Experimental Study on Voltage Sag Tolerance of LED Electronic Display

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Abstract. Widely used LED electronic displays have high requirements for power quality. Because of the status quo of LED technology update and the lack of related experimental work, this paper first analyzes the hardware composition of LED electronic display and switching power supply module. In addition, the paper points out that the transient tolerance of LED screens is mainly determined by switching power supply modules. Then, a test platform was built, and a certain type of LED screen was selected to investigate the influence of voltage temporary drop value and duration, phase jump, and initial Angle of temporary drop on the tolerance of LED electronic display. It provides data support for evaluating and managing the effects of voltage sags on LED electronic displays and the design of power supply schemes.

1. Introduction
A voltage sag is an event in which the average root of the supply voltage suddenly drops in a short period. Voltage sag is not a new power quality problem. It did not attract widespread attention because most electrical equipment was not sensitive to sudden changes in voltage in a short period of time. But now, with the continuous improvement of technology and the large-scale use of much sensitive electrical equipment, voltage sag has become the most important power quality issue. The light voltage drop will have a negative impact on the work and life of residents, and the heavy one may cause significant economic losses and even cause accidental casualties. According to statistics, among the numerous power quality problems, the economic loss caused by voltage sag is the most serious, and users complain the most. The influence of voltage sag on sensitive equipment is becoming more and more prominent, which has attracted more and more attention from scholars at home and abroad. Typical sensitive devices include switching power supply, AC contactor, Programmable Logic Controller (PLC), frequency converter, etc. [1]. As the working power supply or control power supply of electrical equipment, switching power supply has been widely used in household or industrial electronic equipment due to its advantages such as high efficiency, small size, low power consumption, high reliability, and large output voltage range [2]. When the switching power supply is subjected to voltage sag, the relevant process control system may be interrupted, thus causing the abnormal operation of the controlled equipment, and causing huge losses to the relevant users.
At present, some researchers at home and abroad have also researched voltage sag tolerance of sensitive equipment, most of which are theoretical and simulation analysis, and less work has been carried out on experimental research. Among them, the influence of voltage sag on switching power supply is mainly analyzed. Some experimental studies combine special electrical equipment. For example, in the literature [3-4], based on analyzing the influence of voltage sag on switching power supply, a computer sensitivity curve is obtained through experiments. LED electronic displays with built-in switching power modules are increasingly used in public places. Voltage sag may cause the LED electronic display screen to be unable to display normally, but there is no in-depth test analysis on this aspect at home and abroad. In this paper, the voltage sag tolerance characteristics of LED electronic display are tested, and the influence of phase jump, sag starting Angle and other factors based on sag is considered. Finally, we get the voltage sag tolerance of the LED electronic display and draw the voltage sag tolerance curve of the LED electronic display. Not only for the use of LED electronic display Settings is of practical guiding significance, such as multiple LED power supply and distribution system design, LED power supply module to improve and evaluate the effects of sag on the LED screen, etc., and more enrich the application of switch power supply affected by voltage sag, the research content, for the application of switching power supply and management of the voltage sag, it provides effective data support.

2. LED electronic display screen

2.1. Hardware composition of LED electronic display
The display of LED electronic display screen is composed of several display units that can be combined and spliced to constitute the screen body, plus a set of controllers, it constitutes the LED electronic display screen. LED display can be divided into graphic display and video display. The hardware structure of LED video display and its relationship with each other are shown in Figure 1 below.

![Figure 1. LED video display working principal system block diagram](image-url)
The test equipment in this paper is a certain type of LED display screen provided by one of the equipment suppliers of Beijing Winter Olympic Stadium. Its main components and connection diagram are shown in Figure 2. The main components are the unit board, control card, power supply, frame, and so on.

The unit board is one of the core components of the full-color LED display, which is composed of LED module, driver chip and PCB circuit board. The LED module is made up of several dots with resin or plastic encapsulated dot matrix. The driver chip is mainly composed of 74HC595, 74HC245/244/74HC138/5026 and other circuits.

The function of the data receiving control card is to use the control signal sent by the signal sending card to output the corresponding row and column control signals and control the LED unit board to emit light according to the law.

The display card is equipped with DVI output and VGA output, respectively, to supply LED data transmitter and computer display. In addition, the display card also has an S-VHS input terminal and VIDEO input terminal, for the input of the VIDEO signal.

The in-machine sending card is the data signal needed to convert the DVI video signal into an LED display screen and send it to the LED control card.

Signal distribution cards are designed for multi-screen or super-large display, etc.

2.2. Switching power supply

The above-LED video display system block diagram shows that the working state of the DC side of the switching power supply output directly affects the LED electronic display screen. During the voltage sag, when the input voltage is less than the DC side of the rectifier capacitor voltage link does not work, all the energy is stored by the DC side capacitor, the load capacitor-discharge makes its voltage drop. When the voltage drops to the specified minimum voltage value, the load with it will lose power, that is, switching power supply is the key to be affected by the voltage sag, which can be explained according to the working principle of switching power supply.

