New Passive Filter For PWM Based Devices

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16.9 New Passive Components for System Integration
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Abstract

This paper presents the new passive filter, based on a foil inductor and called hybrid *LC* filter (HLCF). HLCF integrates inductance and capacitance in one component. This is achieved using auxiliary foil (AF) placed between the turns of the main foil (MF). The stray capacitance in HLCF is thus cancelled and converted into the useful capacitance between MF and AF.

Introduction

The pulse-width modulation (PWM) based devices have found wide industrial implementation. However, PWM sequence of pulses contains harmonics, which are not required for control, but contribute in noises. The noises can cause damages of the loads, problems with electromagnetic compatibility, increase losses and heat loads. The filters used in devices with PWM should effectively operate in wide range of frequencies. However, stray impedances existing in filter worsen the high-frequency (HF) attenuation. Thus, the commonly used filters are not capable to protect the loads from the adverse effects of the PWM.

Hybrid LC filter

In HF applications, e.g. in power drives, foil inductors are widespread, because of low DC and AC resistances. In order to avoid short-circuits, essential surfaces between coil turns have to be separated by insulation. This way a large self-capacitance is formed and HF noise travels through the coil without damping. Fig. 1 presents an HLCF, which contains two isolated foil layers coiled on a core [1–5]. The core material is air, but can also be a magnetic. MF is placed between the PWM device and load. AF is introduced between the turns of the main foil and is connected to a neutral. This way, there is a remarkable capacitance between MF and AF. Such a system can be described by a simple equivalent *LC* filter in a wide range of frequencies [1–3].

To activate the capacitance between the HLCF layers, the AF should be connected to a neutral: either via Terminal 1 (T1) or via Terminal 2 (T2), as shown in Fig. 2, where L_m and L_a are inductances of MF and AF, M is the mutual inductance, C_b is the distributed useful capacitance, C_{i1} and C_{i2} are the self-capacitances of MF and AF, Z_{in} and Z_{out} are the voltage source and load impedances.

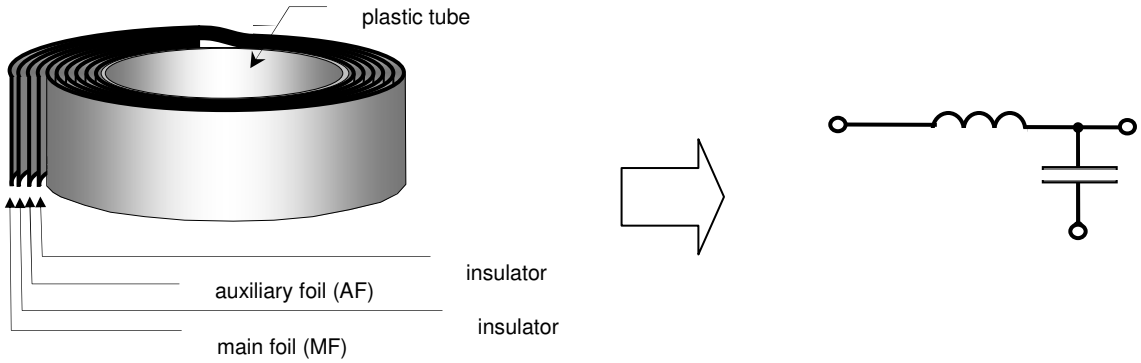

Fig. 1. Single-phase column of the proposed hybrid LC filter.

Frequency and time domain measurements

Measurements in frequency domain were done with HP4194a analyser. Input Z_{in} = 0.5 Ω and output Z_{out} = 1 MΩ impedances describe source and load existing in real applications well. The prototype parameters are: $L_m = L_a$ = 126 µF, C_b = 158 nF, M = 124 µF, C_{i1} = 10 pF, C_{i2} = 150 pF. Results shown in Fig. 3 indicate that connection to neutral at T2 provides much

