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A New Method Improving Sensor Reliability in HVDC Control and Protection Measurement System

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Abstract. Aiming at the problems such as high failure rate, unable to perform state detection, difficult diagnosis of failure mode existing in optical measurement Sensor in HVDC, a state detection technology of the Sensor is proposed. Based on this technology, a dynamic accelerated aging test is carried out in which the Sensor is extracted by independent factor variables such as input voltage, temperature, laser input power, operating years, etc., and its failure mode and failure mechanism are comprehensively analyzed. Finally, it is found that temperature and laser input power are the main factors affecting the operation state of the Sensor, the temperature should not be higher than 30°C and the laser input power should not be greater than 1.2W.

Keywords. Optical measurement sensor, state detection, failure mode and failure mechanism, life and aging assessment

1. Introduction

The SENSOR is an important component that converts electrical signals into optical signals in the optical measurement system of the HVDC station. It is sensitive to external influences. In actual use, the failure rate is about 60% of the optical measurement system, which has seriously affected the normal and stable operation of the high-voltage converter station [1].

However, it is still impossible to perform state detection of SENSOR in the industry, and the failure mechanism is difficult to diagnose. Therefore, for the characteristics of SENSOR, a technology for state detection needs to be developed. Based on this technology, the failure mechanism analysis of the SENSOR is carried out, which provides a technical support for the realization of equipment life cycle management.

2. Sensor State Detection Technology (SSD)

2.1. Sensor

Energy management module converts light energy into electrical energy through the PPC battery and supplies energy to the ASA and the DSP. The ASA collecting the real-time

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data of the electrical signals of the high-voltage converter station, and the DSP converts these electrical signals into optical signals and outputs them by the LED.

Figure 1 is a schematic diagram of the structure of the Sensor, which mainly includes three modules: Analog signal acquisition module (ASA), Energy Management Module (EM), Digital signal processing module (DSP) [2].

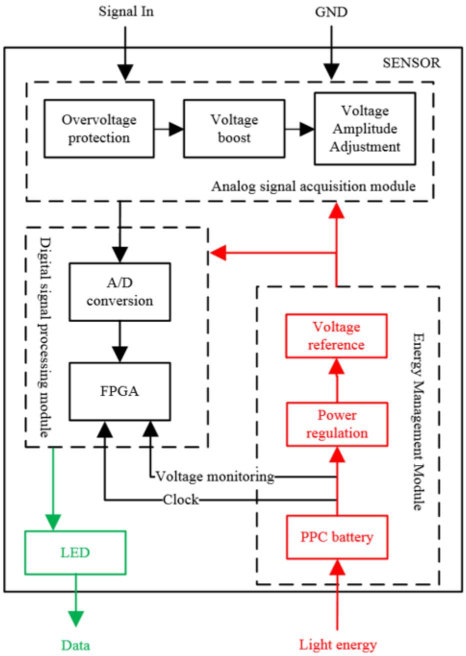

Figure 1. Sensor structure.

2.2. Sensor State Detection Technology Principle

The aging degree of the main functional modules such as PPC battery, LED, and FPGA, etc. in the Sensor directly affects the operating status of the Sensor, and the aging degree of each module will be reflected in parameters such as the frequency, amplitude, pulse width and position of the under-energy pulse of the returned data [3].

Therefore, by collecting the signal waves returned by the Sensor, comparing and analyzing the variation laws of the parameters of the signal waves before and after the failure of the Sensor, and clarifying the corresponding parameters information representing the fault state of the Sensor, the Sensor state detection technology can be realized.

Figure 2 shows the waveform of the data signal returned by the Sensor. The status of the Sensor can be judged by analyzing the following waveform parameters:

- Presence or absence of pulse signal;
- Peak-to-peak value: Differential value between the peak value and the trough value [4];

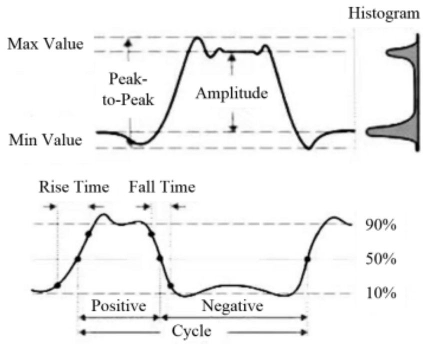

Figure 2. Parameters of the signal waveform of the sensor.