Switching power supply is relative to linear power supply, usually consists of a rectifier and a voltage regulator (DC/DC converter). The LED panel studied and tested in this paper adopts a single-phase voltage-type bridge PWM rectifier, and its circuit structure is shown in Figure 3.
Figure 3. Single-phase voltage-mode PWM rectifier circuit structure

When working normally, the AC voltage is rectified by the rectifier to obtain a higher amplitude DC voltage, and then the voltage regulator will adjust it to the design range of DC voltage and provide it to the electricity module. If the ac measuring voltage decreases, the voltage on the rectifier's DC side will also decrease. However, within a certain range of voltage changes, the voltage regulator could keep its output voltage constant and ensure the normal operation of the device. If the rectifier DC side voltage is too low, the regulator output voltage is not enough to maintain the fixed value, it may affect the normal operation of the equipment.

3. Experimental scheme design

3.1. Experimental platform
According to the standard GB/T 15969.239269-2020 voltage sag/short-interrupt low-voltage equipment tolerance test method [5-8], the experimental platform is built, as shown in Figure 4. The test platform mainly includes a voltage sag generator, test equipment, and a data acquisition system. The voltage sag generator here uses Chroma power 61860, the test equipment is an LED electronic display screen, and the data acquisition system uses IPQ-1 multi-channel power quality analyzer and HIOKL memory recorder.

3.2. Test equipment and test instruments
The parameters of LED electronic display screen used in the test are as follows:

![Test experimental platform diagram]
### Table 1. Basic parameters of LED display

| model        | The product type | AC input voltage (V) | AC input frequency (Hz) | Maximum AC input power (W/m²) | Average AC input power (W/m²) |
|--------------|------------------|----------------------|-------------------------|-------------------------------|------------------------------|
| M3013 Display unit | AC100~240        | 50/60                | 521 W/m²                | 235 W/m²                      |                              |

The test instrument parameters used in the test are as follows:

### Table 2. Main parameters of the test instrument

| The name of the | model                      | manufacturer                | Sampling frequency |
|-----------------|----------------------------|-----------------------------|--------------------|
| Voltage Slip Generator | Chroma 61860               | Taiwan Zhimao Electronics Co., Ltd | ---- |
| Data acquisition system | IPQ-1 Multi-channel Power Quality Analyzer | Anhui Xinli Electric Equipment Co., Ltd | 12.8kHZ |
| Memory recorder  | HIOKI 8860-8861            | hioki                       | 10kHz              |

### 3.3. Test methods

LED electronic display for voltage sag resistance characteristic test experiment, the need to control variable method is used to increase each influence factor, can be divided into three conditions, namely, regardless of the phase jump and sag starting Angle of the voltage sag resistance properties, regardless of the phase jump and sag starting Angle of the voltage sag resistance properties, considering the sag starting Angle of voltage sag resistance properties. The method used to draw voltage sag tolerance characteristic curves under each working condition is the improved closing method [3], which is a test point selection method that can improve test efficiency to a certain extent.

![Figure 5. Voltage sag tolerance curve drawn by modified closure method](image-url)

### 4. Analysis and discussion of experimental results
According to the above analysis, the key to be affected by the voltage sag is the switching power supply, which can convert the mains power into the DC power required by the power modules in the LED electronic display.

4.1. Parameter analysis of DC side of switching power supply

From the above analysis of the working principle of LED electronic display, the voltage drop generated by mains power mainly affects the switching power supply of sending card and system card, which is the key factor that leads to the abnormal working of LED electronic display, i.e., the screen going out and the system restarting, respectively, as shown in Figure 6. If the screen is only off until the full recovery of approximately 10 seconds (during the screen will appear but with occasional phenomenon); When the screen is off and the system is restarted, the time to return to the main screen is about 48 seconds, plus the time required to manually control the main screen to display the screen, the total time is about 60 seconds (depending on the reaction time of the human). The discussion is divided into two aspects.

4.1.1 Analysis of DC side parameters of sending card

After the LED electronic display screen is extinguished due to the influence of voltage sag (the residual voltage is roughly 55V–60V, and the voltage sag event lasting longer than 50ms will cause the LED electronic screen to extinguish), the output voltage of the DC side of the power module of the sending card in this process drops from the normal voltage of 12V to about 4V, which is the cause of the screen extinguishing. As shown in Figure 7, U4 is the output voltage of the DC side of the power module of the sending card. The output voltage of the DC side of the power module of the sending card will return to the normal voltage of about 12V with the end of the voltage sag, that is, the LED screen will start from the black screen phenomenon after about 10 seconds.

![Figure 6. Reasons for abnormal phenomena caused by voltage sag](image)

4.1.2 Parameter analysis of DC side of system card

When the LED electronic display is depressed by the voltage (18v-27v residual voltage, a voltage sag event lasting more than 150 Ma will cause the LED electronic display to restart the whole system), the system’s output voltage of the DC side card power module will drop to 0V in the process triggering a relay block. This causes the DC input voltage of the LED driver to drop to around 0V, which is the reason for the restart. As shown in Figure 8, U3 is the output voltage of the DC side of the power module of the system card. The output voltage of the DC side of the power module of the system card will gradually return to normal voltage with the end of the
voltage drop. The solid-state relay will recover after a period of continuous locking, and the input voltage of the DC side of the LED driver will also return to normal, and the output voltage medium of the DC side of the LED driver will return to the normal voltage of about 12V. That is, the LED screen will start from the black screen phenomenon after about 10 seconds.

