Electromagnetic Interferences on Power Lines

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Interferences are the most common cause of malfunction in the electronic system. Interferences can impair correct operation, render operation impossible or even destroy the equipment. Interference can enter into the electronic system through conductive paths like power cables, signal cables, ground etc or through radiative paths like equipment's case, or through both. This situation is shown in Fig. 1.

Power line interferences

Interferences present on power lines are most crucial and are encountered frequently. Noisy equipments like motors, switches, relays etc sharing the same power line add to the interference. Momentary power interruptions also generate interference.

Local power distribution line acts as a huge antenna and picks up all forms of man-made and natural emissions. Lightning during thunderstorm, static electricity generated in the atmosphere and powerful waves generated by broadcasting stations and transreceivers are picked up and distributed to all users in addition to the pollution accepted from other sources.

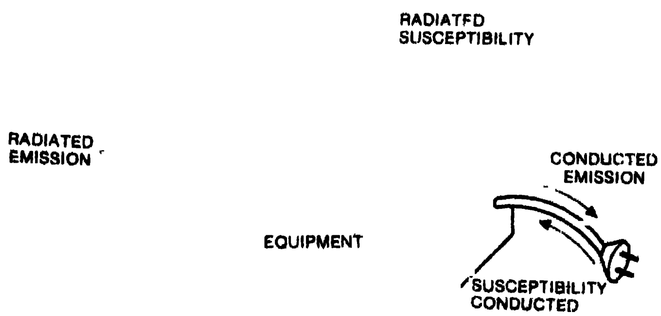


Fig. 1: Various modes of interferences.

Fig. 2 shows a typical plot of conducted emissions present on power lines. The high level of interference present below 1 MHz results from fluorescent lamp and other home appliances within installation. The spectrum beyond 1 MHz is mainly contributed by the broadcast shortwave HF, TV, FM and other electromagnetic emissions intercepted by the power line.

If interferences are to be removed from a power line, it must be established whether the interferences present are in common mode or differential mode. Common mode interference is one in which interference exists between phase-earth and neutral-earth lines. In differential mode, interference exists between phase-neutral lines. Both these states are shown in Fig. 3.

Isolation transformers, chokes and filters are extensively used to reduce interferences present on the power lines. The following paragraphs discuss the characteristics of these devices and the situations in which they can be used.

Isolation transformer

A conventional transformer magnetically couples desired energy from primary to secondary while isolating the windings from one another. However, in such a transformer, isolation between primary and secondary is poor. The noise potential between primary and ground reaches the secondary through resistive and capacitive coupling between the transformer's windings.

Isolation transformer is designed such that the interwinding resistive and capacitive couplings get minimised. In isolation transformer, a grounded conductive foil called