- The mean value of the maximum value and the minimum value and its corresponding variance value;
- The Rise Time: The time differential value between the intersection of the lower threshold (10% of the top value) and the intersection of the higher threshold (90% of the top value) of the positive rising edge;
- The Fall Time: The time differential value between the intersection of the higher threshold and the intersection of the lower threshold of the negative edge;
- Positive Pulse Width: The time from the middle threshold of the rising edge (50% of the top value) to the middle threshold of the next falling edge;
- Signal-to-noise ratio and signal glitches.

2.3. Sensor State Detection Device

Figure 3 shows the schematic diagram of the state detection device of the Sensor. The laser source provides the Sensor with working energy and clock signal by emitting pulsed laser light. At the same time, the optical data detector is responsible for receiving the optical signal returned by the Sensor and converting it into a digital signal. It is sent to the signal acquisition system for high-speed A/D sampling and storage. Finally, the signal acquisition system processes the digital signal and sends it to the data analysis system for data analysis and display.

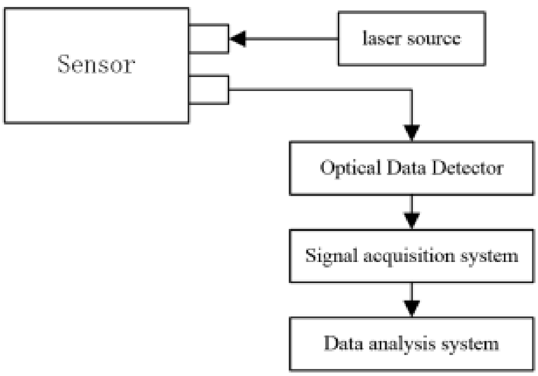

Figure 3. Sensor state detection device.

2.4. Function Test

The function test of SSD was carried out using two sets of different performances of sensor samples.

No. 1 is a new sample, and No. 2 is a faulty sample. The state of the two samples was detected by the SSD, the laser output power was fixed at 0.8W, the input voltage was 5V, and the detection was performed once per hour, for a total of 6 detections [5].

Figure 4 shows the test results of two Sensor samples, curve (a) is the test result of sample NO.1, curve (b) is the test result of sample NO.2.

Table 1 shows the test result data, it can be seen from the test results that the rise time slope, fall time slope, max average value and max variance value of the No. 2 sample are about half smaller than the corresponding parameter values of the No. 2 sample, while pulse width, min average value, min variance value and signal quality factor are not much different. Therefore, the test results of the remote module status detection and fault diagnosis system can be verified by comparing the results of this experiment [6].

