Study Committee C4

Power System Technical Performance

Paper 10165_2022

Comparison of Harmonic Study Results with Long Term Measurements to Propose a more Realistic Way to Represent the System Impedance in Harmonic Performance Studies

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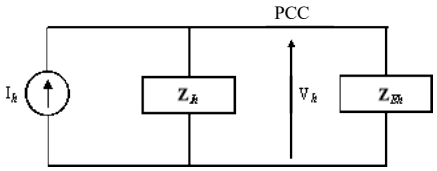
Motivation

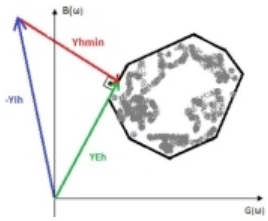
- Different approaches are applied to assess the harmonic performance of a disturbing installation
- In many cases, harmonic studies are performed to capture worst case operating condition, combining the worst harmonic current with the worst impedance resonance condition
- This approach combined with scarcity of real data available during the design stage and modelling inconsistencies may lead to overestimated distortions and oversized filtering solutions
- Evidence of this rigorous approach is the high percentage of Brazilian WFs that need to install filters due to simulation studies and the fact that long-term measurements of voltage distortion at WFs' PCC can be quite different from the figures predicted in studies
- Due to these relevant divergences, the paper evaluates and proposes adjustments to the criteria for carrying out studies to assess the performance of disturbing installations in order to find a modelling that more realistically represents the distortions verified in long-term measurements
- The main proposals are changes in the criteria and in the system operating conditions used to define the harmonic impedance of the network in the studies

Harmonic Performance Assessment

- The harmonic performance study methodology required in Brazil is based on the classical procedure of filter design in HVDC systems



Circuit for Overall Assessment

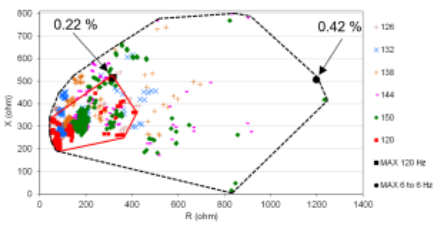


Discrete polygon and minimum admittance

- The wind park owner has to demonstrate that the voltage distortion generated by the project at the PCC is bellow the distortion limits stated in the grid code, otherwise, harmonic filters must be installed to reduce the distortion
- According to the grid code, the impedance loci can be represented only by two forms of envelope of impedances for wind farm (or photovoltaic) studies: discrete polygon and sector diagram
- For the sector diagram, each impedance envelope must include two additional orders besides the harmonic order assessed (h-1, h, h+1)
- For the discrete polygon, each envelope must include, in addition to the impedances of order h, impedances of inter-harmonic frequencies until h±0,5 with a frequency step resolution of fn/10, i.e., h-6 Hz, h-12 Hz, until h-30 Hz and h+6 Hz, h+12 Hz, until h+30 Hz for a 60 Hz system
- The modification of the existing voltage distortion at the PCC caused by the interaction of the customer impedance with the utility impedance is not assessed through simulations in Brazil

Some Causes of Differences between Study and Measurements Results

- The use of a methodology originally developed for filter design in LCC HDVC systems to assess the harmonic performance of installations that have low harmonic current emissions
- The modeling of the harmonic source of WTs as an ideal current source can lead to inaccurate results
- The influence of background harmonic voltages on the currents measured at the terminals of WT
- The use of the equation and exponents established in IEC 61000-3-6 to sum the currents from all wind turbines at the PCC of an installation
- The criteria and scenarios considered to define the impedance loci



Impedance envelopes defined with different criteria

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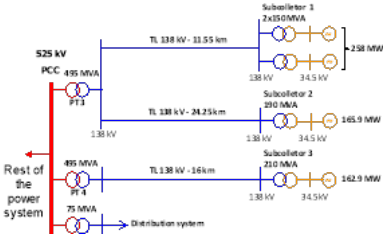
continued

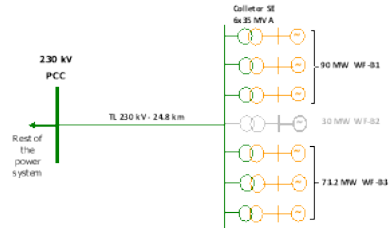
Case Study

- The case study is carried out in two different wind farms: WF-A (586.8 MW) and WF-B (163.2 MW)
- WF-A started operation between 01/2015 and 01/2016



Simplified diagram of WF-A

- WF-B1 started operation between 06/2011 and 06/2012 and WF-B3 between 08/2015 and 12/2016



Simplified diagram of WF-B

- Study results for WF-A1 and WF-A2 – V (%)

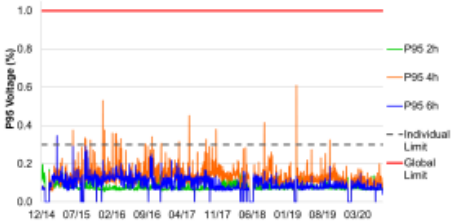
h		2	3	4	5	6	7	THD
Individual Limit		0.3	0.6	0.3	0.6	0.3	0.6	1.5
WF	A1	0.66	1.34	0.72	0.70	0.08	0.90	1.82
	A2	0.26	0.97	0.67	0.40	0.26	0.56	1.48

Study results for WF-B – V (%)

