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Broadband Interference Sources Require Broadband Filters –

With the modular filter system, value creation remains with the switchgear manufacturer.

In today's power supply networks, poor voltage quality can have severe consequences, such as the failure of frequency converters, malfunction of electronic controls, or even the shutdown of entire production facilities. While the primary costs, such as damage to equipment, are still manageable, immense secondary costs can arise from downtime, production losses, and scrap costs. Additionally, significant financial risks emerge since manufacturers of frequency converters and production equipment are exempt from warranty obligations if the relevant voltage quality standards are not met. The following phenomena can impair voltage quality: low-frequency harmonics, higher-frequency harmonics due to resonances, switching frequencies, and commutation dips, issues with voltage levels, and reactive power. For each of these voltage quality problems, Condensator Dominit's portfolio offers a product solution. This article focuses on introducing the GridClass®-Mod product line, which solves harmonic problems across all frequency ranges as an integrable switch cabinet solution.

The current transformation of our energy supply system is characterized by the increasing use of power electronics. The integration of renewable energies, the use of LEDs, consumer electronics, and the control of motors by frequency converters result in an increase in the proportion of non-linear loads in our networks. These loads all absorb harmonic currents, which are not proportional to the voltage and thus do not correspond to the fundamental frequency (50 Hz). Harmonic currents typically occur in low-frequency ranges up to 2.5 kHz and are specific integer multiples of the fundamental frequency; for example, the 5th order corresponds to 250 Hz. Without the use of appropriate filtering measures, this current encounters the network impedance. According to Ohm's law, the harmonic current causes a voltage drop across the network impedance, which superimposes on the fundamental frequency and distorts the network voltage.

In addition to harmonic currents, an increase in network impedance due to resonance can lead to voltage quality problems. Resonances occur due to capacitances present in EMC filters, extensive cable networks, or non-inductive compensation systems. Combined with the inductance of the transformer, a resonant system forms. This leads to an increase in network impedance at the resonance point, so even a small harmonic current can excite the resonance and cause enormous interference levels. Resonances can only be mitigated by introducing lossy damping into the network.

To assess the voltage quality in an industrial network, IEC 61000-2-4, as the product standard, specifies defined limits for the maximum allowable voltage distortion in the frequency range up to 2.5 kHz. If these limits are exceeded, equipment and processes may be disrupted without the manufacturers being held liable. Ultimately, the operator of the industrial facility is responsible for maintaining voltage quality criteria and must therefore install appropriate filtering measures. This presents a new value creation potential for switchgear manufacturers to integrate these filter solutions into their switch cabinet concepts.

Various filtering technologies exist to improve grid quality and comply with limits, generally divided into active and passive filters. The GridClass®-Mod product line, consisting of SΦFIA®-Mod and RεSI-Mod, is an innovative filter system that combines the advantages of different filters in a modular system. The combined filter provides a broadband filtering effect across the entire frequency spectrum and dampens resonances. The modular design of GridClass®-Mod allows high adaptability and expandability according to the specific filtering requirements. Switchgear manufacturers can benefit from this flexibility, as the filter modules can be easily integrated into systems and expanded to meet the required performance. Thus, switchgear manufacturers can offer their customers a comprehensive product and integrate voltage quality assurance into their value chain.

The first component in a modular filter system is the 100 A module SΦFIA®-Mod, which is a 'Voltage-Guided Harmonic Filter with Intelligent Adjustment.' The SΦFIA® filter (see Figure 1) has been protected by a European patent (European patent No. 3065247) since 2016 and is currently the most commonly installed filter system in the global automotive manufacturing industry.

