Analysis and Protection of Electromagnetic Interference in the Industrial Field

Guanqi Niu

Abstract.

With the continuous progress of science and technology, all kinds of electrical and electronic equipment are applied to production and life. However, bad electromagnetic interference will affect the normal operation of the equipment and reduce work efficiency. This paper analyzes the situation and source of electromagnetic interference in the industrial field and introduces several common anti-interference methods. And take corresponding measures according to different types of interference. This paper introduces electromagnetic shielding, filtering, and other technologies, and the application scenarios of various anti-interference methods are analyzed. When the working environment and the nature of interference emission change, the anti-interference strategy should be adjusted accordingly. Implementing these measures will significantly improve the electromagnetic compatibility of the system, reduce the electromagnetic interference phenomenon in the industrial site, and ensure the stable and efficient work of the system. Although electromagnetic interference cannot be eliminated, summarizing and analyzing existing technologies helps to develop new technologies and provides more possibilities for anti-interference.

Keywords: Industrial site; electromagnetic interference; anti-interference measure; electromagnetic compatibility.

1. Introduction

With the development of the electronics industry, electromagnetic waves, as a carrier of modern information, have brought great convenience to our production and life. At the same time, it also appears as interference, affecting the operation of various systems in industrial sites. With the wide application of automation technology in industry, many electronic equipment and control systems have been introduced into industrial sites, which increases the possibility of electromagnetic interference. Meanwhile, the interconnection and communication between industrial equipment is becoming more complex, so the problem of electromagnetic interference is getting more prominent. The use of frequency converters and other power electronic devices is increasing in power systems, and these devices can introduce harmonics and other electromagnetic interference. This potentially impacts other devices and control systems in the power system. To explore the methods to combat interference, this paper analyzes the electromagnetic interference problems in industrial sites and summarizes the existing solutions. At the same time, various anti-interference technologies have their scope of application and limitations, so which method to take depends on the situation of the industrial site. In addition, anti-interference methods are not independent, and many technologies can often be used together to achieve better anti-interference effects. This paper aims to provide better electromagnetic compatibility for industrial equipment and systems and reduce the adverse effects of interference on production processes and equipment performance.

2. Electromagnetic Interference Generated in Industrial Sites

2.1 Electromagnetic Interference

Electric and magnetic fields can be divided into constant and alternating fields. The constant electric field is mostly generated by a DC power supply or electrostatic field, and the constant magnetic field is mostly generated by permanent magnets or DC [1]. The effect of a constant field on electronic equipment in industry is fixed. It can be manifested as constant electric and magnetic fields deflecting the electron beam in the oscilloscope tube, electrostatic induction electrifying objects, the constant magnetic field deflecting the instrument pointer, etc. However, because the influence of the constant field on the electronic equipment is mostly fixed, it will not cause irregular changes in the electrical signal. So, it is only called influence rather than interference. Alternating electric and magnetic fields often randomly change polarity, frequency, direction, and intensity, showing randomness and disturbance. Therefore, the effect of alternating fields is called electromagnetic interference.

2.2 Source and Conduction of Electromagnetic Interference

According to the principle, the cause of electromagnetic interference is the irregular change of electric and magnetic fields. So, in theory, electromagnetic interference will occur if there is a rapid change in current. In the industrial field, relays, AC contactors, electroknife switches, and frequency conversion governors are the main sources of such interference [2].

There are two main transmission routes of electromagnetic interference:

The energy of electromagnetic interference is propagated in the form of electromagnetic waves through the electric or magnetic field in space, resulting in a coupling between the interference source and the disturbed body [3].

The energy of electromagnetic interference travels through the power line or signal cable in the form of voltage or current. It is very difficult to eliminate because it only travels through the circuit, and rapid changes in current and voltage are almost inevitable [4].

2.3 The Effects of Electromagnetic Interference

Electromagnetic interference has a wide range of effects. In an analog circuit, electromagnetic interference will randomly change the parameters and waveform of the analog electrical signal. In particular, in the detection system, electromagnetic interference will act on the transmission process of the signal so that the signal-to-noise ratio is reduced, and the signal source is flooded in serious cases, resulting in detection misjudgment [5]. In digital circuits, electromagnetic interference can disrupt logical relationships and randomly tamper with data values in digital counters or memory, making data transmission wrong. It can also cause timing interference, that is, the jitter or drift of the clock signal, which can affect the synchronization performance of the entire system. Electromagnetic interference may also cause some electronic devices to work unstable, increasing energy consumption. This can be a problem in systems that require energy savings and long running times.