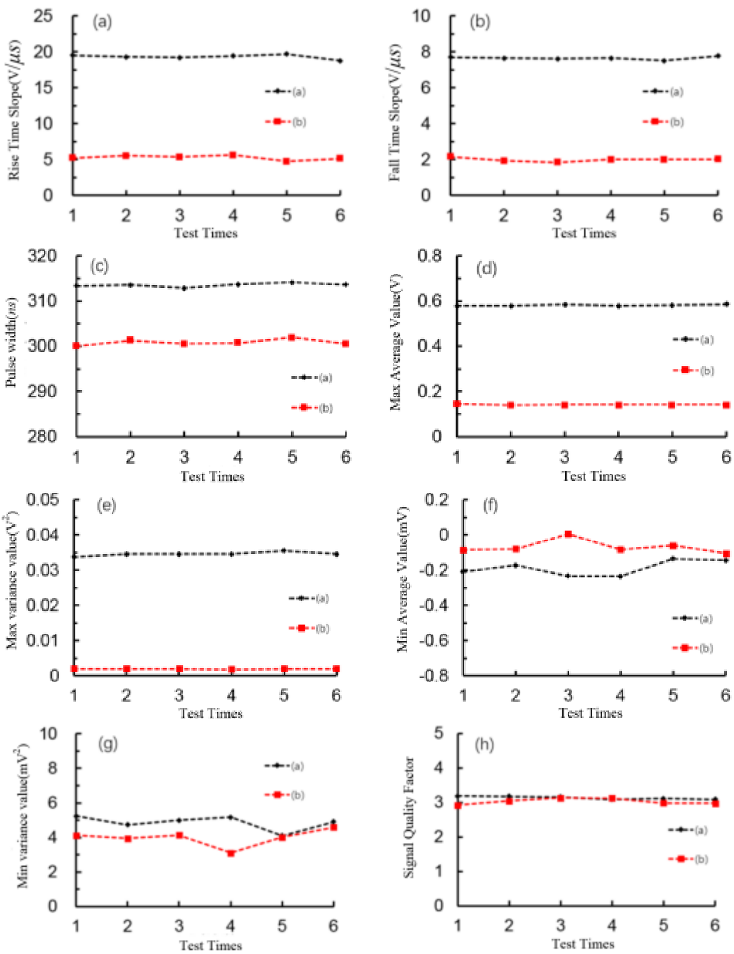

Figure 4. Sample test result.

Table 1. Two sensor sample test results by SSD.

Sample	**1**	**2**
Rise time slope (V/μs)	19	5.2
Fall time slope (V/μs)	7.5	2
Pulse width (ns)	313.5	301.2
Max average value (V)	0.57	0.14
Max variance value (V^2)	0.034	0.002
Min average value (mV)	-0.166	-0.109
Min variance value (mV^2)	0.004	0.004
Signal quality factor	3.1	3.0

3. Sensor Failure Mechanism

In order to study the failure mechanism of the Sensor, five types of Sensor samples with operating life are 1, 12, 5, 8, 3 years which were selected to carry out the dynamic accelerated aging test of independent factor variable extraction, and the factors such as input voltage, temperature, optical power, humidity, operating life, etc. effect on Sensor failure [7].

3.1. Input Voltage Factor Test

Sensor samples of Type 1 and type 2 are selected, and the test laser input power of the Sensor is set to 0.8W, and the input voltage is slowly increased from -10V to 10V. During the test, SSD is used to collect Sensor working status data under different input voltages [8].

The test results are shown in Figure 5. It can be seen from the test results that under different input voltages, the changes of the parameters of the Sensor with different operating life are basically unchanged, so it can be seen that the change of the input voltage has basically no effect on the working status of the Sensor.

3.2. Temperature Factor Test

Sensor samples of Type 2 and type 5 are selected, and the test laser input power of the Sensor is set to 0.8W, and the test voltage of the Sensor is set to 5V, and the input temperature is slowly increased from 25°C to 70°C. During the test, SSD is used to collect Sensor working status data under different temperatures [9].