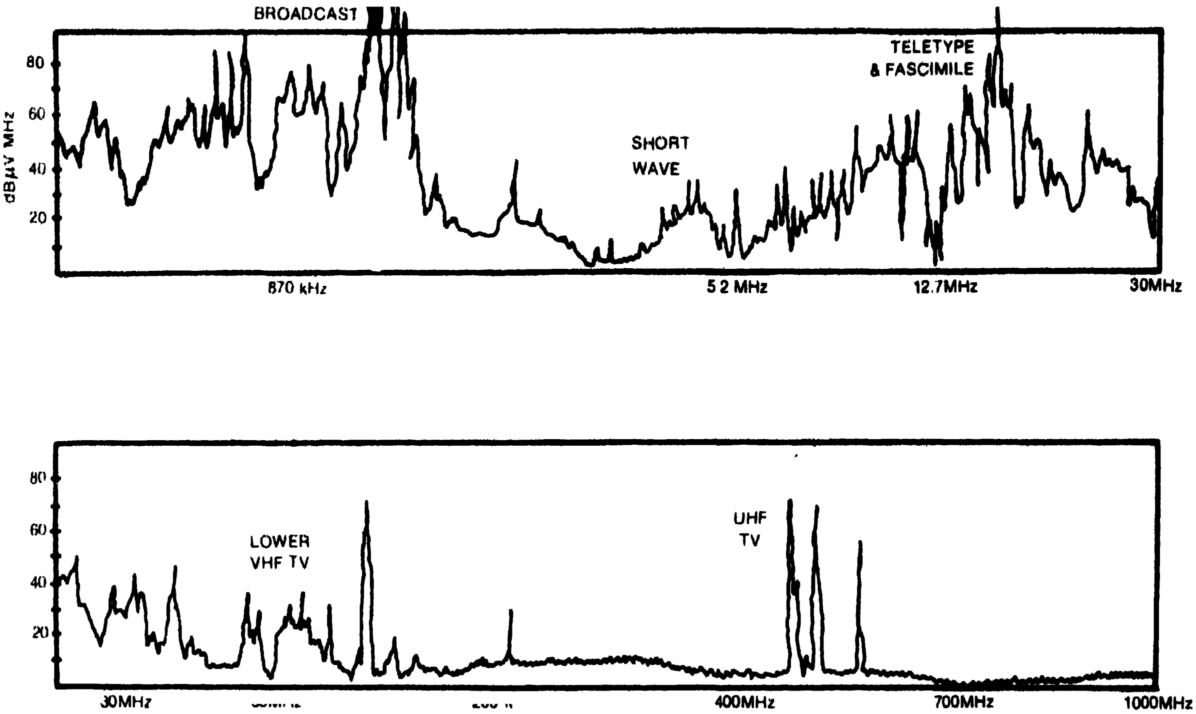


Fig. 2: A typical plot of interferences present on power lines.

faraday shield is placed between the primary and secondary winding to divert most of the primary noise current to ground.

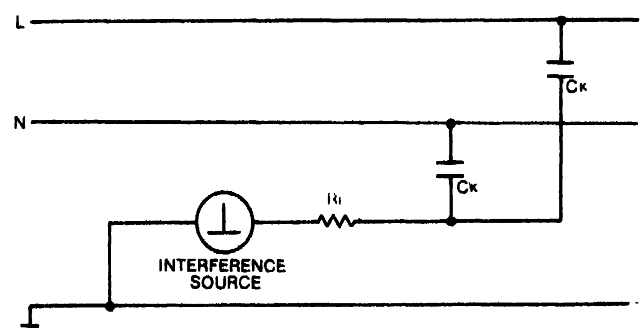
However, electrical noise is still coupled into the secondary because of the electrostatic field around the faraday shield. This problem is overcome by using a unique box shielding technique which provides extremely high impedance of the order of 10,000 megohms and capacitance from 0.005 to 0.0005 pF between the primary and secondary.

An isolation transformer offers common mode rejection from 120 dB to 140 dB. It also reduces differential mode noise to a certain extent. A good isolation transformer effectively eliminates interferences up to 50 kHz. For high frequency interference suppression, filters are used along with the isolation transformer. It is a good practice to use twisted shielded pair and an EMI suppressant tube in the secondary to reduce the differential mode interference.

Chokes

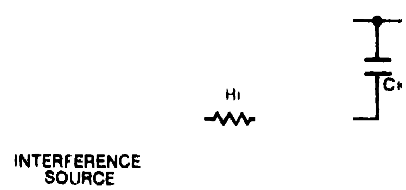
Although it is possible to use large value capacitors between phase-earth and neutral-earth power lines, safety regulations in most of the country limits their value. The capacitor between phase and neutral is limited to keep the switching current to a reasonable value, when load is switched on and off. Hence with capacitors alone, it is not possible to reduce interference to a desired value and normally inductors are used with capacitors. There are three types of chokes used in interference suppression:

1. Saturable choke.
2. Multiple ring-core choke.
3. Rod-core choke.



(b)

Fig. 3(a): Differential mode interference.



(a)

Fig. 3(b): Common mode interference.

Saturable choke. Saturable core offers high inductance at switch-on when current is zero and low inductance when core magnetic material gets saturated, i.e. at nominal current. An attenuation of about 70 dB can be achieved using these chokes.

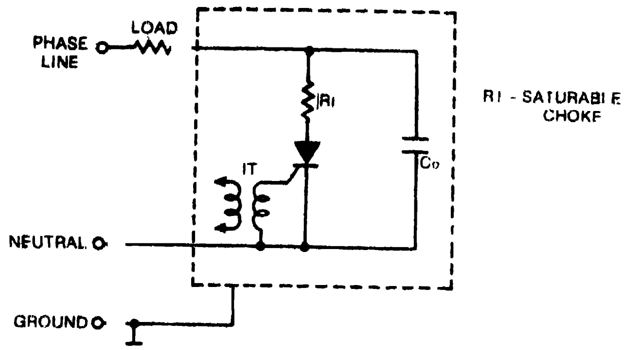


Fig. 4: Typical application circuit for a saturable choke.

A typical application circuit is shown in Fig. 4. A saturable core is connected in series with thyristor which extends the current rise time, thereby reducing the differential mode interference.