Electromagnetic interference can cause communication system disruption or quality degradation, affecting real-time data transmission, especially in industrial automation systems, leading to control system failure. In the measurement and control system, the influence of electromagnetic interference on the sensor may lead to measurement errors and reduce the sensor's accuracy. For systems that require high-precision measurement, electromagnetic interference can cause electromagnetic compatibility issues between devices. Different devices interfere, causing some devices to fail to work properly simultaneously.

Most microcontrollers use CMOS technology, and all CMOS devices have a noise threshold beyond which the device will produce an error. Components have the following forms of destruction under the action of interference: excessive interference power causes the semiconductor device PN node to melt or burn; the high voltage causes the oxide film insulation layer of the semiconductor device to be broken down; too much current will burn the metal-plated semiconductor device; the occurrence of a peak voltage makes the semiconductor device unable to recover automatically, resulting in a circuit 'crash' [6].

The damage to electronic devices also has a cumulative process; any adverse effects will lead to permanent damage from latent damage. The damage to the device eventually leads to decreased rated voltage, decreased system performance, lost computer data, misoperation, rejection, and so on. In some critical systems, electromagnetic interference can damage the electronics and pose a security risk. For example, in industrial control systems, misoperation due to electromagnetic interference can lead to safety incidents.

3. Suppression Methods of Electromagnetic Interference

The formation of electromagnetic interference must have the following three factors: electromagnetic interference source, sensitive equipment, and coupling channel. Therefore, the suppression of interference should be started from the following two aspects: reducing the emission of RF energy and reducing RF energy entering the device.

3.1 Electromagnetic Compatibility

Electromagnetic compatibility (EMC) is a branch of science that studies how various devices can coexist without causing their performance degradation under limited space, time, and spectrum resources. It is defined as 'the ability of a device or system to operate in its electromagnetic environment in compliance with requirements without causing intolerable electromagnetic interference to any equipment in its environment.' Therefore, from the above definition, electromagnetic compatibility includes electromagnetic interference (EMI) and electromagnetic susceptibility (EMS). EMS means that the equipment can not reduce the working performance due to interference in the electromagnetic environment; EMI refers to devices capable of generating electromagnetic interference [3].

Electromagnetic compatibility involves the following issues: Characteristics of interference sources; Anti-interference performance of sensitive equipment; Characteristics of electromagnetic interference, including radiation and conduction; Electromagnetic compatibility measurement, including measurement equipment, measurement methods, data processing methods, and result evaluation; Electromagnetic compatibility within and between systems.

The study of EMC ensures that different devices that use or respond to electromagnetic phenomena operate properly in the same electromagnetic environment. In the industrial field, the following measures are often used to improve the electromagnetic compatibility of the system: use perfect shielding enclosure, adopt appropriate filtering technology, design a reasonable grounding system, and correct selection of connection cables and wiring methods.

3.2 Electromagnetic Shielding Technology

Electromagnetic shielding is based on the metal isolation principle to block interference energy transmission. Shielding can be classified according to different principles: Firstly, electrostatic field shielding is mainly used to prevent the influence of electrostatic field. The principle is that under the action of the external electrostatic field, the charge on the conductor's surface is redistributed so that the combined field strength inside the conductor is zero. This kind of shielding requires perfect shielding and good grounding. Secondly, magnetic field shielding is mainly used to prevent the influence of external static magnetic fields and low-frequency current magnetic fields. The principle is to use the high permeability material to generate a small magnetoresistive path so that the current and the magnetic field flow in the shielding body to achieve the shielding of the magnetic field. Lastly, electromagnetic shielding, mainly to prevent the influence of alternating electric fields and alternating magnetic fields, is a method of applying magnetic materials and metals to weaken or suppress magnetic fields and electromagnetic fields. Electromagnetic shielding not only requires good grounding but also requires the shield to have good electrical continuity, and no conductor can pass through the shield [7].

