The principle and practice of measuring the sensitivity of power line spike pulse interference

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Abstract: The measurement of power line spike interference sensitivity is an important item of EMC test. In this paper, the focus of the item and the principle of measurement are described. Combined with the engineering practice of cs06 project, a new way to solve the peak pulse interference of power line is given. Key words: EMC Spike pulse Peripherals

1. Introduction
The power supply circuit is the energy supply part of the electronic circuit. Its general function is to convert the mains power into low-voltage DC. Due to the connection of the municipal power grid, the noise of the power grid will interfere with the electronic circuit through the power circuit, which is one of the main reasons for the interference of the electronic circuit. Many documents think that if the problem of anti-interference of power circuit is solved, the problem of anti-interference of electronic circuit is solved more than half[1-2].

There are two kinds of strong noise in power grid: surge voltage noise with high amplitude and wide pulse width, and spike pulse with high frequency and narrow pulse width. For the causes of surge voltage noise and the suppression methods, please refer to the relevant literature. This paper will focus on describing several problems related to spike pulse noise.

2. Analysis of spike noise
The peak pulse noise pulse amplitude is not necessarily very high, but it has a very steep rising and falling edge, including a very high frequency component, which is very easy to bring interference to the follow-up circuit. There are many reasons for this kind of high-frequency spike pulse in the power grid, but most of them are due to the electrical equipment connected in the same power grid, especially the inductive load equipment and high-frequency equipment feeding to the power grid during operation[3-5]. In the circuit model of the inductive load in Figure 1, when the DC voltage \( V_D \) generates the current \( I \) on the L and R series load, the switch \( s \) will generate a peak voltage dozens of times larger than \( V_D \) and opposite polarity at both ends of L at the moment of switching from on to off.
From Ohm’s theorem in circuit, we can get  \( I = \frac{V_D}{R} \)  

From the conservation of energy in the inductance, we can get:  \( \frac{1}{2}LI^2 = \frac{1}{2}C_0V_L^2 \)  

From the frequency formula of the oscillating circuit, we can get:  \( f_0 = \frac{1}{2\pi\sqrt{LC_0}} \)  

According to the relationship between voltage and current in the inductor, we can get:  
\[
v_L = -L \frac{di}{dt}
\]  

According to formula (1), (2) and (3), if  \( V = 12\text{V}, C = 100\text{pF}, L = 5\text{mH}, R = 100\Omega \), after calculation,  \( f_0 = 225\text{kHz} \),  \( V_L = 848\text{V} \). Since the change of the current in the inductance conforms to the law of exponential function, the change curve of the voltage in the inductive load circuit can be obtained by integrating the two ends of (4), as shown in Figure 2. It can be seen from the figure that this curve is a spike pulse. When this circuit is continuously on and off, the spike pulse group of Figure 3 is obtained.

3. The measurement of the sensitivity of power line spike pulse interference

In order to ensure the robustness of electronic products to the peak pulse interference of power lines, the chapter cs06 in national standard requirements for electromagnetic emission and sensitivity of electronic equipment and subsystems specifically specifies this. After the peak signal generator is calibrated, the test equipment shall be tested. The steps are as follows:
a. Test and configure the test equipment of AC and DC power supply according to figure 4, and test and configure the test equipment of DC power supply according to figure 5.

b. Slowly increase the spike generator output level to provide the specified spike voltage, but not more than the pre-calibrated spike generator output level. At last the peak voltage value is 600V.

c. Adjust the synchronization and trigger so that the peak signal is at the specific position where the sample will produce the maximum sensitivity.

d. Add positive, negative, single and repeated (6-10pps) spike signals to the ungrounded input of the tested equipment. The peak signal shall be synchronized with the power supply and adjusted at every 90° phase, with the injection time not less than 5min. In addition, it is also required to adjust the trigger phase of the spike signal to make it appear in the range of 0° - 360° of the power frequency. Change the synchronous frequency of the spike signal (from 50 to 1000Hz), and pay attention to its influence on the sensitivity of the equipment. For the equipment using digital circuit, the trigger spike signal shall appear in any opening time and any pulse time generated by the logic circuit;

4. Engineering practice
In the process of this test, four X-type display and control consoles developed by our institute all failed. When peak interference is injected into the first phase of three devices, the 200V or so display screen will be black; when the tracking ball is rotated, the documents on the desktop will be automatically "copied", "pasted", "opened" and many other operations, the desktop will be in a state of confusion, click the left key of the tracking ball, and the tracking ball icon will move vertically upward; when the keyboard is tapped, the keyboard sometimes fails to respond. Another device, the same phenomenon occurs at about 400V.

4.1 phenomenon analysis
When the monitor is black, the tracking ball is confused, and the keyboard is out of order, these peripherals show confusion when injecting spikes. The reasons are from two aspects.

First, the impact of power. When the power supply enters the platform and is distributed to each functional module, the peak pulse injected by the test is also brought in. These strong amplitude pulses affect the level characteristics of the functional modules, resulting in peripheral misoperation. Inside the platform: the power supply first enters the filter, then enters the platform switch and is distributed to each functional module. The power supply shall be processed in each functional module.

Second, the influence of signal. Because the spike pulse is brought into the platform, if the signal line of the peripheral is interfered, it will cause the peripheral misoperation.

