Leakage Currents in the Right Perspective

Trade-off between best attenuation effectiveness and minimum leakage current

Network filters (EMC filters) are often regarded as a Blackbox and, justifiably, the user doesn t concern himself with its inner workings. However, for the effective use of filters, it is advantageous to have some background knowledge. The focal point of this article deals with leakage currents and what is to be observed in connection with this.

GENERAL ASPECTS OF EMC AND THE PRINCIPLE FUNCTION OF FILTERS

Electrical installations must have the property of functioning satisfactorily in their electro-magnetic environment (immunity) without affecting that environment (emission) in an intolerable manner. This is referred to as electromagnetic compatibility. We make a differentiation between radiated and conductive interferences. With conductive interference, there are symmetrical as well as asymmetrical interferences (also known as push-pull and push-push interference). Symmetrical interference flows between phase and neutral whereas asymmetrical interference flows between phase/ neutral and earth (ground). The causes of these kinds of interferences are network switches, frequency converters, processors, switching operations in electronic or electrical installations, motor controls, etc.
Symmetrical interferences are attenuated with X-capacitors. For the attenuation of asymmetrical interferences, current compensated chokes are used for lower interference frequencies and Y-capacitors for the higher interference frequencies.

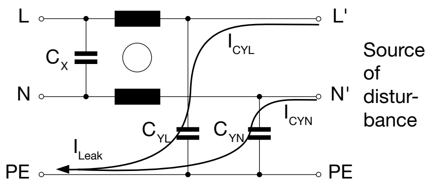

Figure 1: Leakage of asymmetrical disturbances

These Y-capacitors are connected between phase/neutral and earth, and conduct the asymmetrical interferences rom phase/neutral to earth. Leakage currents ensue from this (Figure 1). The bigger the capacitors, the better the attenuation with correspondingly higher leakage currents.

THRESHOLD VALUES PERMIT SAFE OPERATION

Parasitic coupling capacities of an installation or equipment as well as long power lines also contribute to the leakage current of a filter. These lead to a summation of leakage currents that flow through the earth conductor that can give rise to a safety risk. The higher the impedance of the earthing conductor, the greater the safety risk for the user. Should a person touch an item of equipment having a defective (broken) earth conductor, the leakage current will flow through that person to earth (Figure 2).

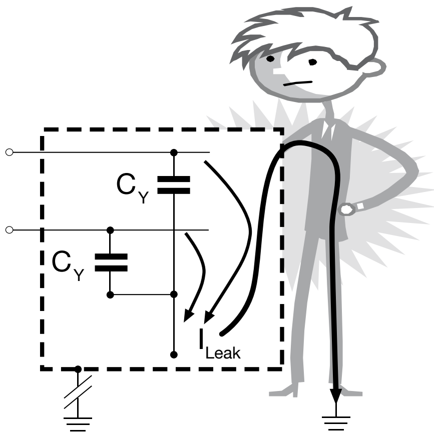

Figure 2: Path of leakage current at broken protective conductor

On the other hand, any residual current circuit breakers connected in a building network influence the reliable operation of equipment resulting from too high a leakage current. These residual current circuit breakers detect currents flowing in the earth conductor and disconnect the supply voltage should a certain threshold value be exceeded. For this reason, there are threshold values for leakage currents that permit reliable operation and ensure that even with defective earth connections, no person is injured.

DEMANDS ON THE PRODUCT DEVELOPER

Manufactures of equipment and installations must ensure that their products meet those requirements egarding leakage current and electro-magnetic compatibility. And here is a conflict of objectives. Normally both basic conditions can be adhered to without any special measures being necessary. It is important, however, to understand with this that we are dealing with a voltage field that, with a good filtering effect, will automatically give rise to high leakage currents.

