Research on pressure wave transmission coding and implementation of testing and adjusting system for layered water injection in oilfield

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Abstract: Based on the communication of pressure wave in layered water injection pipeline, considering energy consumption and time consumption, the binary coding method and time coding method are analyzed and counted. A new improved time coding method which can reduce energy consumption by more than 50% is proposed. It improves the universality of the product and designs, and implemented in a distributed storage measurement and adjustment system.

1. Introduction

As a production control system, water injection testing and adjusting is usually composed of oil field monitoring center (decision-making), the main station of wellhead water distribution control (communication conversion and information temporary storage) and several downhole water distributor sub-stations (detection and execution agencies). As monitoring center and the main station of wellhead water distribution control are located on the ground, the transmission medium is atmosphere, there are many kinds of digital communication modes to choose. While the sub-station of downhole water distribution device is in the formation water injection pipeline which is full of water medium, the available communication modes are limited.

Using mud pressure continuous wave to transmit downhole data is an important technical means to obtain downhole information while drilling (MWD). It is considered as a good application prospect in the wireless transmission of sound wave, electromagnetic wave and mud pulse. In view of the propagation of pressure wave in water injection pipeline, Professor Zhang Guozhong's research "Transient Flow Analysis of Pipeline" provides the theoretical formula [1]. Professor Liu Xiushan has found the relationship between the transmission medium and the transmission speed of pressure wave signal [2][3]. Moreover, the test results of "research on communication between pressure wave and oilfield layered water injection measurement system" [4] have given theoretical verification.

At present, the wireless testing and adjusting of water based on pressure wave in pipeline is still in the initial trial stage. Pressure wave (or flow wave) is used for wireless transmission of layered water injection. The main problem is that the power of downhole pressure wave signal generator is too small,
the time consuming for data upload is too long, and the practicability of the system is poor. In this paper, the key technologies such as reducing energy consumption and improving the coding efficiency of pressure wave are studied and deduced, and a distributed layered water injection testing and adjusting system is designed.

2. Pressure wave coding
There are many wireless transmission coding methods of layered water injection pressure wave, each of them has its own characteristics. In general, they can be classified as binary method and time method.

- **Binary method**: Binary method transmits data serially at a certain frequency. It is usually suitable for situations where transmission conditions are stable and signal fluctuations are easy to control. Its main advantage is that the data coverage is wide (taking 8 bits of byte as an example, the data coverage range is 0-255, and the 10 bits data coverage range is 0-1023), which conforms to the chip processing habits.

- **Standard time method**: Set up a basic time unit T, and transmit data as multiple of the basic time unit T. Take the decimal number "46" as an example (Figure 1). The value of the data is described by the multiple of the basic time unit (the length of the time period) when the signal changes [5].

![Figure 1. Standard time coding principle (decimal number "46" as an example)](image1)

This method introduces a two-dimensional time axis, which can greatly reduce the difficulty of signal recognition when there are many disturbances, large fluctuations in amplitude, unclear rules or difficult to identify and control. The disadvantage is that it takes a lot of time (10T per decimal digit), which is not conducive to the speed-up of signal transmission.

![Figure 2. Improved time coding principle (decimal number "46" as an example)](image2)

After investigating and comparing the above methods, in order to reduce energy loss and transmission time, we proposed an improvement of the time method in this paper (Figure 2). It still takes decimal number "46" as an example, the new method reduces the change action of data value signal to one time and changes the fixed time period to variable length.
The improved time method has two-dimensional design of variable time and pressure (flow) wave. The starting and ending bits are not counted (Decimal Number "46" as an example), the required time is 4T+6T+2T=12T, and the required action is just 2 times. Compared with the standard time method, it saves communication time (20-12)/20 =40% and reduces energy loss by 50% in action.

3. Discussions based on action energy loss

Normally, decimal 3-bit data (0-999) can meet the requirements of data transmission, and binary representation needs 10 bits. The energy loss of data transmission depends on the action.

In binary transmission (word length 10 bits), there are 1000 numbers in 0-999, 11 numbers in 10 actions (155H, 255H, 295H, 2A5H, 2A9H, 2AH, 2ABH, 2ADH, 2B5H, 2D5H, 355H), 50 numbers in 2 actions, and other statistical results in turn are shown in figure 3.

![Figure 3. Relation between the number of binary numbers and the number of actions](image)

As far as signal action is concerned, 1000 numbers (0--999) are counted:

- Binary method: There are 1 data in 0 actions, 50 data in 2 actions, 316 data in 4 actions, 457 data in 6 actions, 165 data in 8 actions and 11 data in 10 actions.
- Standard time method (Word length 30T): Six actions are required.
- Improved time method (Word length 3-30T): Three actions are required.

