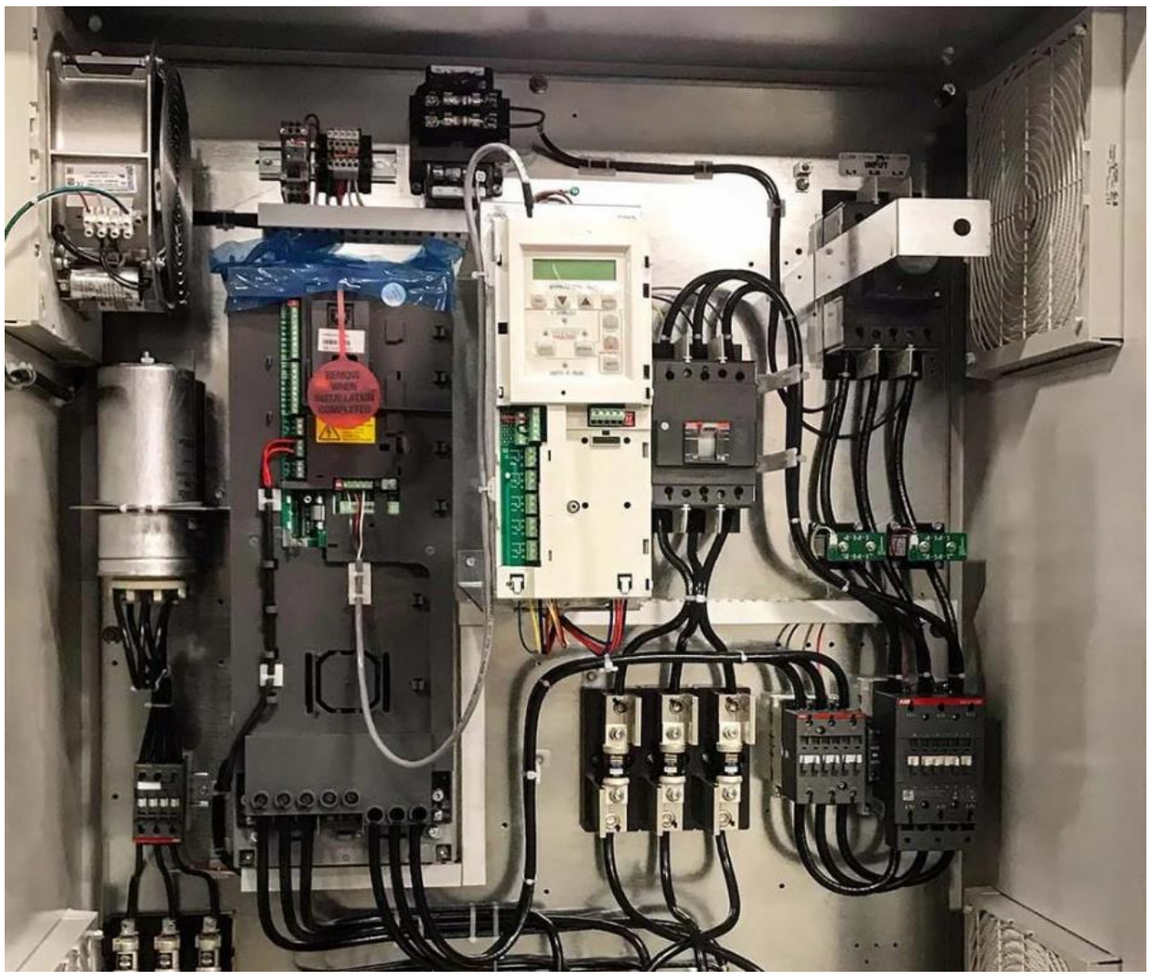
The essentials of harmonic filtering techniques

High-pass filter at generator terminals

This example is aimed at illustrating the reduction of THDV using a high-pass filter in an installation. High-pass filter is used to control a resonant condition. The example describes another real-world application in which harmonic-related problems arose and even damaged a generator unit. This case presented an excellent opportunity for conducting investigations on a complicated phenomenon.



The AC source, a 3-MVA synchronous turbo generator, was the power supply for **two 1.5 MVA step-down transformers**, which in turn fed a number of VFDs powering downhole electrosubmersible pumps. Apart from a small service transformer that sourced the platform services, the VFDs were the only loads as illustrated in Figure above.

A number of harmonic measurements indicated that voltage and current harmonic levels were excessively high. The suspecting element was a 0.27-μF surge protection capacitor bank, which apparently combined with connecting cables between generator and transformers to excite a resonant condition at the generator bus.

