An Experimental Research on EMI filters' Capability in controlling EMP

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Abstract
In an EMP filter there must be some suppressing components, such as TVS (transient voltage suppressor) or MOV (metal oxide varistor). They play a very important role in controlling transient at certain level. On the other hand, both of TVS and MOV have their defects, such as the frangible overload capability, huge transient energy may cause EMP filters' failure. We have investigated some EMI filters. Initial results show improving EMI filter without suppressing components exhibits excellent capability in controlling EMP. Feed-through filters with larger capacitance can effectively control very high EMP amplitude.

Introduction

Engineers usually know how EMI controlled by EMI filters. If some transient suppressors, such as MOV and TVS, are added into these filters, they become EMP filters that can obviously reduce transient. However, MOV and TVS have their shortages. For example, TVS lifetime is unlimited if the surge remains within its energy handling range. But TVS can not handle much current. It might be damaged if the random transient energy exceeds much more than the handling level. For MOV in this case, electrons tunnel break through and conduction occurs when it is clamping the transient. At maximum rated surges, the granules heat and melt together. Melted granules cannot reunite to form zinc oxide. At last, the MOV is mostly zinc and degrades, until short circuits happen. So this kind of EMP filters exhibits potential trouble. In order to know EMI filters without MOV and TVS can control EMP to a certain level, we have investigated some EMI and feed-through filters as mentioned bellow.

Test arrangement

The test set-up is shown in Fig.1. The tested EMI filter is installed in an enclosure that is used for insertion loss test according to requirements of CISPR No. 17 Publication. The input EMP amplitude to the filter is supplied by an EMP generator that maximum voltage is 250kV. Its output peak-amplitude can be adjusted by changing input voltage into the generator. A voltage divider of water-resistors (R1 and R2) is also connected at output terminals of EMP generator. They can do the further adjustment of the input to the filter. The input EMP of the filter is through a proper attenuator and monitored by a digital oscilloscope. The output of the filter is connected to the other channel of the oscilloscope via the other proper attenuator. This oscilloscope observes and records all information of input and output of tested filters. And the same time data is transferred into a computer for the further processing. The oscilloscope and computer are located within a shielding room and its power supply is connected to the power network through a shielding room filter. All connected cables are shielded coaxial ones of 50Ω. In order to withstand the high EMP amplitude, they are hardened. This set-up can control the most unwanted coupling from EMP generator.

A general-purpose EMI filter testing of

A general-purpose EMI filter is installed like Fig.1. Fig.2 shows its insertion loss and network. This filter is consists of common mode inductors, common mode capacitors and differential mode capacitor. EMP was applied between L (or N) and ground (the case of the filter). All cables and connectors were checked under the condition of 10000VDC, 5s before tests started. The input and output of this filter are recorded and shown in Fig.3. The EMP amplitude of 1670V is loaded into the input and the recorded output is 630V. There is evident delay between the

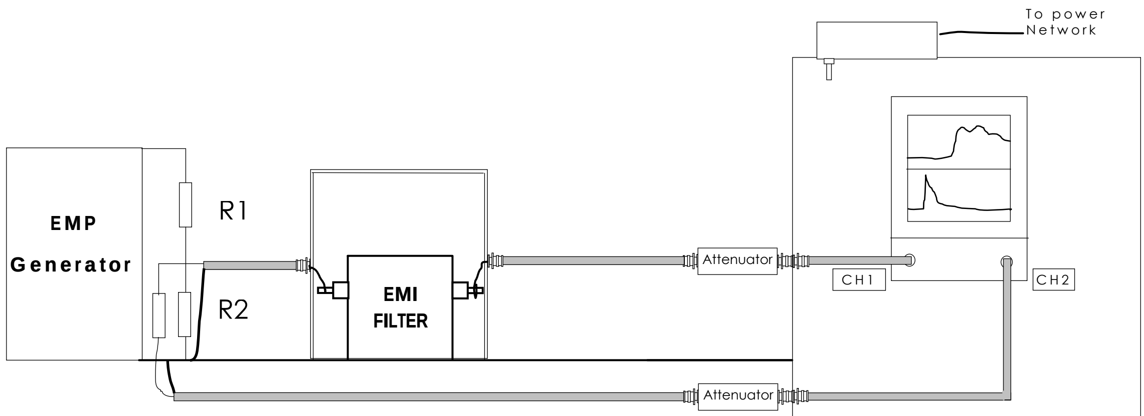

Fig. 1 Test set up

input and output that can be seen clearly in Fig.3. The suppressing capability of this filter is bad obviously. The main reason is that common coils made on a ferrite core that is saturated. And the insertion losses are getting worse and worse when heavy unbalance surge current flowed