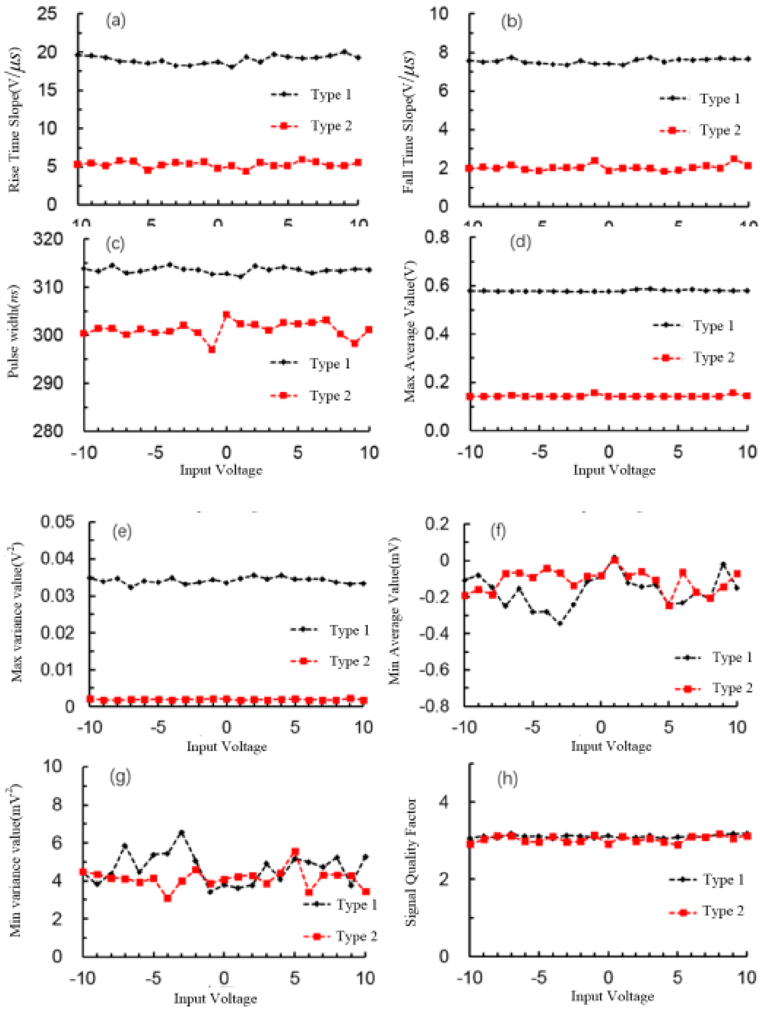

Figure 5. Input voltage factor test result.

The test results are shown in Figure 6. It can be seen from the test results that the temperature has a great influence on the working state of the Sensor. As the temperature increases, the rise time slope, fall time slope, max average value and max variance value of the output signal of the Sensor show a downward trend, while the pulse width shows an upward trend, and other parameters are almost unchanged. This is because when the temperature increases, the operating efficiency of the PPC battery in the Sensor decreases, and the corresponding frequency of each working component decreases [10].

3.3. Laser Input Power Factor Test

Sensor samples of Type 1 and type 5 are selected, and the laser input power is slowly increased from 0.6W to 1.4W, and maintained each power for 2 hours, During the test, SSD is used to collect Sensor working status data under different laser input powers [11].

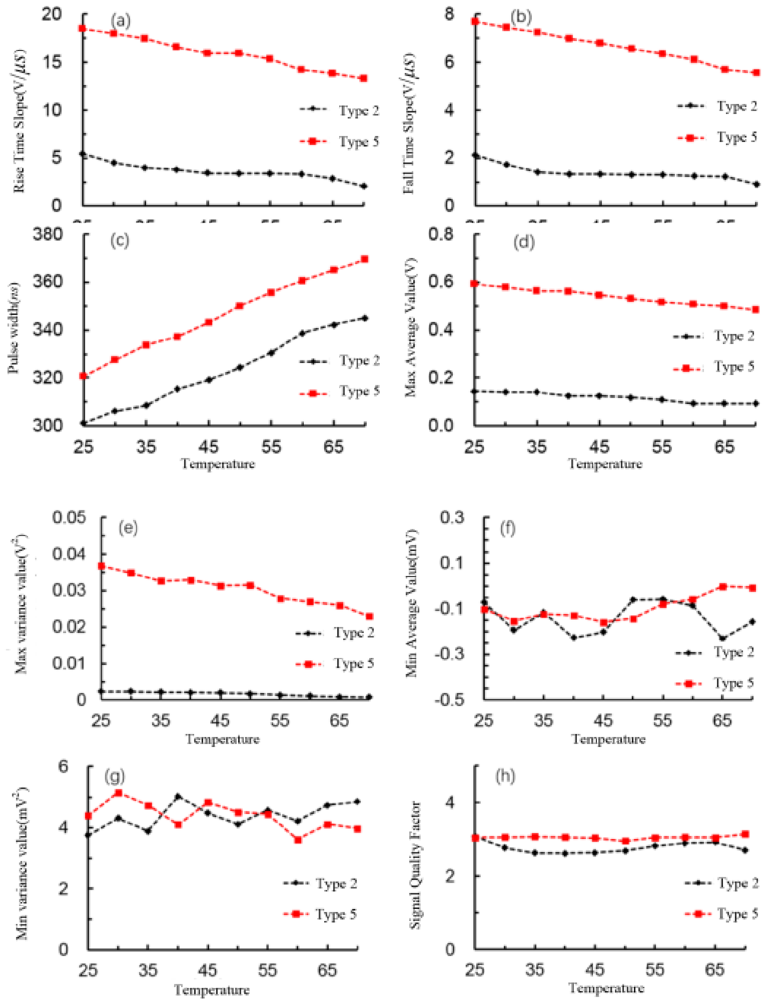

Figure 6. Temperature factor test result.