Electromagnetic shielding is a common anti-interference method. Using high permeability and high conductivity materials (such as silver-plated copper plate and copper mesh for electromagnetic shielding, the electronic circuit is installed in a closed shielding space made of these materials, and the shield is equal to the earth's potential. According to the situation, the shielding space can be made into boxes, rooms, cages, etc. The electromagnetic shielding material can be made into a coating or film covering the surface for precision instruments or components with complex shapes. In addition, shielded twisted pair cables can be used for data transmission. Compared with ordinary twisted pair, shielded twisted pair has more shielding layers, which reduces the generation and influence of interference through shielding, thus providing a purer electronic signal.

3.2.1 Electromagnetic Shielding Principle and Theoretical Calculation

When the electromagnetic radiation reaches the shield's surface, there are three different mechanisms for attenuation: first, the reflection attenuation on the incident surface; Second, the electromagnetic wave entering the shield is absorbed by the material; third, there is multiple reflection attenuation inside the shield. The greater the attenuation, the better the shielding effect. The total shielding effect of electromagnetic waves passing through the shield can be calculated as follows:

$$SE = R + A + B \tag{1}$$

SE is the shielding efficiency (dB); R is the reflection attenuation of the incident surface; A is absorption attenuation; B is internal multiple reflection attenuation. The shielding efficiency of electromagnetic shielding materials can meet the needs of general industrial electronic equipment between 30dB and 60dB and the needs of precision instruments and military equipment between 60dB and 90 dB.

In general, the shielding effect of the electrical shielding material is mainly determined by reflection attenuation, and the absorption attenuation is not main, so the electrical shielding can be made of relatively thin metal materials. The absorption attenuation mainly determines the shielding effect of the magnetic shield, and the reflection attenuation is not important [8]. At the same time, the higher the conductivity of the material, the higher the reflection attenuation and absorption attenuation. The conductivity has a positive effect on the reflection and absorption of electromagnetic waves the higher the permeability of the material, the higher the absorption attenuation, but the reflection attenuation is reduced, which means that the magnetic properties of the material help to enhance the absorption of electromagnetic waves and reduce the reflection of electromagnetic waves. From a safety point of view, low-reflective materials are more popular.

3.2.2 Electromagnetic Shielding Material

Electromagnetic shielding materials are closely related to the effect that can be achieved. The research progress in this field has been remarkable all over the world. In some countries, the electromagnetic shielding material industry has been commercialized. In recent years, electromagnetic shielding materials have included metal, carbon, ceramics, glass fiber, wood, fabric, conducting polymers, and other special materials.

Metal materials are preferred to be electromagnetic shielding materials due to their high conductivity. And they are widely used for electromagnetic shielding. Metal conductive coatings are prepared and applied on the surface of some insulators to prepare metal-coated electromagnetic shielding materials. The method is easy to produce and can be applied to various complex shell shapes. Metal foam is a new material with a mutually conductive metal skeleton and internal pores to form a three-dimensional network structure. Compared with the two-dimensional metal network, it has higher shielding performance and is often used to manufacture heat-dissipation structural components of precision instruments. As for amorphous alloys have high strength, corrosion resistance, and magnetic shielding properties and can be used in various magnetic devices, such as switching power supplies and transformers [9].

Carbon materials have electrical conductivity and good electromagnetic radiation absorption performance in a wide frequency range. Carbon foam is a carbon-based material with a light, porous skeleton. It is lightweight, corrosion resistant, high-temperature resistant, strong, and has other excellent properties. For another material, thin film carbon-based electromagnetic shielding material is a material with a dense structure and high conductivity based on carbon material or conductive filler. It is suitable for some instruments and devices requiring size and thickness. One of the most representative is carbon fiber. In addition, the latest material is biomass carbon electromagnetic shielding material, which is a class of materials prepared with organic crops as carbon precursors or templates. It has attracted the attention of many researchers because of its advantages of environmental friendliness, complete degradation, and wide source. In recent years, researchers have successfully prepared biomass-derived materials using loofah, wheat straw, lactic acid bacteria, and so on. Such materials show great potential in electromagnetic shielding [9].

Ceramics have low conductivity and are not often used for electromagnetic shielding. However, MAX phase ceramics not only have good electrical and thermal conductivity similar to metal but also have low density, high strength, and high modulus characteristics similar to ceramics. Therefore, as electromagnetic shielding materials, MAX-phase ceramics have broad application prospects [9].

Glass fiber itself is not conductive but has superior economic, mechanical, and dielectric properties. Glass fiber is often used in electroless plating or composite with other materials for electromagnetic shielding. These materials are widely used in structures that require lower costs, such as wind turbines, ships, and concrete structures [9].