Due to the common mechanism of three kinds of peripheral interference, this paper starts from the phenomenon of black screen. The reason for the black screen of the display may be the interference of the display signal, the interference caused by the improper processing of the power system, or the result of the joint action of the two. See Figure 6 for the fault tree of the black screen of the display.
4.2 troubleshooting process

See Figure 7 for the internal wiring of the display console. According to the fault tree model, we gradually check m1-m6 to find out the problem.

4.2.1 select one of the three display and control consoles with the same effect, unplug the rgbhv signal line connected with the reinforcement machine and the power line in the cabinet, and connect it to the external notebook display and separate power line through the debugging cable. At this time, the case
ground and signal ground of the display are still connected to the ground. Add 5us rectangular spike pulse to the power input, and the display passes the test. In this way, the problem of the display itself is eliminated. That is to say, the problem of X1 in fault tree is eliminated.

4.2.2 remove the display line and power line on the ruggedized LCD, and lead the display line of the ruggedized machine from the console to the external commercial display. At this time, the casing ground and signal ground of the reinforcement machine are connected to the ground. Add 5us rectangular spike pulse to the power input, and the screen will be black at about 200V. After inspection, it was found that the cable from the counter to the commercial display was not shielded, which may be one of the reasons for the black screen, so it cannot be concluded that it was the problem of the reinforcement machine.

Remove the reinforcement machine from the cabinet, connect the commercial display, and connect the casing ground and signal ground of the reinforcement machine. Add 5us rectangular spike pulse to the power input, and the screen will be black at about 200V. After inspection, it was found that the cable from the cabinet to the commercial display was not shielded. Replace the shielded cable and pass the test. Therefore, it can not be concluded that it is the problem of reinforcement machine.

4.2.3 place the display and reinforcement machine on the platform, and connect all lines except the display line. The display line is replaced by the finished line with good shielding effect, which is wrapped with copper sheet at the joint, and then placed inside the platform. It is found that there is still a black screen around 250V; the display line is placed outside the platform with a black screen around 300V. This debugging proves that the display cable of the platform is not the decisive reason for forming the black screen.

4.2.4 open the reinforcement machine and find that the display signal wiring from the reinforcement machine inner base plate to the external adapter socket is afr-250-0.2 aviation wire. After changing into SYV-75-2 coaxial cable, add 5us rectangular spike pulse, 400V black screen, continue to increase the voltage, 600V reinforcement machine restart. However, it should be noted that the effect of replacing the display signal line is obvious. So m3 is a factor that causes the black screen.

4.2.5 because it is suspected that the specifications of the power cord in the console are not in conformity with the regulations, peel off the power cord connecting the display in the console, and find that the shielding layer in the console is not grounded according to the requirements of the wiring table, that is to say, the shielding layer of the display power is floating. When there is a spike pulse, there will be a higher voltage on the shielding layer, which will be coupled to the signal line, resulting in a black screen. After grounding, add 5us rectangular spike pulse, 600V to about 10 minutes, the mouse is abnormal, and the screen is black once. Therefore, X11 in M6 is an important factor leading to black screen.

4.2.6 observe the power wiring in the reinforcement machine, and find that the power wiring sequence is: SOCKET AC input switch filter fuse power module (ps5-34 and ps5-55s). After changing into socket AC input filter switch fuse power module, add 5us rectangular spike pulse, 600V test machine for about 15 minutes, the display will recover immediately after the black screen, and the tracking ball will be confused. It is proved that although all the above measures have improved the anti-interference of the platform, there are still some factors affecting the normal operation of peripherals that have not been found. Of course, X8 in M4 is also a factor of black screen.

4.2.7 connect the sockets of keyboard, tracking ball and display module with general aviation wire cable and reinforce the sockets corresponding to these modules on the aircraft. The modules are placed inside the display and control console, and the debugging cables are routed outside the console. The experiment can pass.

It is found that the cables from the reinforcement machine socket to the keyboard, tracking ball and display inside the platform are all unshielded aviation wires. After adding a layer of snake skin insulation
layer outside these aviation wires, the effect is slightly improved. When the test is about 16 minutes, the display screen is black and the tracking ball is confused. X3 in M2 is a secondary cause of failure.

4.2.8 the cable from the internal reinforcement of the unit to the power supply of the display has been shielded. We put a layer of snakeskin shield wire on the outside, and it is well grounded. It is found that the effect has not been improved, and the fault occurs again in about ten minutes.

4.2.9 remove the spare parts unit, observe the power wiring in the platform, and find that the cable from the socket to the filter is too long, and the shielding layer before entering the filter is not grounded. Cut the wire before entering the filter short, and ground the shielding layer well, and pass the test after rectification. Therefore, x9 and X10 in M5 are an important cause of failure.

4.2.10 test conclusion
In a word, the black screen of the display is the comprehensive result of the following five factors.
  a. The cable from the power supply to the filter is too long;
  b. The power supply is not grounded before entering the platform filter;
  c. The screen of display power supply is not grounded;
  d. The power supply entering the reinforcement machine does not enter the filter directly;
  e. The shielding effect of signal wire inside the reinforcement machine is poor

After the problem of black screen is solved, the faults of keyboard and tracking ball disappear. It is proved that the peak interference introduced by power supply can not be released to the chassis through the grounding point, which is the root cause of keyboard failure and tracking ball confusion.

5. Summary
The sensitivity measurement of power line spike interference is an important part of EMC test. To improve the robustness of products to spike pulse, we can consider power supply and easily interfered devices. In addition, the form of EMC test fault is the comprehensive result of many factors. Only by eliminating all the weak links that can be found can we get the ideal results.

6. References
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