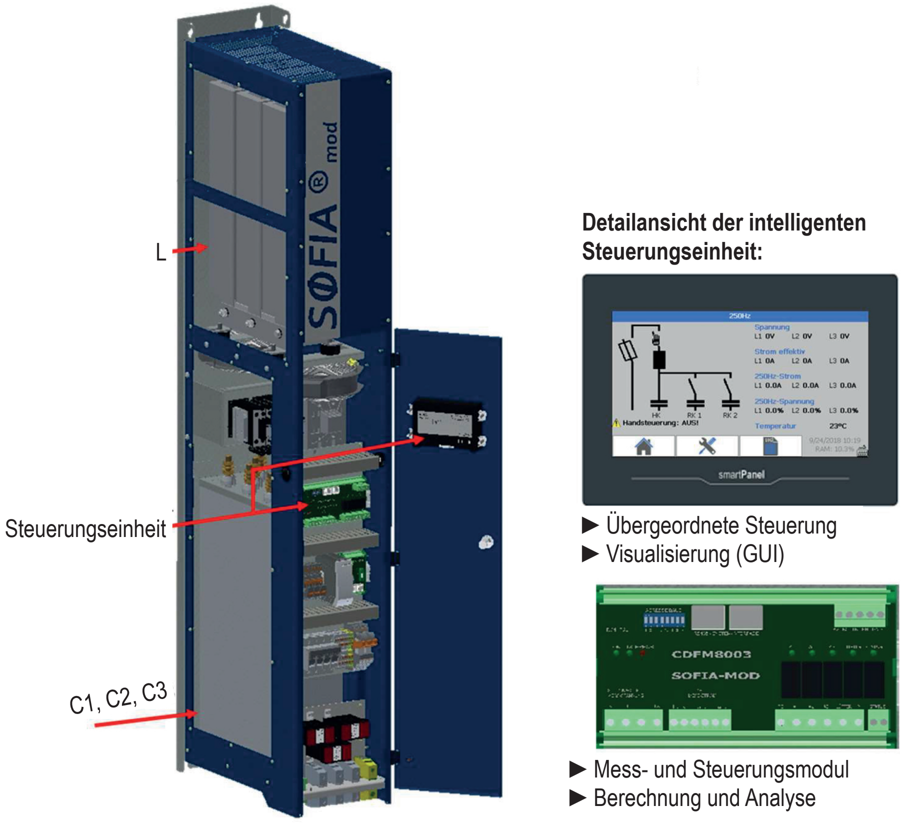

Figure 1: Structure of an SΦFIA®-Mod filter module (100 A). The most important component and the brain of the filter is the intelligent control unit.

Unlike traditional passive filters, which achieve a specific absorption effect at defined frequencies through a combination of a capacitor and an inductor, the SΦFIA® filter independently adjusts its current intake based on the load of the network and other conditions using an intelligent control unit. This allows for subsequent changes in the network and rising or falling levels to be readjusted, ensuring an optimal filtering result at all times. The main disadvantage of traditional passive filters, which shut down in case of overload—precisely when they are needed the most—is overcome with SΦFIA® filters.