As shown in Figure 7, when the laser input power is less than 1.2W, the max average value, max variance value and signal quality of the Sensor have no significant changes. However, when the laser input power is gradually higher than 1.2W, the rise time slope, fall time slope, pulse width, min average value and min variance value of the Sensor show a downward trend. The reason for this phenomenon is that the internal temperature of the Sensor increases due to the high laser input power, which leads to a longer Sensor response time and affects the working state.

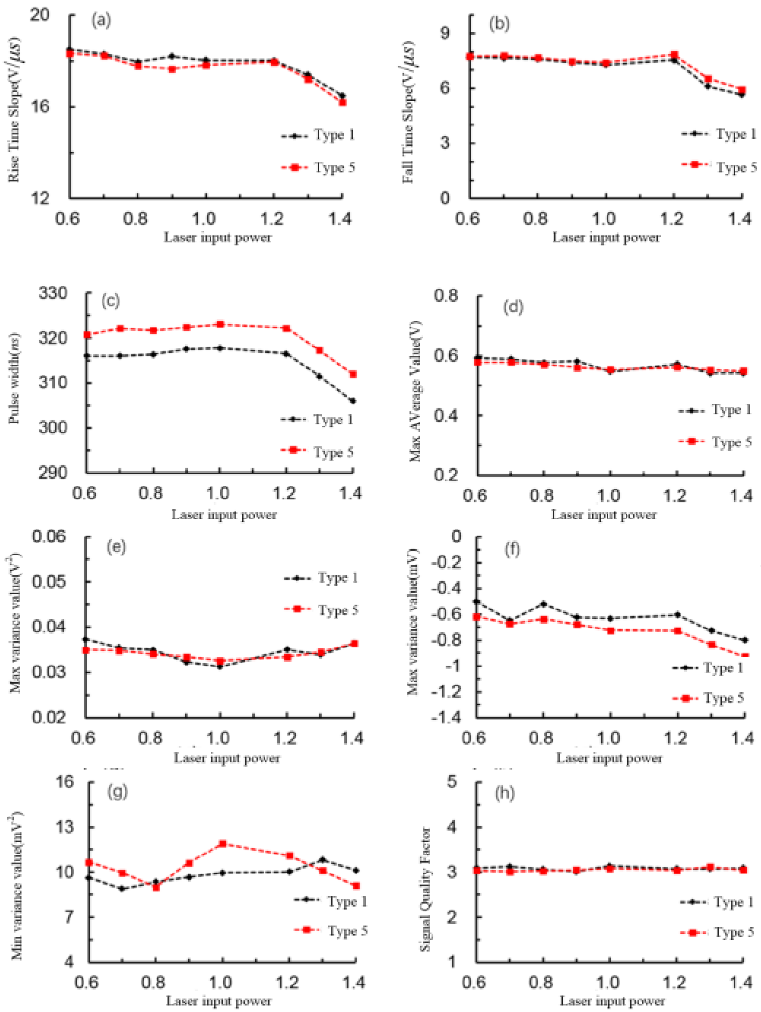

Figure 7. Laser input power factor test result.

4. Conclusion

In this paper, sensor state detection technology (SSD) of the optical measurement system of the HVDC is proposed and the function is verified by experiments.

At the same time, based on the SSD, through the aging test, the failure mechanism of the Sensor is carried out. It is found that temperature and laser input power are the main factors affecting the Sensor.

Therefore, it is necessary to avoid the operating temperature of the Sensor higher than 30°C, and the operating laser input power should not be greater than 1.2W. When it is found that the rise time slope, fall time slope and max average value of the output signal of the Sensor less than half of the original, it means that the Sensor has been seriously aged. To ensure the normal operation of the optical measurement system, it is recommended to replace the Sensor immediately.

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