As the earliest natural polymer material used by humans, wood has the advantages of high strength, renewable, low density, and wide source. Combining wood with metal can prepare surface conductive or filling composite materials. This kind of material has the advantages of wood and metal, respectively, and has good electromagnetic shielding performance, which is an ideal electromagnetic shielding material [9].

In addition to fabric properties, electromagnetic shielding fabrics also have electromagnetic shielding functions, which meet people's need for wearable electromagnetic shielding materials. Electromagnetic shielding fabrics mainly shield electromagnetic waves through surface reflection and internal absorption, and the reflected electromagnetic waves will cause secondary electromagnetic pollution to the surrounding environment. Therefore, developing electromagnetic shielding fabrics with low reflectance has become the current research trend [9].

Conductive polymer electromagnetic shielding materials can be divided into two types according to intrinsic and composite material structures and preparation methods. Intrinsically conductive polymer materials refer to polymer materials that are conductive or doped to be conductive. Because of its good absorption ability of electromagnetic waves, it helps to reduce the harm of secondary radiation to the environment caused by electromagnetic wave reflection in the shield. Composite conductive polymer material is obtained by combining a polymer with various conductive substances in a certain way. The composites' mechanical properties, conductive properties, and electromagnetic shielding properties are determined by the properties and ratio of conductive fillers. This means that the material's properties can be regulated in several ways to meet demand. These advantages make the composite conductive polymer material expected to be an ideal electromagnetic shielding material [9].

3.3 Filtering Technology

Filtering technology is the operation of filtering out the frequency of a specific band in the signal. It is an important means to restrain the conducted interference of electrical equipment and improve the anti-interference level of electrical equipment. Its essence is that when the frequency spectrum of the interference noise differs from the frequency band, the filter is applied to eliminate the interference noise. A classical filter is called a circuit that only allows signals within a certain frequency range to pass normally and prevents or attenuates signals of another frequency from passing. Compared with classical filters, modern filters can use the circuit's frequency characteristics to select different frequency signals, such as high-pass, low-pass, band-pass, and band-stop filters.

3.4 Grounding Technology

In electronic equipment, grounding is an important method to suppress interference. A combination of grounding and shielding can solve most interference problems. There are three common grounding technologies in industrial measurement and control. The first one is safety ground, which means connecting the shell of the high-voltage equipment to the ground to prevent charge accumulation and insulation damage to the human body. The next one is working grounding. In construction, the staff must take effective measures to provide a reference conductor or potential point for the normal operation of the entire system circuit. Thirdly, ground the various shielding layers, that is, shield grounding. The shielding system and grounding system are combined to achieve the ideal shielding effect [2].

3.5 Electrical Wiring Technology

In the operation of industrial systems, the cable or wire itself is both the generator and the receiver of interference. Therefore, the layout and wiring have a great impact on EMC. Certain measures must be taken to suppress interference in the system's wiring [2]. For example, the digital, analog, and power circuits are placed separately, and the high-frequency circuit is separated from the low-frequency circuit so that the coupling of useless signals is minimized [10].

4. Conclusion

As a result, various systems in industrial sites will have different degrees of electromagnetic interference. Electromagnetic interference can degrade communication quality in communication systems, change measurement results in measurement systems, and affect system action in control systems. In addition to reducing the efficiency and quality of the system, it will also cause safety accidents in serious cases.

The conclusion is that to reduce the influence of electromagnetic interference on industrial systems, electromagnetic shielding technology, filtering technology, grounding technology, and wiring technology are often used in construction. It should be noted that different coping strategies should be adopted for different kinds of interference. For example, select different electromagnetic shielding materials according to the equipment's working environment, select different filters according to the frequency band, and so on. Taking the right anti-interference means is the key to improving the electromagnetic compatibility of the system.

In summary, from the actual situation of the industrial site, the generation of electromagnetic interference is unavoidable, and the existing means can not eliminate electromagnetic interference. Therefore, the goal of anti-interference in industrial sites is to try to reduce the impact of electromagnetic interference on equipment and ensure the system's normal operation. Although there are many means to combat electromagnetic interference, the specific method must be combined with the actual situation, which requires the staff of the industrial site to have sufficient knowledge and experience accumulation.

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