The comparison results are shown in table 1.

| Percentage of data | Binary method | Standard time method | Improved time method |
|--------------------|---------------|----------------------|----------------------|
| 11/1000=1.1%       | Maximum 10 times |                     |                      |
| 633/1000=63.3%     | Six or more times | Six times           | Three times          |
| 949/1000=94.9%     | Three or more times |                   |                      |
| 51/1000=5.1%       | Less than three times |                |                      |

Because the number of action of pressure wave generator is proportional to energy loss, the less the action number, the less the energy loss. Table 1 shows that 63.3% of the data energy loss of binary method exceeds that of standard time method, while the energy loss of improved time method is 50% lower than that of standard time method, and the energy loss is greatly reduced.

4. Discussions based on the time-use (both using the same time bit T)

Similarly, 3-bit decimal data (0-999) are transmitted:
- Binary method: 10 bits, fixed to 10T, data representation range is 0-1023, of which 1000-1023 are unique to binary method.
- Standard time method: 10T per decimal number, 3-bit decimal number takes 30T, and the range of data expression is 0-999.
- Improved time method: because of the variable length of each decimal number, 3-bit decimal number takes 3-30T, and the range of data expression is 0-999.

The time-use of improved time method can be calculated by 100-bit+10-bit+digit-bit+3T. Compared to standard time method, the new proposed one can save 90% timing at most \((\frac{30-3}{30}=90\%)\) which is much better in performance.

Based on the improved time method, 84 species (000, 001, 002, 003, 004, 005, 006, 010, 011, 012, 013, 014, 015, 020, 021, 022, 023, 024, 030, 031, 032, 033, 040, 041, 042, 050, 051, 060, 100, 101, 102, 103, 104, 105, 110, 111, 112, 113, 114, 120, 121, 122, 123, 130, 131, 132, 140, 141, 142, 200, 201, 202, 203, 204, 210, 211, 212, 213, 220, 221, 222, 230, 231, 240, 300, 301, 302, 303, 310, 311, 312, 320, 321, 330, 400, 401, 402, 410, 411, 420, 500, 501, 510, 600) are less than 10T and 36 species are equal to 10T.

According to these statistics, the relationship between 0-999 and corresponding new time method-using T is shown in figure 4. The comparative analysis results are shown in table 2.

![Figure 4. 0-999 and corresponding new time method -using T relation](image)

Analysis of table 2 shows that 88% of the data time used by the improved time method is greater than 10T of the binary method, 78% of the data of the improved time method are less than or equal to 20T. 22% of the data (220 data) consume more time than 20T.

| Grouping conditions | Binary method | Improved time method |
|---------------------|---------------|----------------------|
| Over 20T            |               | 220/1000=22%         |
| Less than or equal to 20T | 10T,100%    | 780/1000=78%         |
| More than 10T       |               | 880/1000=88%         |
| Less than or equal to 10T |         | 120/1000=12%        |

In summary, compared to binary method, although the new proposed improved time method covers 78% of the 0-999 data consuming the double time (20T), it reduces the energy loss of 94.9% of the data. For 63.3% of the data, the energy loss saving is higher than 50%.

Considering all factors, the energy is the most important item for under-well equipment. In the reasonable timing scope, the new improved time method can reduce the energy loss (number of transfer action), which has great advantages on energy saving and improve the efficiency of the data coding and transmission.
5. System implementation
Based on the above research, the new distributed storage testing and adjusting system is shown in figure 5.

The pressure wave mode is used for communication in pipeline. Because the pressure wave generator acts slowly, the proposed improved time coding method has great advantages. At the same time, the life of equipment is increased by more than 50% due to the reduction of energy loss.

The distributed system on the ground relies on the cloud platform of China Mobile OneNet Internet of things. Wellhead equipment had cooperated with it through EDP protocol. With the advantage of Cloud Platform, data storage and equipment management and front-end man-machine interface are realized. Managers can send instructions conveniently through the front-end interface, and monitor graphical water injection data at the same time. Figure 6 shows some interfaces for the development of centralized measurement and control system.

The man-machine interface shows a layer of control panel for water injection. In this paper, two curves are used to show the flow and pressure information respectively. The curves can display the latest data in real time, and the values of data points are also marked beside the corresponding numerical points, which is intuitive and visual. The two dashboards show real-time pressure information. Then there are four knobs to control the flow and pressure values. Turning the knob with the mouse, you can choose the values to issue orders. The operation is very convenient and fashionable.

6. Conclusion
In view of the pressure wave communication in wellbore, this paper analyzes two kinds of coding
methods commonly used at present at first, then proposes a new improved time method to reduce energy loss, and points out their respective application situations. For the ground wireless communication, this study implements the application of distributed testing and adjusting system with the help of china mobile onenet internet of things cloud platform.

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