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# Time division control optical pulse width method of distributed optical vibration sensing system in smart power plant

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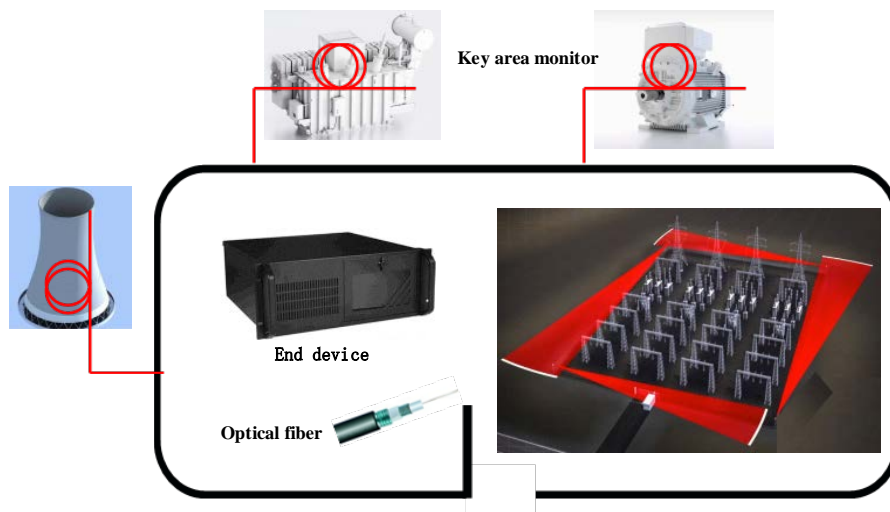
**Abstract.** To improve the performance of distributed fiber vibration sensing system used in smart power plant, time division control optical pulse width method is proposed. It used periodic optical pulses during transmitting and a series of signal processing after received the backscattered signal. By using this method, system positioning accuracy is better than the single pulse width case. It can also compensate for the defects of low sensitivity and weak signal strength at long distance.

## 1. Introduction

Smart power plant which is an important part of Smart Grid will require a large number of sensors that can provide detailed information for better monitoring and controlling [1]. According to the monitoring system requirement of smart power plant, a distributed fiber vibration sensing system (DFVSS) can be an important effect for real-time monitoring of the plant key areas, guarantee safety of the plant, integrating to management system of the plant. To achieve the high performance defense system, as Fig. 1 shows, a distributed optical vibration sensing system is used in smart power plant.

DFVSS has the advantages of large dynamic range monitoring, good concealment, excellent flexibility and immunity to electromagnetic interference[2,3]. It plays a significant role in smart power plant defense system. However, there are several disadvantages for the current DFVSS, such as weak anti-interference ability, single feedback for signal processing and high false alarm rate[4,5]. Therefore, it is necessary to find a suitable method to improve signal multiplicity and reduce false alarm rate.