PROBLEMS WITH THE SPECIFICATION OF FILTER LEAKAGE CURRENTS

Filter manufacturers specify leakage currents in their data sheets. The IEC filter standard does not define, however, how these specifications are to be carried out. This leads then to a situation where different manufacturers are not obliged to use the same methods to determine leakage currents. Consequently, the data given by various manufacturers is not directly comparable. Equipment standards on the other hand, e.g., IEC 60950 for office equipment, 60601-1 for medical equipment or IEC 60335-1 for domestic equipment, specify in detail which threshold values are to be kept to and what method is to be employed in determining those values. Equipment and installation manufactures are faced thus with a problem of keeping to the standards governing their products, while having to attempt evaluation of various filter manufacturers whose information regarding leakage currents can only be compared with reservation. Calculation models are used for the determination of leakage currents. These models are based on idealised conditions. With this, capacitor and network voltage tolerances are taken into consideration, but parasitic effects neglected. However, the simplification used in the idealised models lead to errors that can be neglected when compared to the relatively high tolerances used in the calculations. Thus, capacitors are specified with a +/-20% capacitance tolerance, whereas in reality, experience shows that capacitances are subject to much smaller tolerances. With the determination of leakage currents, a differentiation must be made between 1- and 3-phase filters.

LEAKAGE CURRENT WITH 1-PHASE FILTERS

With 1-phase filters it can be assumed that neutral and earth conductors are at the same potential. For this reason the filter circuit shown in Figure 3 can be simplified and represented by the replacement circuit shown in Figure 4.

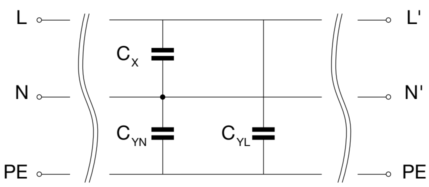

Figure 3: Network of capacitors in a single phase filter

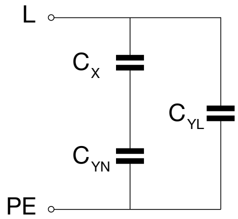

Figure 4: Simplified circuit diagram for determination of maximum leakage current

The leakage current can now be determined more easily:

$$I_{Leak} = U * \omega \left(C_{YL} + \frac{C_X * C_{YN}}{C_X + C_{YN}} \right)$$

The largest leakage current to be expected is derived from a network voltage tolerance of +10%, a capacitor tolerance of +20% and at a network frequency of 60Hz.

LEAKAGE CURRENT WITH 3-PHASE FILTERS

Under the assumption of a symmetrical and balanced load, an ideal 3-phase filter has no leakage currents even with large asymmetrical interferences. Figure 5 depicts the cross-section of the Y-capacitors in a 3-phase filter.

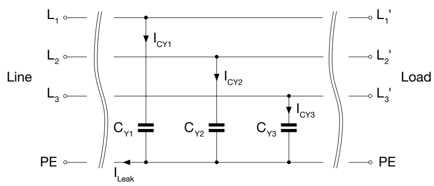

Figure 5: Y capacitors in a three phase filter

In reality, however, and for the following reasons, a 3-phase filter is always loaded in an unbalanced manner:

- Tolerances of the Y-capacitors
- Imbalance in the supply network
- Asymmetrical load
- Asymmetry within the filter resulting from a non-ideal component configuration.

With 3-phase filters the leakage currents of the vectors of individual phases are added together to give a resulting discharge current (Figure 6).

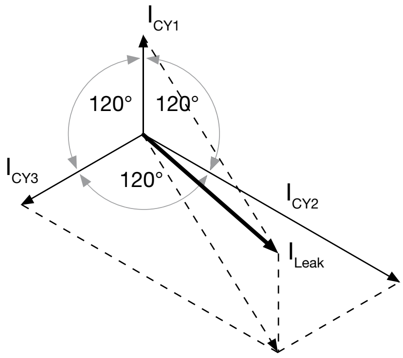

Figure 6: Determination of resultant leakage current at three phase filters

CLASSIFICATION OF LEAKAGE CURRENTS

In order to take the various requirements regarding leakage current into account, manufacturers classify their products. With this, there are filters for standard applications, medical applications, industrial applications, etc. Since patients can come into direct contact with equipment, it is precisely in the medical field where there are increased requirements regarding leakage currents. So as to maintain threshold values, only small, and in many cases no Y-capacitors are used. SCHURTER, for example, speaks of M5 filters having a maximum leakage current of 5µA (no Y-capacitors), or from M80 filters having a maximum leakage current of 80µA.
There are no standards, however, that specify what classes there are, what these are called and what corresponding threshold values are to be applied. Nevertheless, this division helps the user to quickly find the appropriate product for his application.

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