C4-PS1

Challenges and advances in power quality (PQ) and electromagnetic compatibility (EMC)

C4-925

Harmonic studies performed by RTE for wind farm connection

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Motivation

- The increasing number of Inverter Based Resources connected to the transmission grid via long AC cables, may amplify the existing harmonic voltages beyond the planning levels.

- Today, harmonic voltage levels (V_{LIMIT}) are guaranteed by RTE :

Odd harmonic ranks				Even harmonic ranks	
Non multiple of 3		Multiple of 3			
Rank	Threshold	Rank	Threshold	Rank	Threshold
5 and 7	4%	3	4%	2	3%
11 and 13	3%	9	2%	4	2%
17 and 19	2%	15 and 21	1%	6 to 24	1%
23 and 25	1.5%				

- Harmonic studies carried out by RTE to assess harmonic amplifications and design passive filters (if needed), are based on transmission grid, connection and producers installations models.

- New contractual framework will be used for future projects, requiring to adapt RTE studies methodology.

Today methodology
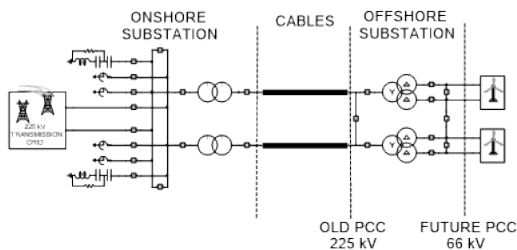
Background harmonic voltage measurements before connection

Modeling TSO grid, connection and customer installations

Amplification factors computation

Hx computation after connection, passive filter design if needed

Today process

Offshore projects evolution

- Point of common coupling (PCC) has a new location.

- Producers data are not available any more at early stage of the project (farm layout, WTG model etc.).

- Generic harmonic models are used to apply today methodology
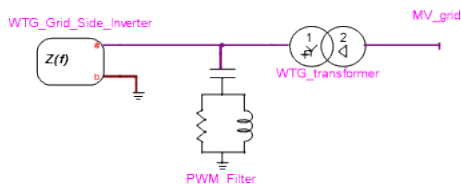

Generic WTG model

- The following parameters are taken into account to vary turbine impedance :

WTG generic model parameter [unit]	Variation range
WTG Power [MW]	[12, 16]
WTG transformer series inductance [p.u]	[0.07, 0.13]
PWM filter reactive power [kVAR]	[1e-6, 920]
Inverter choke inductance [p.u]	[0.1, 0.16]
Inverter Current loop time constant [ms]	[10, 40]
Inverter sampling period [us]	[5,50]
Inverter current low pass filter frequency [Hz]	[600, 3600]
Inverter voltage low pass filter frequency [Hz]	[5, 250]

Harmonic amplification factors calculated with generic models
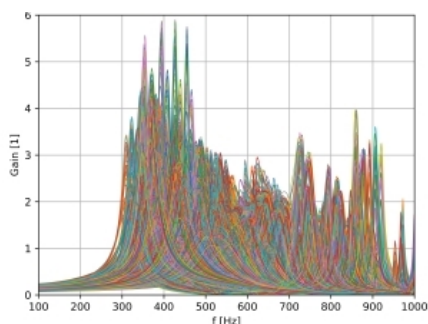
Amplification factors

- Amplification factors, calculated on 66 kV side, are very dependent on generic model parameters.

- Providing filter specification for such high variability is very challenging.

- Filtering multiple ranks would be complex and costly.

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Alternative approach

- Inapplicable results given by generic models

- Lack of WTG and offshore grid data

- → This prompted RTE to consider alternative methodology

- → Identify the largest harmonic impedance loci of the wind farm which prevents to exceed harmonic voltage limits
- For each case studied, the inequality $V_{NEW\ PCC} < V_{LIMIT}$ brings a circle equation
- All circles must be aggregated to represent the global forbidden area

- → Convex or concave hull algorithm needs to be implemented
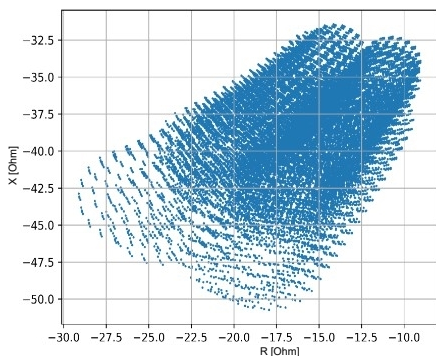
Hx measurements before connection
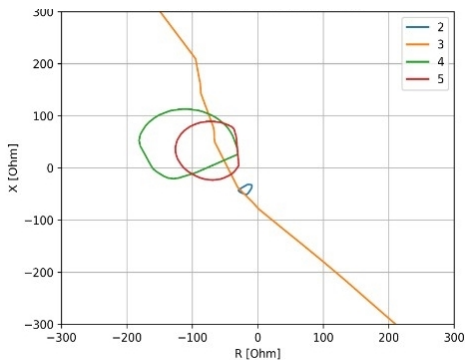
Modeling TSO Grid

Modeling connection

Identification of areas where Hx limits are met

Customer impedance loci after connection

Alternative approach summary

Example of ring impedances to avoid for rank 2

Harmonic loci to avoid, rank 2, 3, 4 & 5

Drawbacks :

- Turbine impedance can have negative resistance

- Customer A impedance can influence area imposed to customer B

- When limits are exceeded : impedance cannot be measured easily in the field

- → RTE decided not to use this alternative approach

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Harmonic regulation modification

- Studies mentioned above show that harmonic assessment becomes very challenging when wind farm data are missing

- Results obtained with new approaches are difficult to use

→ RTE wishes to modify its regulation framework in order to share the responsibility with producers regarding harmonic voltages specifically

- Recommended by both IEC 61000-3-6 and IEEE-519

- The TSO would perform early stage studies, by modeling the existing grid and the connection (no-load case, producer disconnected). Depending on the results, TSO may design onshore passive filters at this stage.

- In a second stage, from the Loci provided by the TSO, the producer would model its power plant and perform its own harmonic voltages studies (load case)

- Harmonic measurements would finally be performed after the commissioning. When exceeding the limits, mitigations should be taken by the producer or the TSO.

TSO study – no load case

Customer study – load case

Harmonic regulation process