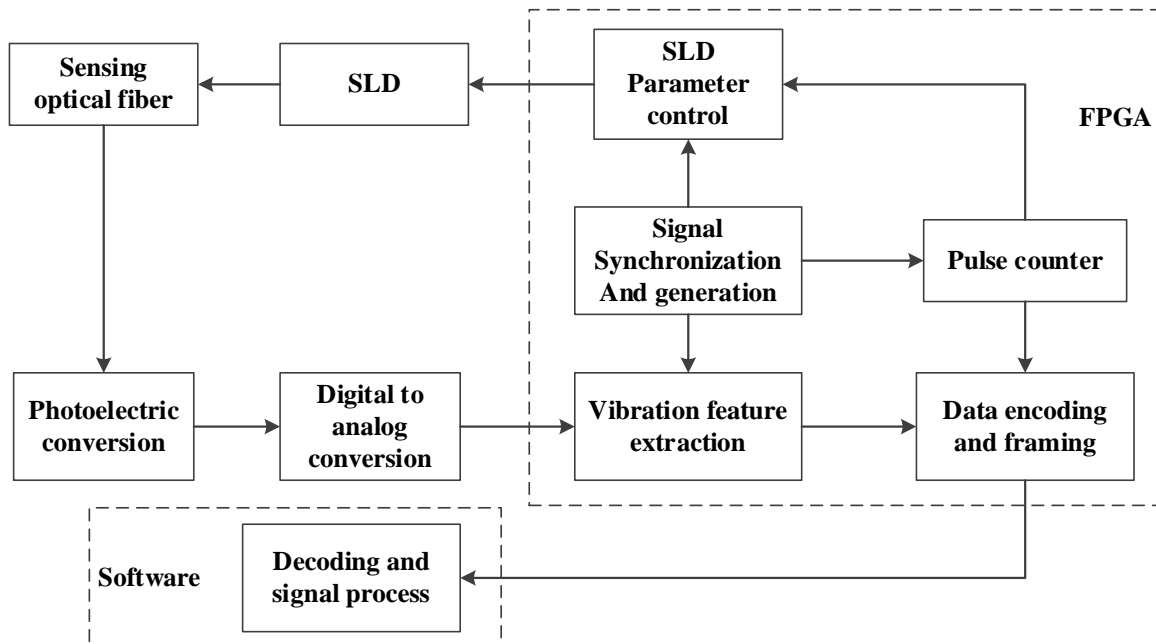




**Figure 1.** Distributed fiber optic vibration sensing system in smart power plant.

## 2. Time division control optical pulse width method

In distributed optical fiber vibration sensing system, there are some important performance factors such as location accuracy, resolution, dynamic range, sensitivity, etc. The optical pulse during transmitting has a great impact on these indicators. The location accuracy and resolution will be higher with narrower pulse width. But that also causes the power of the optical pulse to decrease and reduce the dynamic range and sensitivity. As a result, it is impossible to improve the performance of the system with constant optical pulse.