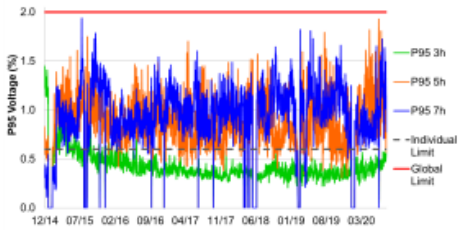
h		2	3	4	5	6	7	THD
WF	B	0.98	1.54	1.29	4.14	0.13	0.60	4.77

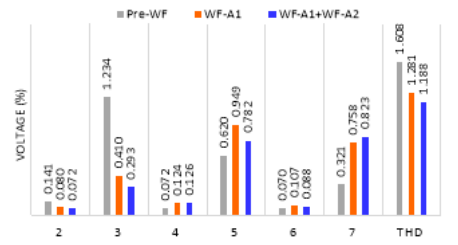
Long-term Measurements and Statistical Assessments of Harmonic Voltages

- Next figures present examples of the harmonic voltages measured on a 10-minute basis (daily 95th percentile values - P95) at the WFs' PCC in the pre-park measurement campaign and in the continuous monitoring of distortions
- P95 of even order distortions (2nd, 4th and 6th) measured at WF-A PCC (about 6 years)

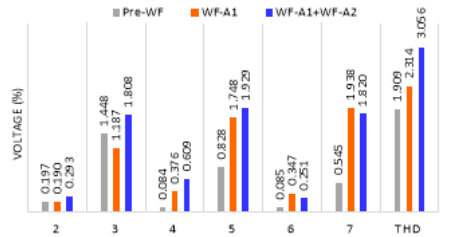


- P95 of odd order distortions (3nd, 5th and 7th) measured at WF-A PCC





Average of the P95 of the harmonic voltages measured per period at the WF-A



Maximums P95 of the harmonic voltages measured per period at the WF-A

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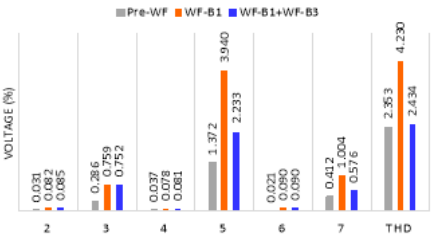
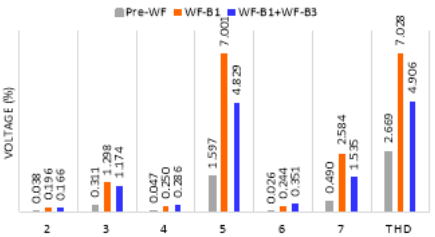


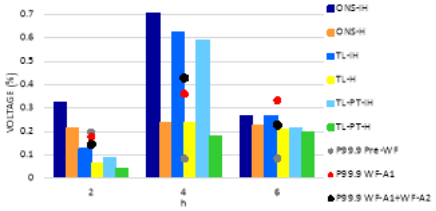
Average of the P95 of the harmonic voltages measured per period at the WF-B



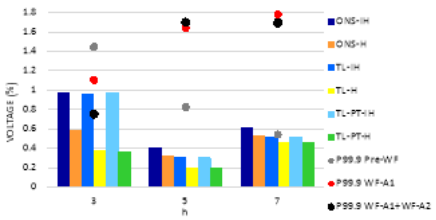
Maximums P95 of the harmonic voltages measured per period at the WF-B

Performance Calculations to Assess the Proposed Criteria

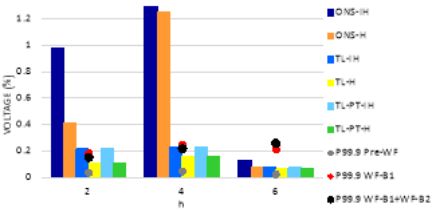
- Comparison of study and measurements results for WF-A – even orders



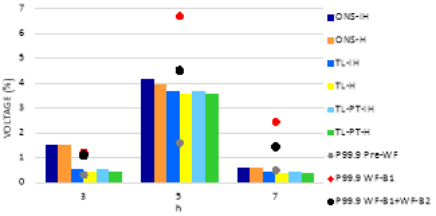
- Comparison of study and measurements results for WF-A – odd orders



- Comparison of study and measurements results for WF-B – even orders



- Comparison of study and measurements results for WF-B – odd orders



Conclusion

- It is not appropriate to adopt the same study criteria for the design of filters and for the verification of their need, at the risk of resulting in the installation of unnecessary equipment
- When verifying the need for filters, it is advisable that the system harmonic impedance is represented in a more realistic way in the studies, covering probable scenarios, especially for low harmonic orders
- The inclusion of inter-harmonic frequencies until h±0.5 with a frequency step resolution of $f_n/10$ for the definition of the impedance envelopes from 2nd to 4th harmonic, results in improbable voltage distortion levels
- The consideration of harmonic impedances calculated in scenarios with TL and PT contingency can generate more severe results than those verified in the measurements when using the P95 of the harmonic voltages to evaluate the harmonic performance
- The article proposes that harmonic performance studies (for a diagnosis of generated voltage distortions) should be carried out without including the inter-harmonic frequencies in the impedance envelopes from the 2nd to the 7th harmonic
- Such studies should also not consider the inclusion of calculated impedances in scenarios with a low probability of occurrence, i.e., scenarios with a duration of no more than 2% (about 1 week) or 5% of the time in a year