Ring-core choke. Common mode interference is attenuated using ring-core choke. Ring-core choke consists of two

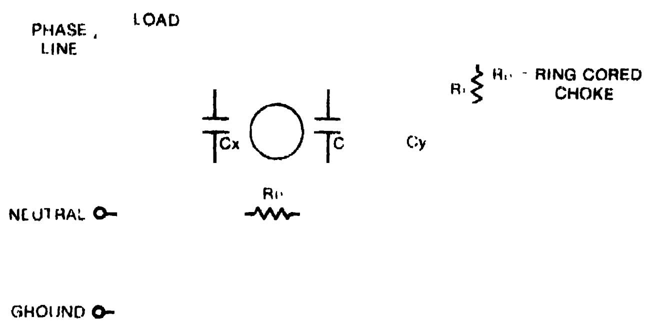


Fig. 5: Typical application circuit for a ring-core choke.

or more identical windings. One winding is introduced in phase and the other in neutral line. The 50Hz current, which induces magnetic fields in the ring core is self-cancelling and hence no voltage drop at 50 Hz is experienced, whereas common mode interference produces supporting field and hence gets attenuated. A typical application circuit is shown in Fig. 5.

Rod-core choke. When the load current is more than 100 amperes, then instead of saturable choke, rod-cores are used. The inductance of rod-core choke always remains constant.

Power line filters

It is preferable to filter out interference before it gets to user areas. This is accomplished by the use of power line filter. Power line filter passes the 50Hz mains frequency with very little attenuation and provides high attenuation from low frequencies such as 1 kHz to 1 GHz, depending upon the type of filter used.

The objective of the filter is to reduce both common mode and differential mode interference to a harmless level. For removal of common mode interferences, filters must be placed between phase-earth and neutral-earth lines. For the removal of differential mode interference, filter must be placed between phase-neutral lines with or without involving earth line.

Understanding of filter parameters greatly helps in selecting the proper type of filter. A brief description of these parameters is given below.

Rated voltage. This represents the maximum admissible continuous operating voltage. If this voltage exceeds by 20 per cent then the filter might get damaged.

Rated current. This is the maximum operating current that the filter handles at a specified temperature. The rated current reduces with increase in temperature

Leakage current. Common mode interference is reduced by connecting capacitors between phase-earth and neutral-earth power lines. When the AC voltage is applied, a current flows through these capacitors to ground.

For safety reasons, this current must not exceed a certain maximum value. There are certain regulations regarding the interference current which can be pumped to the earth terminal. In fact, these regulations along with operating voltage determine the size of capacitors which can be connected between phase-earth and phase-neutral lines. Table 1 gives the leakage current limits for a typical class of equipments.

TABLE 1

Maximum Admissible Leakage Current as Per IEC Standard

Class of Appliance and Application	Leakage Current (max.)
Domestic	
Portable	0.75 mA
Fixed location motor equipments	3.5 mA
Fixed location heating equipments	5.0 mA
Medical appliances	
Analytical	0.5 mA
-Medical	0.1 mA
Computers	0.5 mA
Instruments	3.5 mA

Insertion loss. This is the ratio of output voltage to input voltage at a particular frequency, expressed in dB. This represents how much each frequency component of interfer-

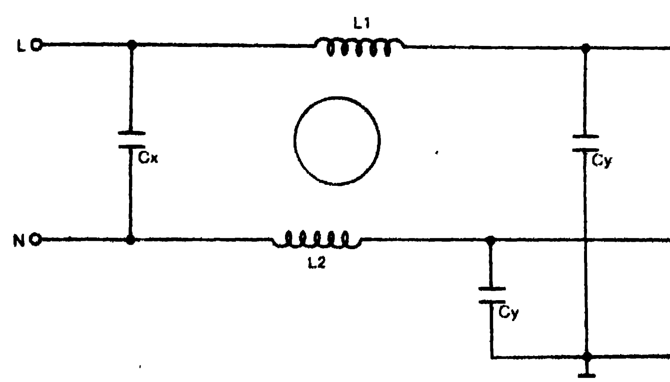


Fig. 6: Typical configuration of a reactive filter.

ence will be attenuated while passing through the filter.

An important point to be noted here is that the figures given in the manufacturer catalogue represent the measurement taken with 50-ohm source and 50-ohm load impedance. This is hardly the case in actual practice. Hence, depending upon the source and load impedance, you may get better or deteriorated performance.

While studying the manufacturer catalogue, clear distinction should be made between attenuation offered for common mode and differential mode and should be compared with the requirements.