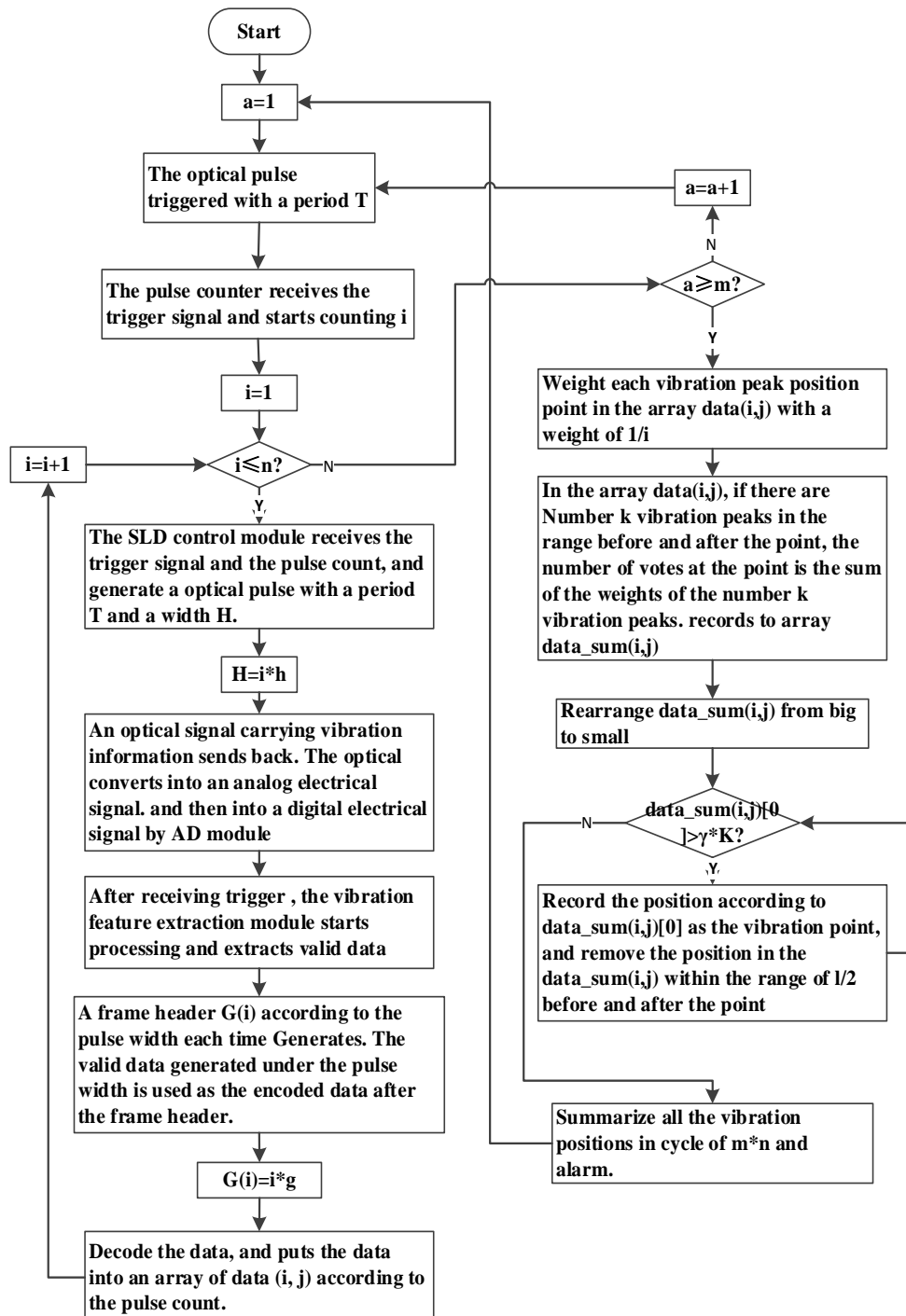


**Figure 2.** Time division control optical pulse width method block diagram

To solve the problems, this paper proposes a method of Time division control optical pulse width. This method needs both hardware and software to control the periodic variation of the optical pulse width in real time. It generates different widths of optical pulse as designed sequence to transmit. The received signal is encoded into a frame according to the current pulse width, and then sends to the

software. The software decodes the received data, extracts the signal data under different pulse widths, and calculates the vibration point. Fig. 2 is a block diagram of the module, the steps are as follows.

### 2.1. Analysis of time division control optical pulse width method



**Figure 3.**Detailed flowchart of Time division control optical pulse width method

Fig. 3 is a detailed flowchart of the method, which shows the relationship of signal layer transfer between modules and the data loop processing flow in system operation.

For example, the synchronization signal generation module generates an optical pulse trigger signal of period T, and informs the pulse counter, the pulse feature extraction and the SLD parameter control

module. The pulse counter module can count from 1 to n. When it receives the SLD light trigger signal, it will add 1:

$$i = \begin{cases} i + 1, 1 \leq i < n \\ 1, i = n \end{cases} \quad (2.1)$$

In the formula,  $i$  is the pulse count of the current cycle and  $n$  is the maximum value of the pulse count. The pulse counter outputs the count to the SLD parameter control module and encodes the data to frame. The SLD light control module receives the optical pulse triggered signal and the pulse count. And then it outputs the control signal to generate a optical pulse which contains a period  $T$  and a width  $H$ . The pulse width  $H$  has to satisfy:

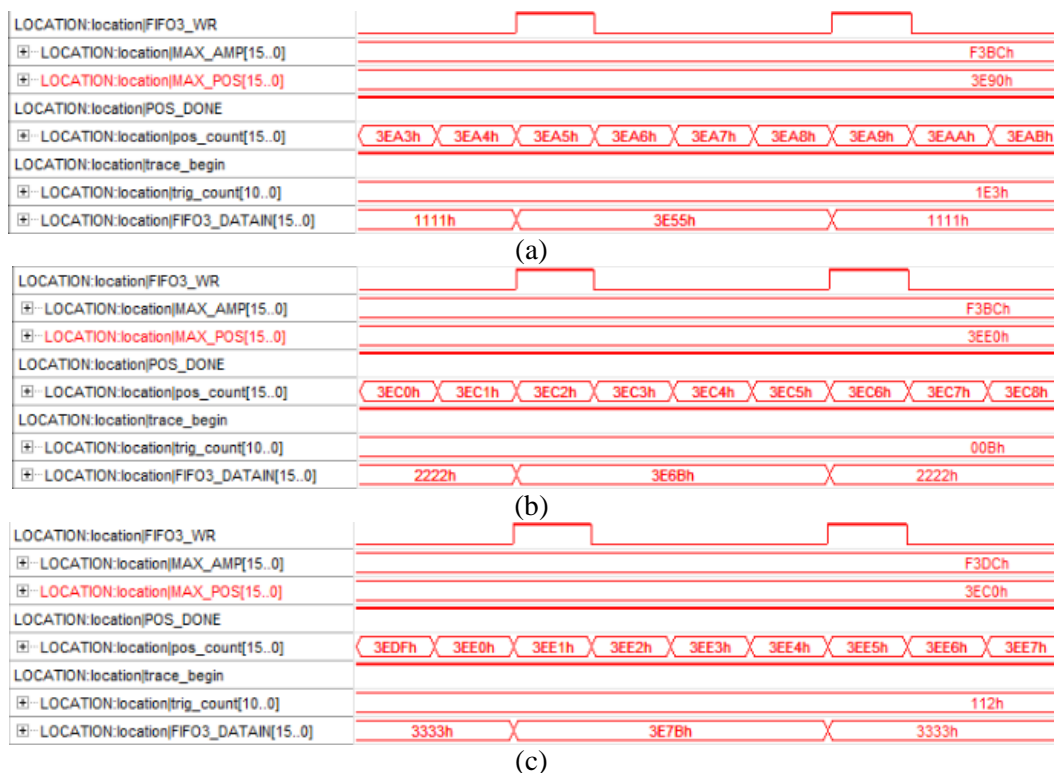
$$H = i \times h. \quad (2.2)$$

$H$  is the minimum pulse width.

## 2.2. Test with the method

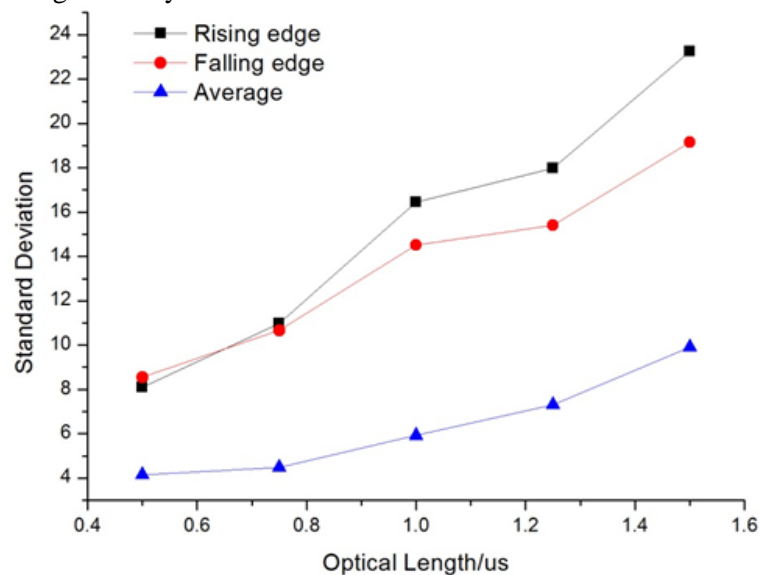
Based on the analysis, the synchronization signal generation, the pulse counter, the SLD parameter control, the vibration feature extraction and the encoded data framing module are implemented in the FPGA. And the decoding and signal processing module are implemented in the software. For the FPGA part, we take Altera Cyclone V series chips which have 6860Kb memory resource, PCIe IP core and sufficient user I/O interface[6]. It can satisfy the entire design requirement.

In the test, we take 0.5 us, 0.75 us, 1 us, 1.25 us, 1.5 us optical pulse width and continuously vibrate at the same point. The rising edge position, falling edge position and peak position of the original vibration peak can be observed by using SignalTap II in Quartus II.



**Figure 4.**Effective data coding diagram for different pulse widths: (a) 0.5us (b)1us (c)1.5us

In the meantime, 1000 sets of data are collected for each pulse width from software part. The standard deviation of the data corresponding to different pulse widths is calculated as a standard for measuring the positioning accuracy.



**Figure 5.** Positioning standard deviation with different optical pulse width

### 3. Conclusion

Based on the analysis and test result, the multi-pulse width used in this method integrates the pulse widths of 0.5us, 1us, and 1.5us, and integrates the peak positioning data of different pulse widths by a weighted voting algorithm. It can improve the performance of DFVSS and better serve the smart power plant monitoring system.

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