Harmonic distortion analysis on the MV and LV distribution networks: problems, influencing factors and possible solutions

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1. Brief introduction

Harmonic distortion problems are increasing on the MV and LV distribution networks, especially with the application of power factor correction capacitors that resulting resonances close to the 5th harmonic. This paper describes two case studies of solving harmonic resonance problems on distribution networks. Procedures to prevent high voltage distortion are presented based on the identification of potential resonance conditions in most probable network configurations.

Key words: Harmonic distortion, power quality monitoring, resonance, HV/MV substations and capacitor bank.

2. Harmonic Distortion

Electric utility power quality monitoring campaigns have been done according to EN 50160 recommended standards, during approximately three months. Measurements have shown that during certain network configurations, the 5th harmonic voltage is close to or slightly exceeds the EN 50160, in some MV buses of HV/MV substations and on the LV side of MV/LV transformers. This paper discusses the cause of these problems, analyzing the influential factors and evaluating possible solutions. The voltage distortion for different topologies in different load and reactive compensation conditions has been studied [1,2].

Both studies were carried out using the software "DPlan – Análise Harmonica", developed by the Institute of Applied Optimization (IOA) and EDP Distribuição, member of EDP Energias de Portugal [2].

3. Case Studies

A. 5th harmonic in a MV busbars

An example is given here for the 5th harmonic monitored in both MV buses of an HV/MV substation, held between April and June 2007 (three months).

The HV/MV substation topology is two busbars connected to two transformers and two capacitor banks (CB), one bus for each transformer and capacitor bank.

The worst week profile for the 5th harmonic of the three phase magnitudes (average values) and the permissible limits by the standard for both busbars are shown in Figure 1 and in Figure 2. The CB schedule is represented by two bars. The green colour means the CB is switched on and the red colour means the CB is switched off.

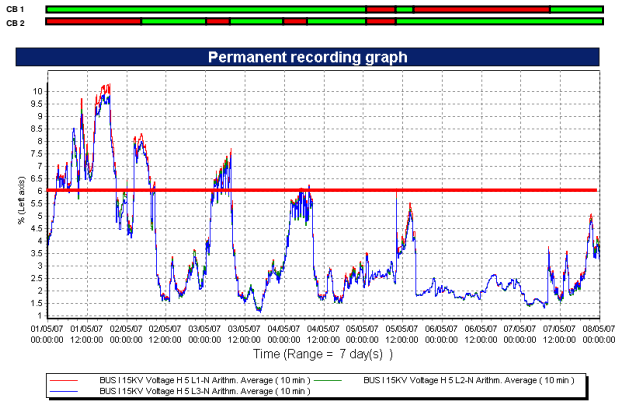

Fig. 1. 5th harmonic in MV busbar # 1

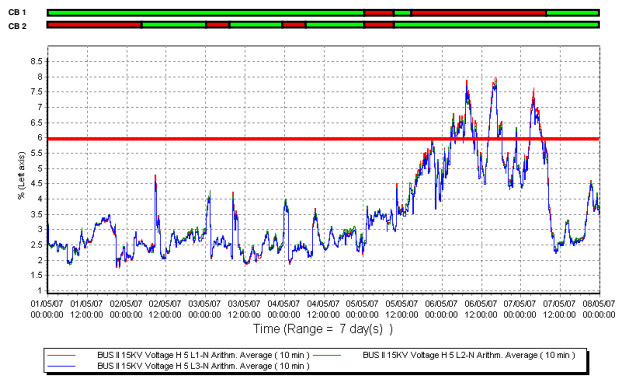

Fig. 2. 5th harmonic in MV busbar # 2

The correlation with the SCADA records shows that the capacitor banks switching has an influence on the 5th harmonic in MV busbar.

For example, it is possible to simulate the effect of switching-on capacitor banks, changing tap positions of transformers, connecting busbars and/or reconfiguring the HV or the MV network. Following the example given before, the results of connecting capacitor banks can be simulated by running a power-flow for the 1st May loads and network topology (CB 1 switched on and CB 2 switched off). The results of the simulation are shown in Figure 3 (busbar # 1) and in Figure 4 (busbar # 2).