Different filter configurations

Mainly three types of filters are available: (i) reactive filters, (ii) lossy line filters, and (iii) active filters.

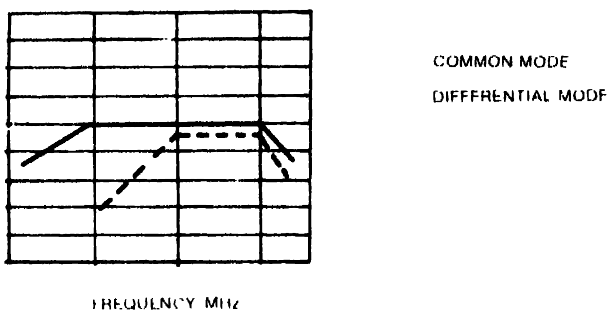


Fig. 7: Attenuation characteristics of typical reactive filters.

Reactive filters are widely used. Lossy line filters are a relatively new concept and offer better performance compared to reactive filters. However they are costly. Active filters are normally not used in power line filtering applications.

Reactive filters

Reactive filters basically consist of a combination of high impedance series circuits (chokes) and low impedance parallel circuits (capacitors) of desired frequency range.

Fig. 6 shows the typical configuration of a filter. Capacitor Cx connected between phase-neutral is responsible for the attenuation of differential mode interference. Inductors L1 and L2 offer high impedance paths to common mode signals and attenuate them, while offering little attenuation to operating frequency. These inductors are constructed on ring cores with two identical windings. These windings are arranged symmetrically so that the operating current (50 Hz) produces opposing fluxes in the two windings of the magnetic materials. This prevents saturation of the core materials at the nominal operating current.

In contrast, for the common mode signal, two fields support each other and hence experience full attenuation. The remaining common mode interference current is returned to the earth via capacitor Cy. Attenuation of interference is directly influenced by the value of Cy. However, as mentioned earlier, their value is limited by regulation of maximum admissible earth leakage current. Fig. 7 shows the typical attenuation obtained by this configuration.

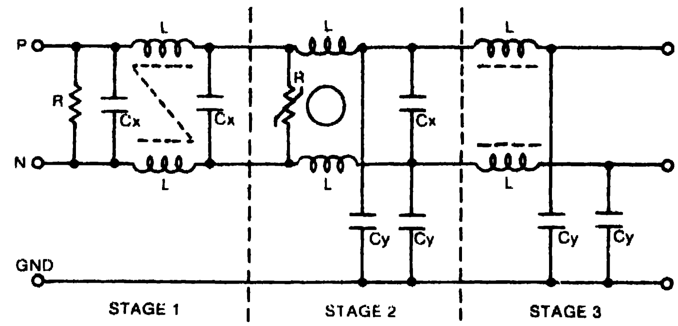


Fig. 8: Wide-band filters for stringent attenuation requirement.

Wide-band filters for stringent requirements are often made up by combining two or three stages (Fig. 8). The frequency range of such filters can easily extend up to 1 GHz. Sometimes, resistors are added to discharge large capacitors connected between phase-neutral. Surge diverters, like varistors, are often used to limit large transients present on the power lines.

When there is a possibility of large common mode interference, filters with earth-line chokes are used (Fig. 9). When external interference occurs simultaneously on all the three lines, then only interference current flowing in the phase and neutral lines are effectively attenuated by the filter. The current flowing in the earth line, however, gets into the equipment without hinderance and flows back via HF-earth as a displacement current to the interference source.

An earth-line choke at the filter input effectively attenu-

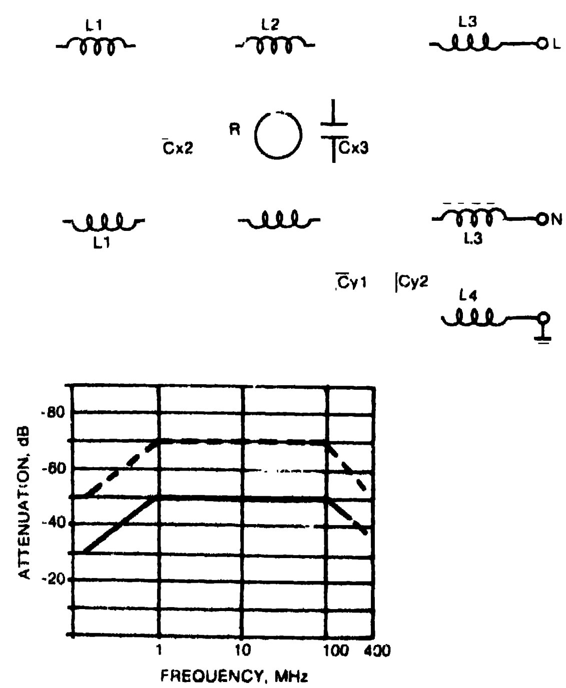


Fig. 9: Filters used with earth-line chokes to overcome large common mode interferences.

ates this common mode interference current. Filters with earth-line chokes have in general a 10dB higher attenuation compared to reactive filters.