Through additional measurements and simulation work, this was further confirmed to be the case.

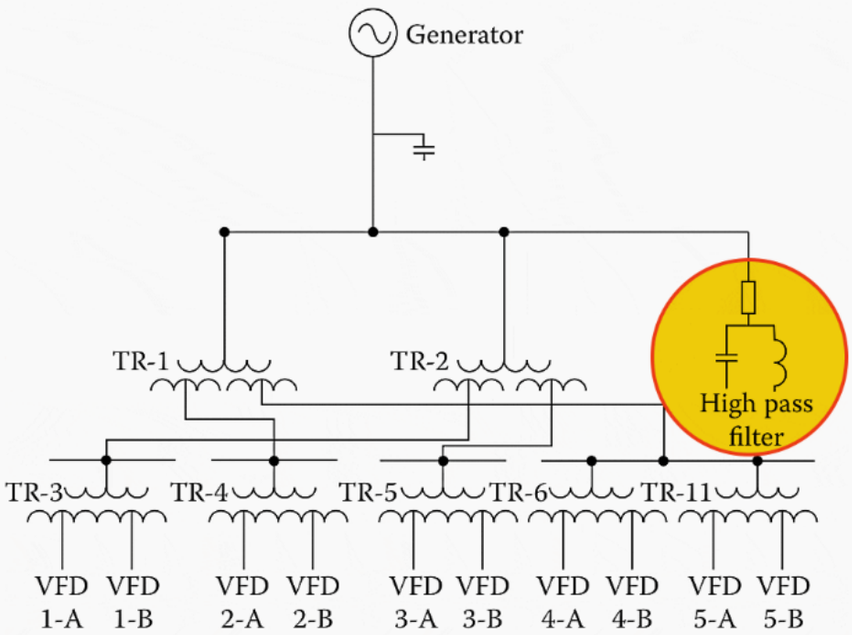


Figure 1 – A high-pass filter at the generator bus on an offshore oil field installation

Here, we will show the resonant condition and how it was controlled using a high-pass filter **to reduce harmonic distortion levels at the generator terminals** within IEEE-519 limits.

Figure 2 shows the abrupt increase in impedance (dotted line) **revealing a resonant condition around harmonics 39 through 43**.

Such a situation imposed severe stresses on the generator that comprised intense shaft vibration and increased operation temperature. Also shown is the Z–f characteristic of the band-pass filter that was applied at the 600-V generator bus. Filter elements were selected to obtain a corner frequency centered at around the 11th harmonic.