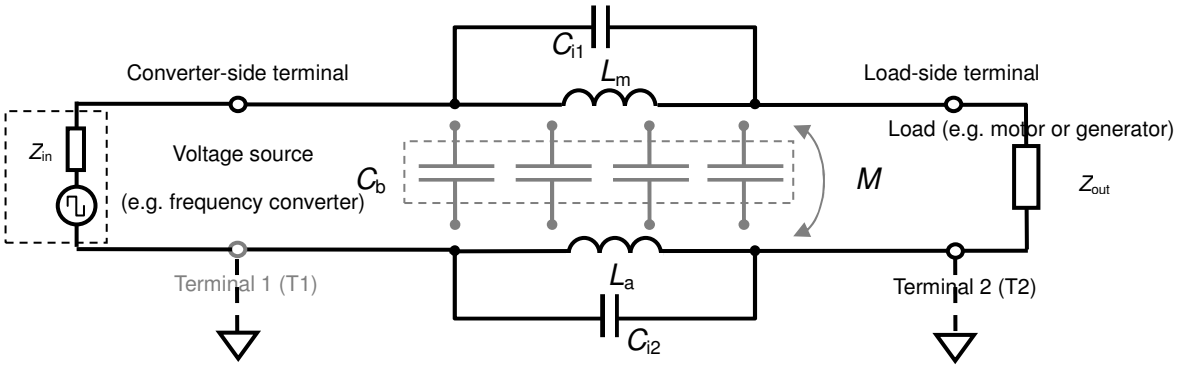

Fig. 2. Lumped model of the hybrid LC filter

better attenuation than at T1. This is because the HF currents flow via capacitance between foils before they reach neutral at T2. Vice versa, current does not use this capacitance if T1 is connected to neutral. When T2 is connected to the neutral resonance at 44 kHz is determined by L_m and C_b.The time domain responses were measured with a 22 kW, 400 V, 3-phase motor driven by an inverter via 90 m cable, which explains overshoots at motor terminals without filter. Again, connection to neutral at T2 provides the best usage of HLCF capacitance. Oscillations at 44 kHz indicate the *LC* nature of the HLCF [3]. When the AF is connected to neutral at T1, situation is similar with the case without AF, i.e. a typical inductor.

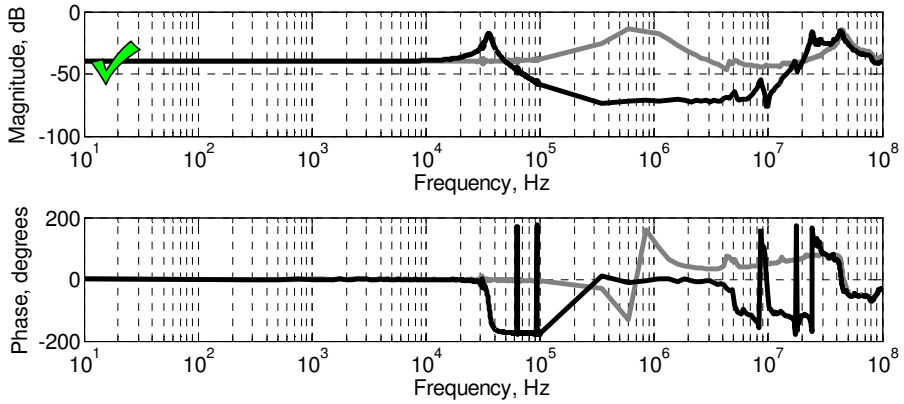

Fig. 3. Frequency responses of HLCF: ▬ – Terminal 1 earthed, ▬ – Terminal 2 earthed

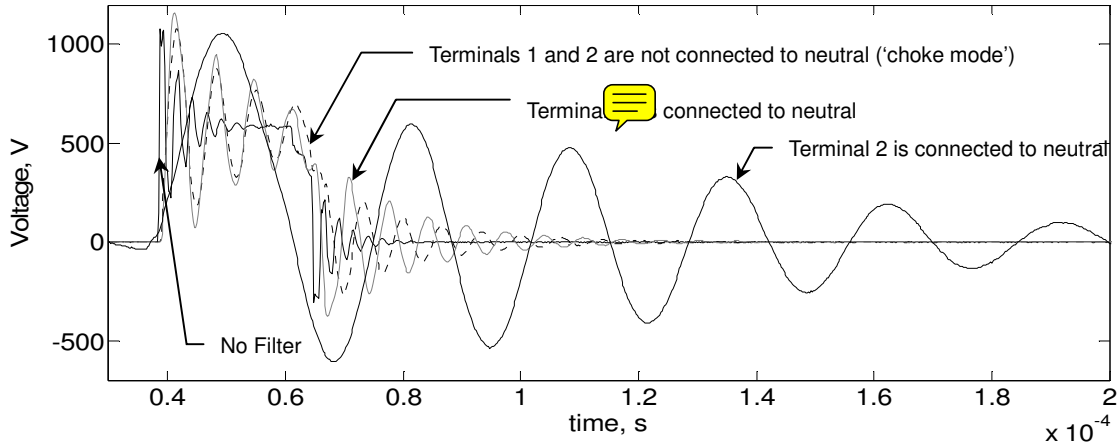

Fig. 4. Time domain measurements of the hybrid LC filter

Conclusion

This paper introduces new hybrid *LC* filter. Such a filter is suitable for modern applications where PWM is used. The best usage of the auxiliary foil can be achieved if it is connected to neutral at the terminal, which respects to the terminal of the main foil connected to a load.

References

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