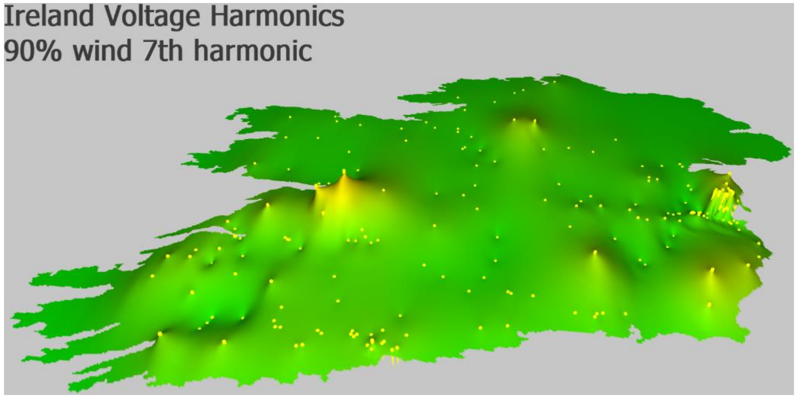
PQ VISUALISATION TOOL (ODIN-PQ)

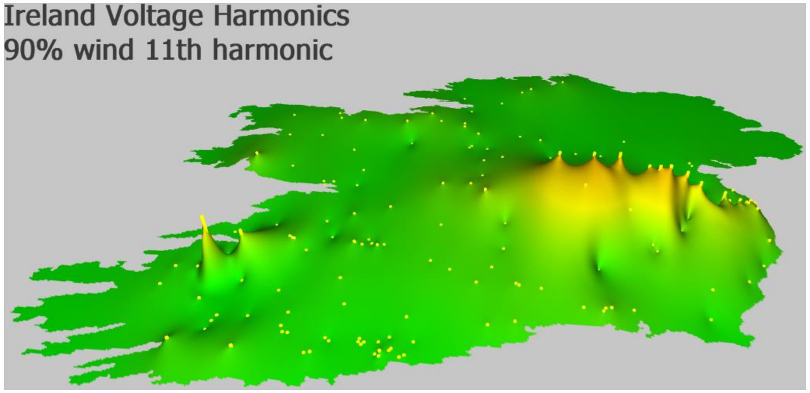


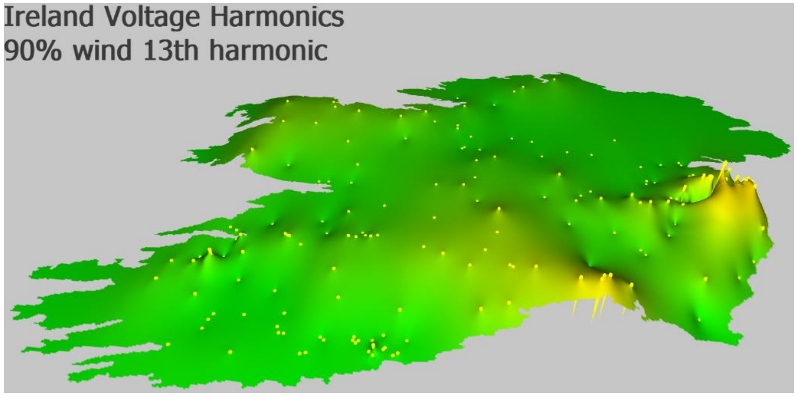
95th percentile of voltage THD 60% - 90% SNSP

PQ VISUALISATION TOOL (ODIN-PQ)