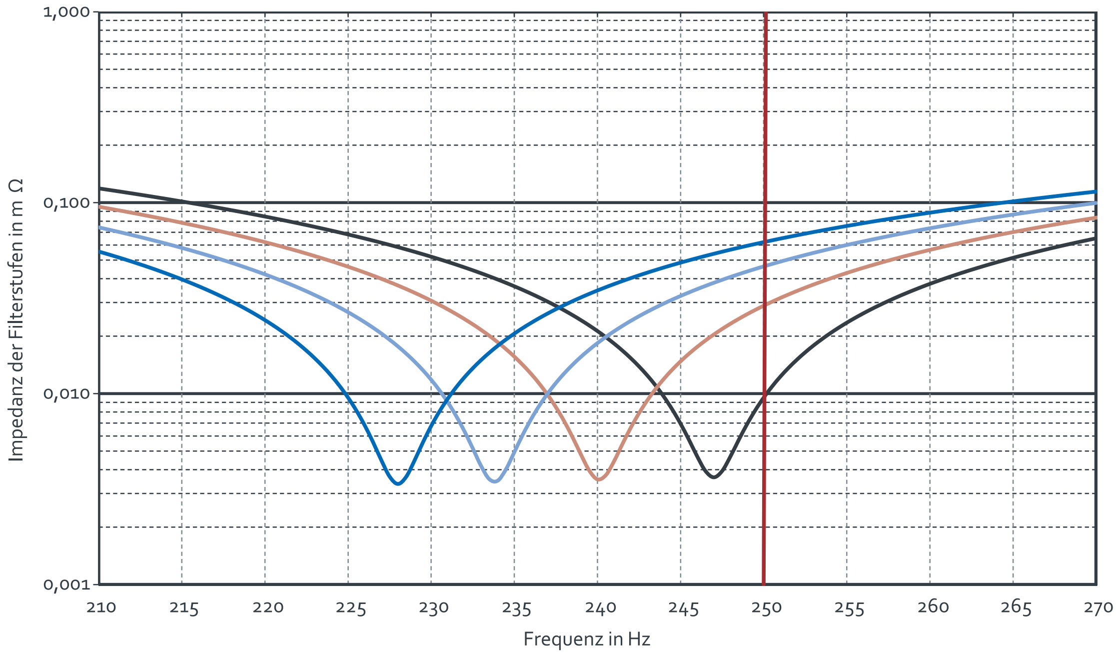

Figure 2: SΦFIA® principle: Impedance curve of an SΦFIA® filter for the 5th harmonic with four stages. By switching capacitor stages, the impedance curve shifts to another tuning frequency.

In addition to passive filters, active filters are widely used to ensure voltage quality. Active filters are controlled rectifiers that measure the harmonic current in the network and then inject an opposite current to compensate by controlling the power semiconductors. The compensation principle of active filters is thus current-driven and differs from the voltage-driven operation of passive filters. Due to the current-driven filtering principle, active filters can only reduce discrete harmonics, i.e., multiples of the fundamental frequency, and do not have a broadband filtering effect compared to passive filters. Moreover, the highest filterable frequency is limited by the switching frequency of the active rectifier. Other significant advantages of passive filters over active filters are lower power loss and lower acquisition and operating costs. SΦFIA®-Mod combines the advantages of passive filters: cost-effective broadband filtering with low losses and the flexibility of an active filter. SΦFIA®-Mod thus offers a universally applicable filter that automatically adapts to the network situation.

In a network with existing or impending resonances, an RεSI filter (Resonance Elimination System in Figure 3) can be modularly integrated into a switch cabinet in addition to the SΦFIA® filter to introduce appropriate damping into the network. Besides resonance damping, the RεSI module can also significantly reduce high-frequency interference levels caused by switching frequencies or commutation dips.