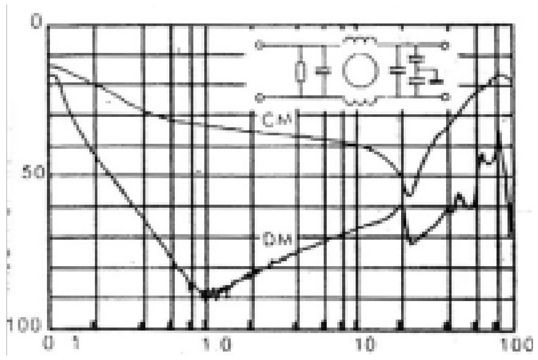

Fig. 2 Insertion loss and network of a general-purpose EMI filter

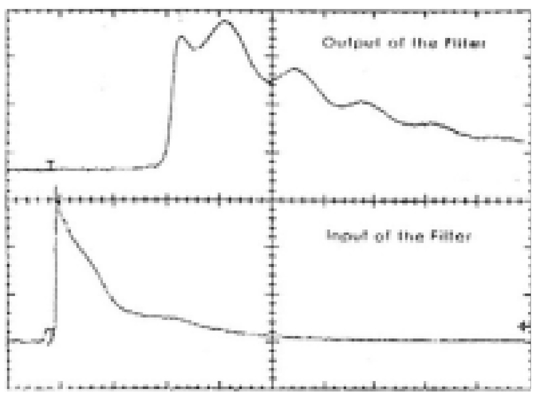

Fig 3 Input and output sampling of Fig.2

through them. The other reason is the coupling between input and output terminals of this filter. When frequency is getting higher, the coupling will be increased. Some energy of its input transforms to the output. That is why the capability of controlling EMP is poor.

<u>An improving EMI filter tested</u>

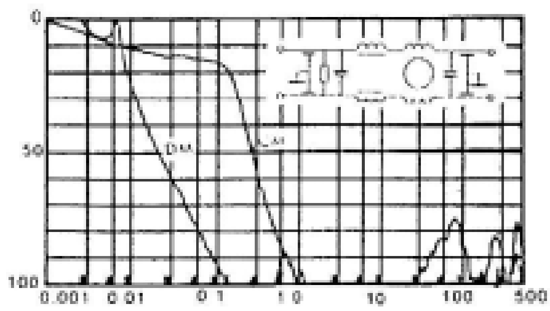

Fig. 4 Insertion loss and network of the improving EMI filter

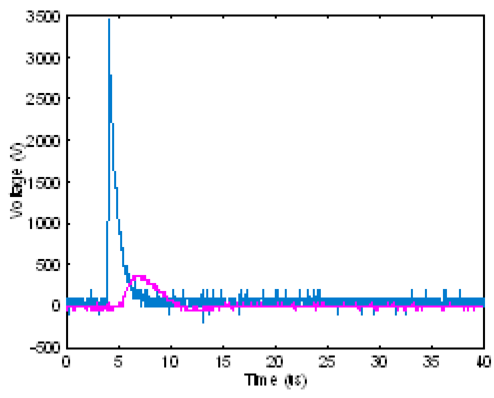

Fig. 5 Input and output sampling of Fig.4

The insertion loss and network of an improved 250V/50-60Hz, 60A EMI filter are shown in Fig. 4. The main difference from the general purpose one is that two differential mode inductors are inserted into the network, and feed-through capacitors are instead of the discrete ceramic capacitors in the network of Fig. 2. Insertion losses of these filters are much better than the general purpose one. The test set-up and installation are the same as the above test. The recorded data is

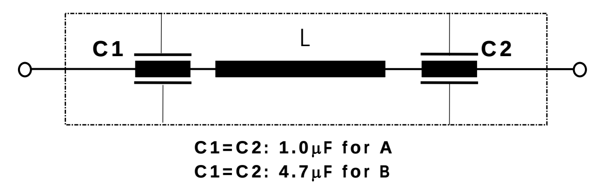

Fig.6 The diagram and parameters of the feed through filter

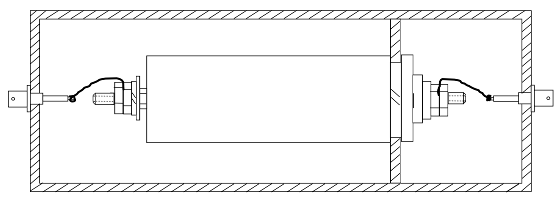

Fig.7 Test arrangement of the feed through filters

shown in Fig.5. The input EMP amplitude is 3500V and output is 380V. This suppression is much better than the general-purpose EMI filter because differential mode inductors can stand very heavy transient current and feed-through capacitors have excellent performance over high frequency bands. All parameters were checked and no any changes were found after testing. This test shows that the elaborated EMI filter without any TVS or MOV components can control high EMP amplitude to a certain low level also.