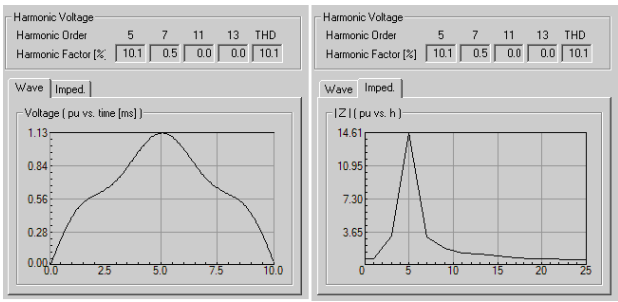

Fig. 3. Harmonic voltage results in MV busbar # 1

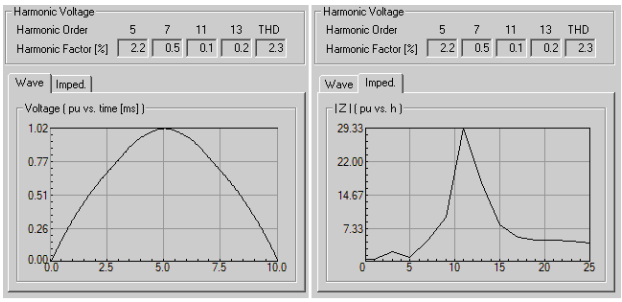

Fig. 4. Harmonic voltage results in MV busbar # 2

It is concluded that the increase in the 5th harmonic in MV busbar # 1 happens when the CB 1, connected to busbar # 1, is switched on and the CB 2, connected to busbar # 2, is switched off, coinciding still higher values of 5th harmonic with the periods in which the load is lower (off-peak hours). For another busbar, the conclusion is similar.

The proposals to reduce the 5th harmonic voltage to regulatory values were changed the schedule of both capacitor banks and decreased the power of the capacitor banks, in 1.60 Mvar (disconnection of 6 elements).

An additional monitoring in the HV/MV substation, held between May and June 2008, has validated the procedures in order to prevent the 5th harmonic voltage.

B. 5th harmonic at LV side of a MV/LV transformer

The second case study is about the 5th harmonic monitored at LV side of MV/LV transformer and in MV busbar of an HV/MV substation, held between April and June 2008 (Figure 5).

The results can be simulated by running a power-flow for the 22nd June (Sunday) loads and network topology (CB switched on). The results of the simulation are presented in Figure 5 (LV side of MV/LV transformer).

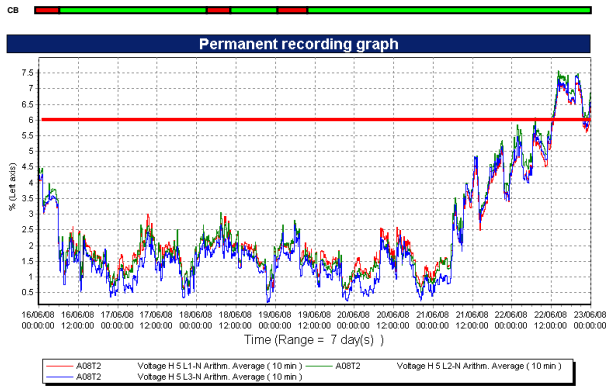

Fig. 13. 5th harmonic at LV side of MV/LV transformer

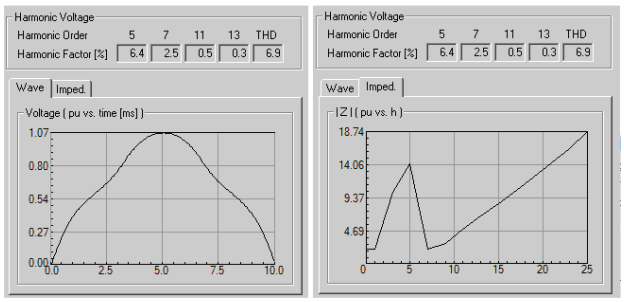

Fig. 5. Harmonic voltage results at LV side of MV/LV transformer

4. Conclusion

Harmonic distortion problem was being caused by resonance created by the substation capacitor banks in the MV busbar. This resonance was magnifying the 5th harmonic component in the currents from all the customers on this system, causing high voltage distortion levels.

In many cases, it may be more economical to control the voltage distortion experienced by all customers by changing the frequency response of the system. This can be accomplished with some changes in capacitor bank on the MV system, particularly by changing the schedule and/or decreasing the power of the capacitor banks.

This paper describes two case studies of solving harmonic resonance problems on distribution networks and reduces harmonic voltage distortion for all customers. Procedures to prevent high voltage distortion are presented based on the identification of potential resonance conditions in most probable network configurations.

An additional monitoring in an HV/MV substation has validated the procedures in order to prevent harmonic voltage distortion.

References

[1] R. Dugan et al., Electric Power Systems Quality, Mc Graw-Will, EUA (2003), pp 167-224.
[2] Carlos Santos et al., “Voltage distortion in large-scale MV and HV distribution networks: harmonic analysis and simulation”, CIRED 2009.