![Figure7. Screen extinguishing test](image1)

![Figure 8. Restart the experiment](image2)

According to the above, it is precisely because the DC side voltage of the power module of the sending card temporarily drops to 4V with the mains voltage that causes the screen to be extinguished. Thus, the voltage sag tolerance characteristic curve of the screen to extinguish can be determined. Similarly, it is precisely because the DC side voltage of the power module of the system card temporarily drops to 0V along with the mains voltage that leads to the restart of the entire LED electronic display system. Thus, the voltage sag tolerance characteristic curve of the restart can be determined.

4.2. Voltage sag tolerance characteristic curve of LED electronic display
4.2.1 Voltage sag tolerance characteristics without considering phase jump and sag starting Angle
To eliminate the influence of different screen colors on the voltage sag tolerance characteristic curve of the LED electronic display screen, in this part of the test, the voltage sag tolerance characteristic curve under five working conditions of different screen colors was tested respectively under the condition of extinguishing and restart.

![Voltage sag curves of the color-color screen for extinguishing and restarting](image)

**Figure 9.** Voltage sag curves of the color-color screen for extinguishing and restarting

As can be seen from Figure 9, the quenching and restarting of various screens have slightly different temporary drop values and durations respectively, but the shape of the voltage sag tolerance curve is roughly the same. The main reason is that different color drive current size is not the same, different power consumption. In the voltage sag tolerance curve of the extinguish screen, blue and yellow are the upper limit, black is the lower limit, and the order from top to bottom is basically blue, yellow, white, red, and black. In the voltage sag tolerance curve of the restart, red is the upper limit and blue is the lower limit. The order from top to bottom is red, yellow, white, black, and blue.

As can be seen from the above chart, the residual voltage is roughly between 55V and 60V, and the voltage sag event lasting longer than 50ms will cause the LED electronic screen to go out. A voltage sag event with a residual voltage of approximately 18V-27V and a duration of more than 150ms will cause the LED electronic panel to restart.

4.2.2 Voltage sag tolerance characteristics without considering phase jump and sag starting Angle
After the test, all kinds of the screen to screen out and restart the corresponding voltage sag resistance curve shape is roughly same, so the color difference of the LED electronic display screen of the voltage sag resistance characteristic curve is not non-ignorable effect, so Bai Sebing, for example, test phase jump for the influence of the voltage sag resistance characteristic curve.
Figure 10. Comparison of voltage sag tolerance curves with phase jump of plus or minus 30 degrees and 0 degrees on the white screen.

As can be seen from Fig. 10, taking the white screen as an example, the voltage sag tolerance curve when no phase jump occurs is the upper limit. When the phase is positive 30° or negative 30° jump, their voltage sag tolerance curves are the same. However, it can be seen from the above chart that the phase jump has no significant effect on the voltage sag tolerance characteristic curve, and the voltage sag with phase jump is relatively more tolerant.

4.2.3 Voltage sag tolerance characteristics considering sag starting Angle.

After the test, the shape of the voltage sag resistance curve of each screen is approximately the same, so the color difference of the LED electronic display screen cannot be ignored. So, Bai Sebing, for example, test sag starting Angle for the influence of the voltage sag resistance characteristic curve.

Figure 11. Comparison of voltage sag tolerance curves between the initial Angle of 90° and 0° on the white screen.

As can be seen from Fig. 11, taking the white screen as an example, when the initial dip Angle is 90 degrees, in the case of the screen extinguishing, it is roughly the same as when the initial dip Angle is 0 degrees. In the case of a restart, the voltage sag tolerance curve with the sag starting Angle of 90° is slightly lower than the voltage sag tolerance curve with the sag starting Angle of
0°, but the maximum difference is not more than 2V. Therefore, it can be seen from the above chart that the sag starting Angle has little influence on the voltage sag tolerance characteristic curve.

5. Concludes
This paper briefly analyzes the working principle of the LED electronic display screen. By building a test environment and test platform, mainly includes voltage sag generator, test equipment, and data acquisition system. Then, voltage sag tolerance test (using improved closure method) and data processing analysis were carried out. The research shows that: (1) The voltage sag mainly affects the switching power of the sending card and the system card of the LED electronic display, which is the key factor to cause the LED electronic display to be extinguished and the system to restart. (2) For a simple voltage sag event, the residual voltage is about 55V-60V, and the voltage sag event lasting longer than 50ms will cause the LED electronic screen to die out. A voltage sag event with a residual voltage of approximately 18V-27V and a duration of more than 150ms will cause the LED electronic panel to restart. (3) The phase jump has no significant effect on the voltage sag tolerance curve. (4) Slip starting Angle has no significant effect on voltage sag tolerance curve.

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