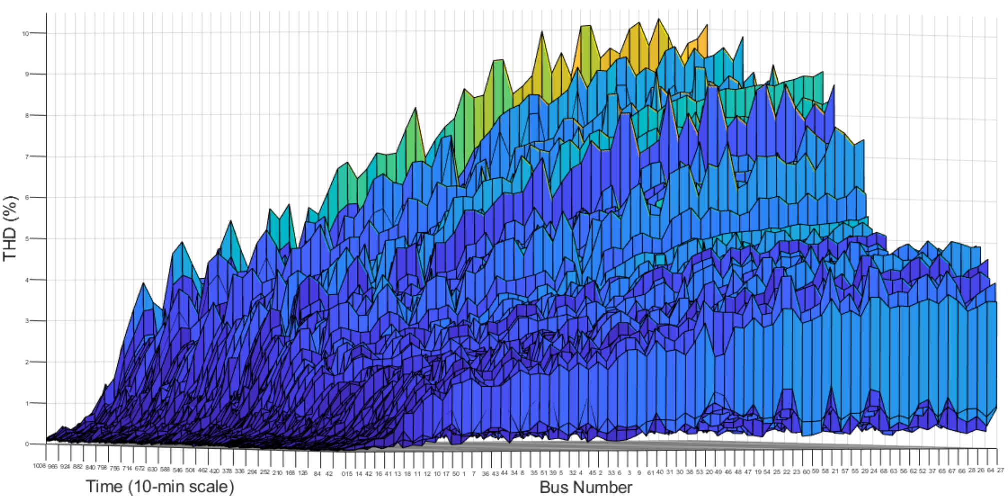


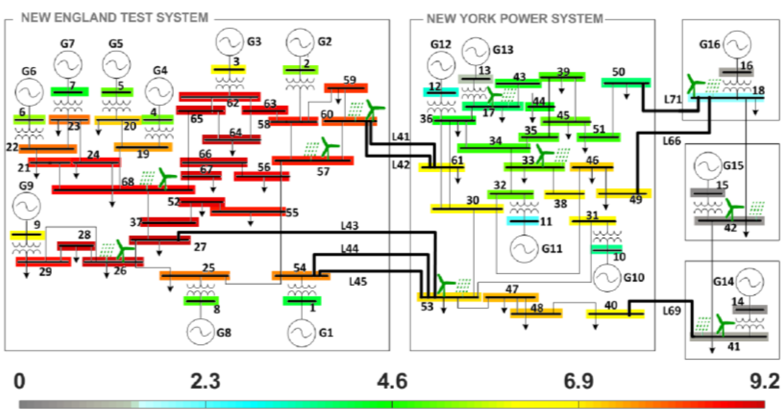


95th percentile of voltage harmonics (5^{th}, 7^{th}, 11^{th}, 13^{th}) 60% - 90% SNSP

HARMONIC DISTORTION MITIGATION - ONGOING

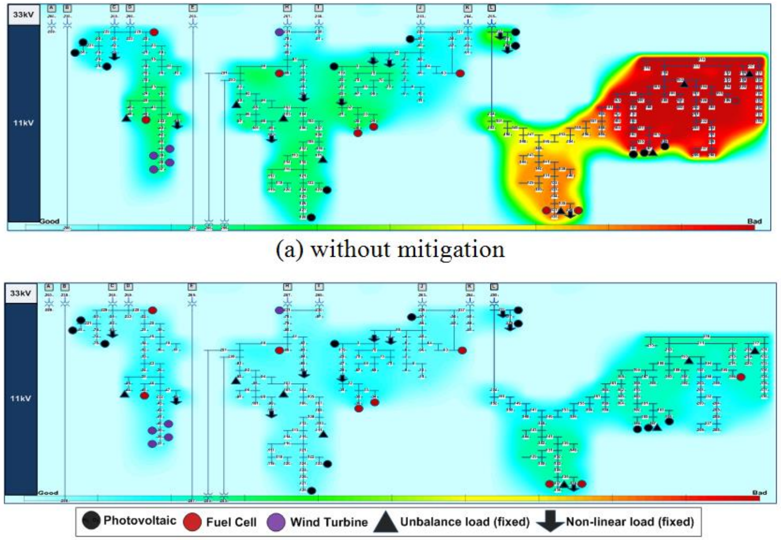
- Methodology will be implemented in IEEE 68 bus network
- Creating a probabilistic case study of one year data varying load (non)linearity, location and quantity of FACTS and PE (wind, solar) devices to achieve 60% to 90% SNSP
- Based on harmonic distortion results, mitigation points in the network will be proposed for each SNSP





HARMONIC DISTORTION MITIGATION - ONGOING

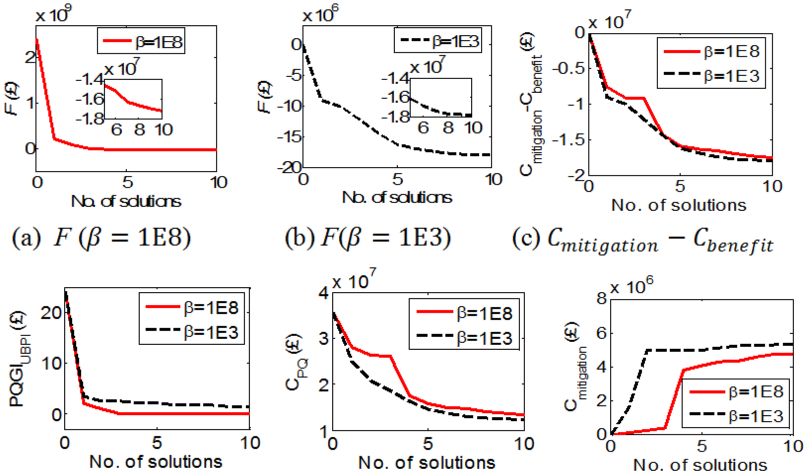
- Methodology of harmonic distortion mitigation for network and device based solution
- CBA based analysis: mitigation with the following parameters: location, number, type and size of mitigation devices (passive / active (part of other devices) filters, active filters at the PE devices)
- CBA based analysis: cost of mitigation vs financial and technical benefit (sensitivity analysis)



(a) without mitigation

(b) with mitigation (β = 1E8)

Fig. 3. Heatmaps of *UBPIs* obtained with the application of 10 solutions with and without mitigation.



(a) $F\ (\beta = 1E8)$ (b) $F(\beta = 1E3)$ (c) $C_{mitigation} - C_{benefit}$

(d) $PQGI_{UBPI}$ (e) C_{PQ} (f) $C_{mitigation}$

Fig. 2. Convergence curves of various components against the number of mitigation solutions applied.

ADDED VALUE FOR STAKEHOLDERS

- Overview of existing and future PQ issues in transmission networks and identification of main sources for PQ issues (T5.1, D5.1).
- Methodology for the assessment of the Influence of PQ Disturbance on Operation of PE Rich Power Networks is proposed in line with the developed scenarios in MIGRATE project WP1 (T5.3/T5.4)
- Mitigation techniques for PQ disturbances will be proposed, techniques include device based solutions (pasive and control) in order to improve the level of PQ in the transmission networks. (T5.5)
- PQ phenomena Visualisation tool developed (T5.3)
- Understanding of PMU applicability for PQ monitoring (T.5.3)

THANK YOU FOR YOUR ATTENTION!

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