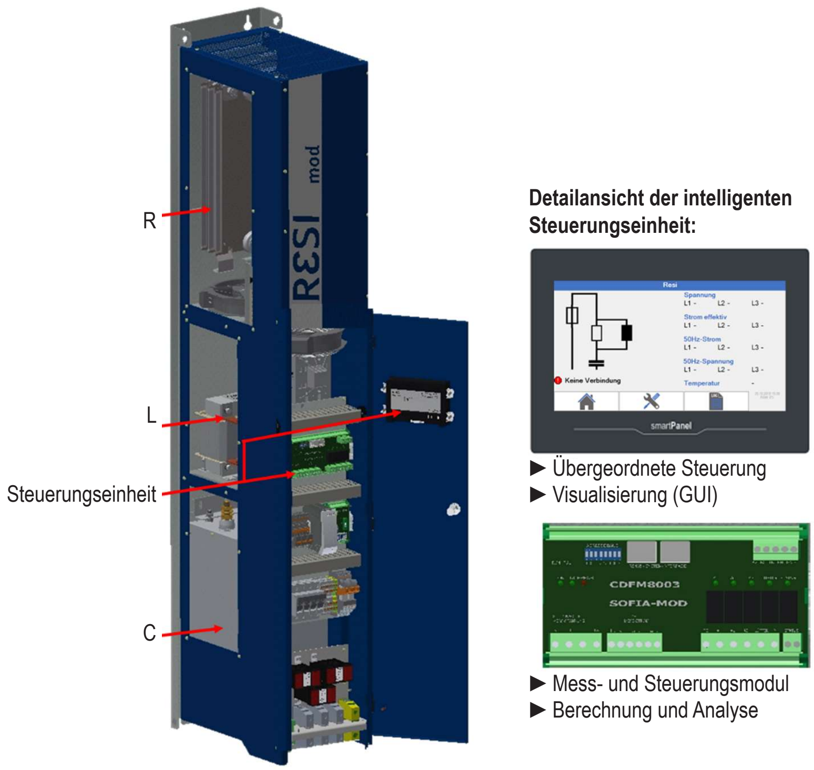

Figure 3: Structure of an RεSI-Mod filter module

The combination of capacitors and inductors in a network forms a resonant system at a specific frequency according to Thomson's oscillation equation $f = 1 / (2 * \pi * \sqrt{(L*C)})$. Classic filters, both active and passive, cannot reduce voltage distortions due to resonances. The only way to reduce resonance-related voltage levels is by introducing damping. Damping is achieved by extracting energy. In the power supply network, energy is converted into heat in resistors and thus removed from the system. This explains why classic filters cannot combat resonance levels. Passive filters introduce capacitors and chokes into the network but no damping. Thus, the resonance problem only shifts to another frequency, according to Thomson's formula, but is not dampened. Active filters also cannot eliminate resonances because they inject harmonic currents with incorrect phase angles due to the current-driven compensation principle. In the worst case, active filters can even excite resonances, which is why they should have resonance detection implemented. If a resonance is detected, no currents are injected at the corresponding order.

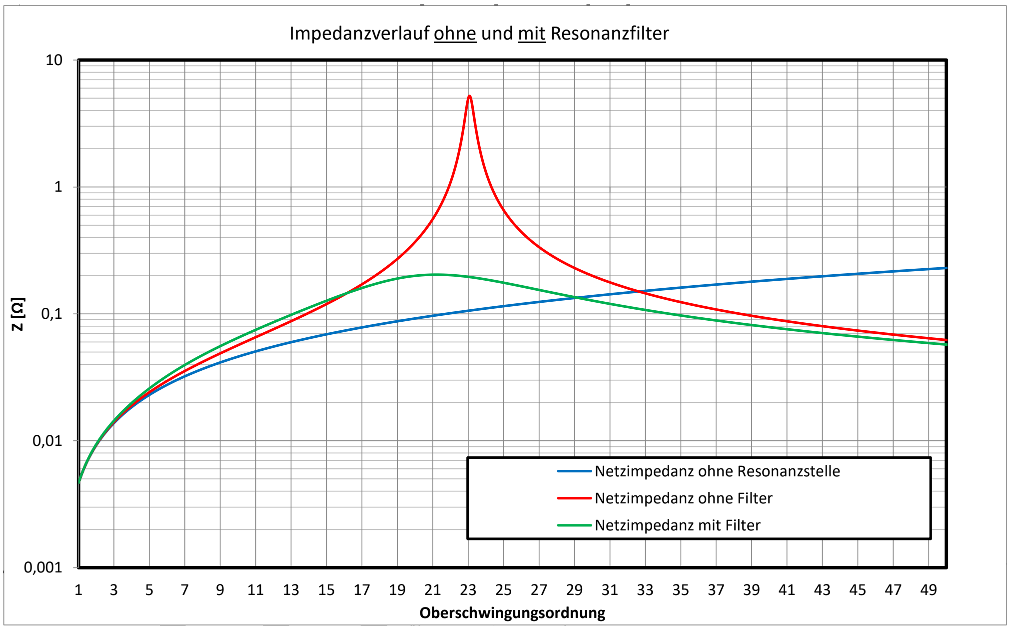

Figure 4: Impedance curve of an RεSI filter. Example: Network 50 MVA, Transformer 630 kVA, Cable 100 µF + RεSI-Mod-400/50-25 kvar.

Summary: Due to the steady increase in power electronic consumers with non-linear characteristics, the load on our power networks is rising. Low-frequency network feedback from frequency converters and higher-frequency disturbances cause the limits of voltage quality standards to be exceeded. A violation of the standard can lead to operational failures, process disturbances, or even the destruction of equipment. The use of appropriate filtering measures, as realized in the GridClass®-Mod product line by combining an intelligent passive filter SΦFIA®-Mod with a resonance damping filter RεSI-Mod, is therefore often indispensable. The concept of the GridClass® series offers a way to combine the advantages of classic passive and active filter concepts without their weaknesses, such as increased power loss or complicated designs. The combination of SΦFIA®-Mod and RεSI-Mod (see Figure 4) achieves a broadband filter effect. The modular design allows filtering measures to be easily and flexibly integrated into switch cabinets or existing systems can be expanded with the filter modules using "plug and play."

Figure 5: The GridClass®-Mod product line installed in a switch cabinet via plug and play. Centrally controlled broadband filtering of harmonics by SΦFIA®-Mod (filtering of the 5th, 7th, and 11th harmonics) in combination with the high-pass filter module RεSI-Mod.