Lossy line filters

The principle involved in the lossy line filter is different than the conventional one. Here, the unwanted interference energy travels through a 'lossy' medium surrounding the conductor, where it is absorbed and dissipated. The lossy medium offers high interference attenuation and low Q.

The main advantage of lossy line filter over the conventional reactive filter is that here the unwanted energy is absorbed rather than rejected. Hence, the problem associated with reactive type filters like mismatch, reflections, grounding and high VSWR are absent here.

Practically no reactive current is present because there is little shunt capacitance. Since there is no saturation at high currents, this type of filter offers constant attenuation at all types of load conditions. Here, the ringing problem associated with interference spike rejection is not present, as energy is absorbed rather than rejected.

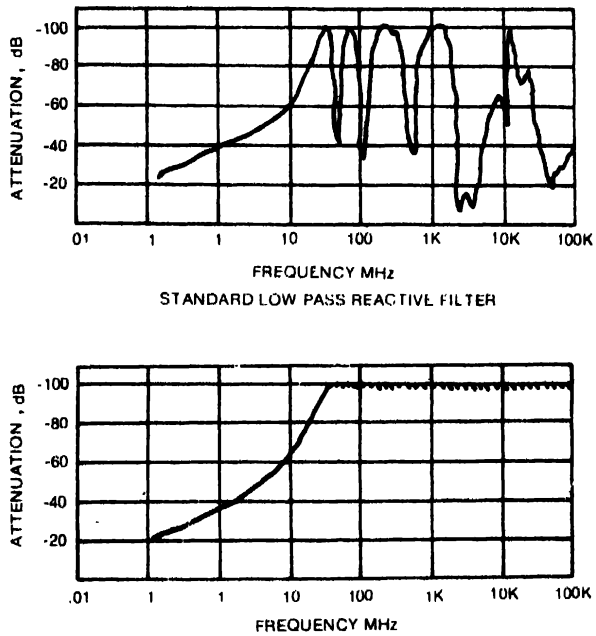


Fig. 10: Comparison of attenuation characteristics of reactive filter and lossy line filter.

This type of filter offers attenuation of 50 dB and more in the frequency range of 10 kHz to 100 GHz. Fig. 10 shows the comparison of attenuation characteristics of conventional reactive filters and lossy line filters.

This type of filter is also available in flexible cable form. Construction details for this are given in Fig. 11. This type of filter is very useful in high frequency applications. These are available in various sizes and current capacities.

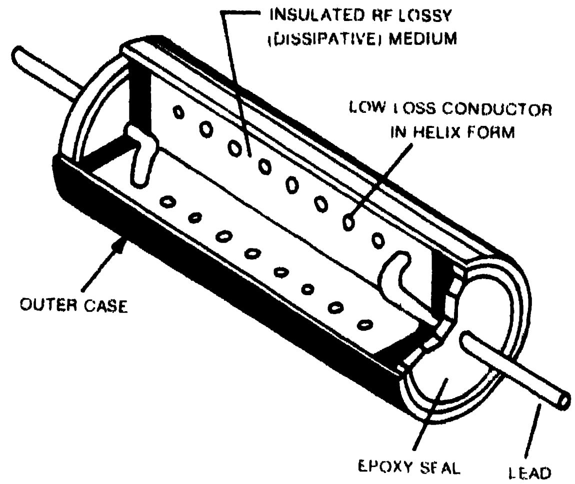


Fig. 11: Cut-section of a lossy line filters.

Suppressant tubes

Suppressant tubes provide a simple, low cost, efficient means for suppressing unwanted interferences. They are merely slipped over insulated or uninsulated standard wires or cables.

Suppressant tubes are made up of lossy materials, which absorb high frequency energy. Suppressant tubes will not cause DC or low frequency AC losses. They are available in different diameters from 1.25mm to 12.5cm and offer an attenuation of 20 dB at 100 MHz and 100 dB at 1 GHz and above. □