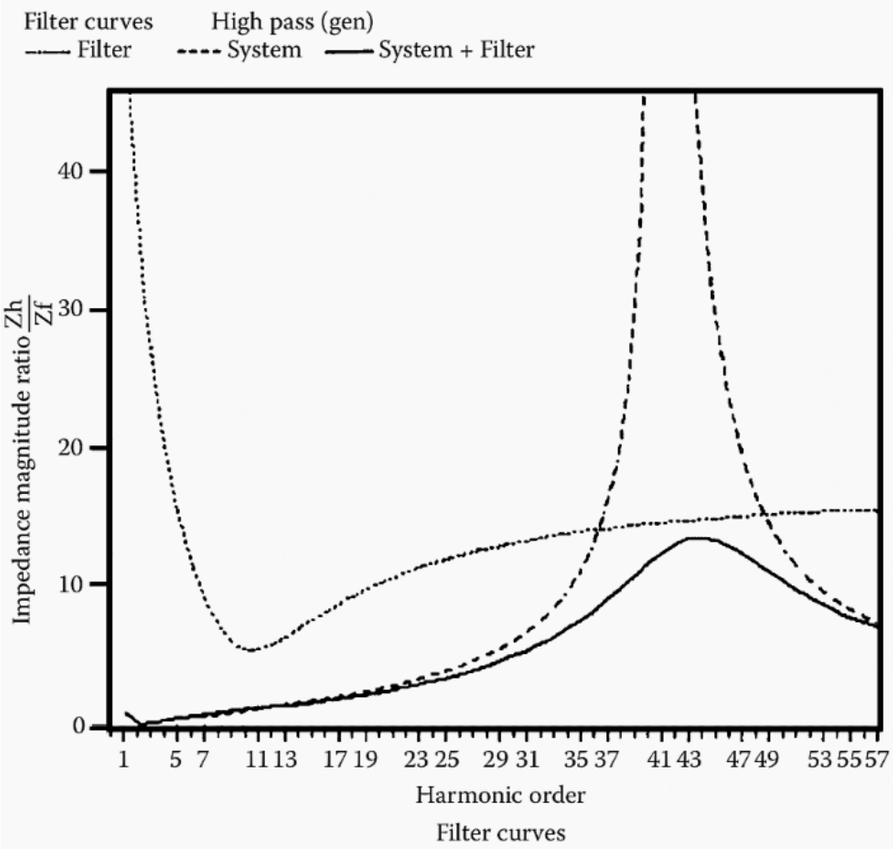


Figure 2 – Impedance vs. frequency characteristics at the generator bus

Notice the system response with the high-pass filter showing **a substantial reduction of the impedance at the resonant point**.

Figure 3 shows how the impedance frequency characteristic looks at the primary of one of the downstream transformers feeding a VFD at one of the oil wells.

At these locations, **5th-, 7th-, and 11th-harmonic filters were installed**. This is noticeable on the Z–f characteristic, which also reflects the band-pass filter effect on the distribution system as seen from that location. Thus, the installation of a low-cost high-pass filter (involving a 67-kVA capacitor bank) at the generator bus allowed a very annoying condition to be brought under control.

Interestingly, the resonant phenomenon, as observed in Figure 6.14, involved a frequency range in which characteristic harmonics show very small (but apparently strong enough) values that, after undergoing amplification, made THD levels soar.

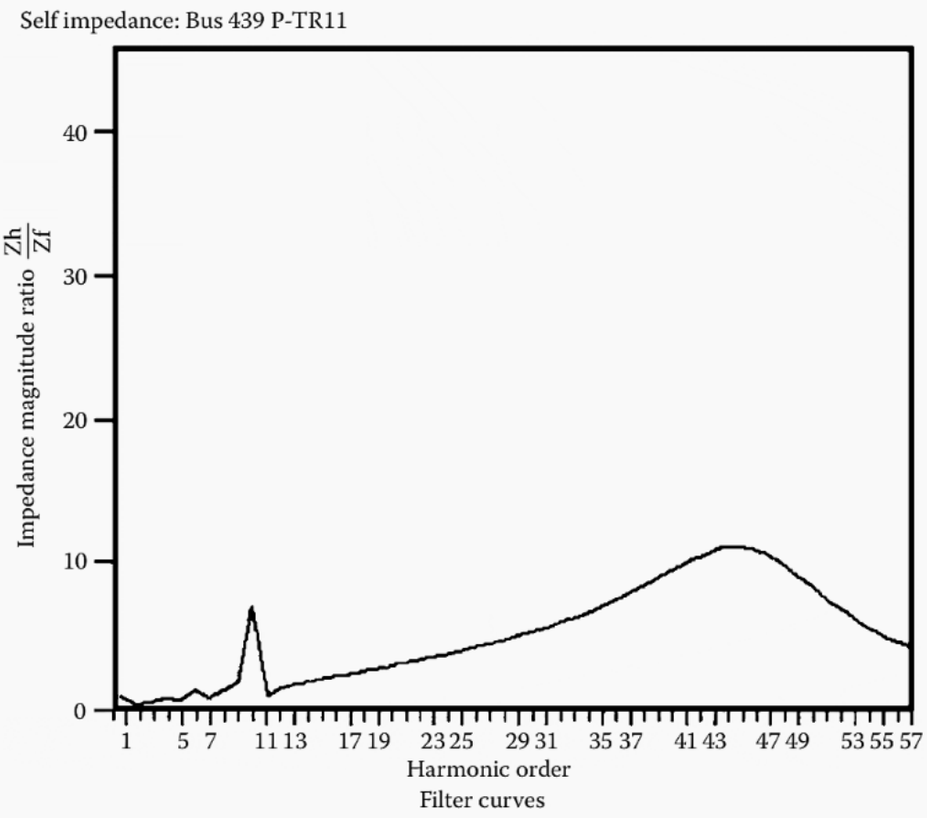


Figure 3 – Impedance vs. frequency characteristics at a downstream VFD

It is important to mention that applications of high-pass filters at the generator bus are usually combined with the application of single-tuned filters at the VFD locations to get THD levels within recommended limits at the generator terminals as well as at the individual VFD sites.

Leaving the high-pass filter at the generator bus as the only harmonic mitigating method may cause excessive heating on the high-pass filter elements.

> *In this example, the real intention of the high-pass filter was **to eliminate the large impedance resulting from the resonant condition** more than to provide a low-impedance path to all harmonic currents generated at the various VFD sites.*