<u>Feed-through filters testing of</u>

Are there any EMI filter that could control EMP amplitude more effectively? Although the improving one shown in Fig.4 has controled high EMP amplitude into a low level, there is still a disadvantage because a direct coupling between input and output exists in the installation shown in Fig.1. A part of EMP energy escapes from input to output without control by the EMI filter. The EMP amplitude at the output may be further improved if equipment shielding could be rearranged for separating the coupling between them.

It is known that feed-through filters are used widely in communication, navigation, radar, aeronautical and aerospace equipment, systems and so on. This kind of filters has two significant advantages. The first, they have very good insertion loss from high frequency into microwave bands. Secondly, its case(shield) is perfectly combined with shielding of the equipment if these are properly installed. In doing so, input and output of feed-through filter can be separated and the direct coupling between them is minimized. They may control EMP very well. In order to evaluate the capability in controlling EMP, two feed-through filters that are widely adopted in communication systems were selected for the following tests. They have the same dimension, but different parameters shown in Fig. 6.

Fig. 7 displays the configuration of the feed-through filter installed in a shielding enclosure while being tested. Its input and output terminals are separated by a metal plane for minimizing the coupling between them. This arrangement basically

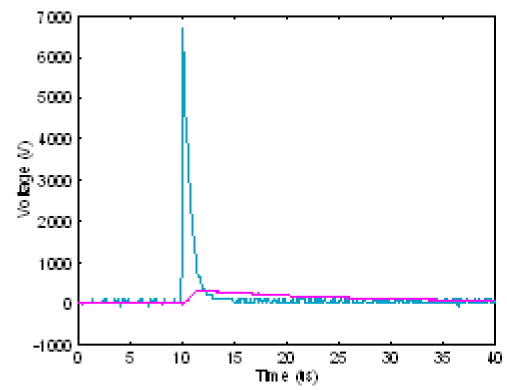

Fig. 8 Input and output sampling of feed-through filter A

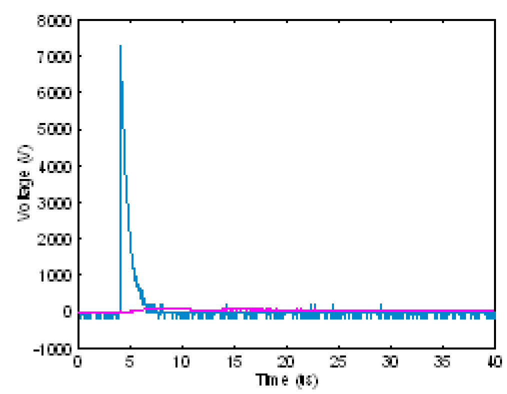

Fig. 9 Input and output sampling of feed-through filter B

simulates where circumstances as in applications, as they should pass through the wall of buildings or rooms and with good contact with the shielding metal of the equipment or the wall when installed. These results are displayed in Fig. 8 and Fig. 9 when filter A and B are tested. The input EMP amplitude is 6912V and output is 300V for filter A. Input 7440V and output 100V for filter B. There is extremely good suppression of EMP. At the same time, the rise time of their output is greatly slowed down and there is obviously delay in contrast with the input. Because there is the large capacitance in the feed-through filters, test results show that the capacitance is larger, the suppression capability is better! After these tests, all parameters were checked for changes which did not occur.

Result analysis

The test voltage (an important parameter of EMI filter) of the feed-through filter A is 2700VDC, 5s, and its breakdown voltage is estimated 3500VDC. It seems incredible to load 6910V loaded onto the feed-through filter A without damage! Actually, there is a great difference between the standing maximum EMP amplitude and DC test voltage. We think that more high EMP amplitudes could be loaded onto this feed-through filter. To prove this idea, further study are needed. How can these feed-through filters bear so high EMP amplitude without breakdown and flashover? One explanation is that loading EMP amplitude onto a feed-through filter can not suddenly change the voltage. The voltage-changing rate on a capacitor has to meet this relation shown in the following

$$\nabla V = \nabla Q / C = \frac{1}{C}\int I(t)dt = \frac{1}{CR}\int V(t)dt$$

∇V: voltage-chang rate on a capacitor;

∇Q: electrons-charg rate into a capacitor;

C: capacitance of a capacitor;

R: EMP generator's resistance;

I(t): the charging current function;

V(t): EMP voltage function.

It can be seen form comparing Fig.8 to Fig.9 that the capability in controlling EMP of filter B is much better than filter A.

Conclusion

EMP is injected into some EMI filters to investigate their capability in controlling EMP. It is found that some elobarated EMI filters without TVS or MOV components have excellent suppression capability. When much higher EMP is loaded onto these EMI filters, in particular feed-through filters, they will reduce EMP to a very low level.

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