WEP Warwick Evans Publishing

International Journal of Natural Resources and Environmental Studies

ISSN: 3006-2012 (Print), ISSN: 3006-0834 (Online) | Volume 4, Number 1, Year 2024

DOI: https://doi.org/10.62051/ijnres.v4n1.04

Journal homepage: https://wepub.org/index.php/IJNRES/index

Research on Online Monitoring System for Oil Formation Parameters

Wu Fan, Qizhi Zhang*, Winhao Qin

School of electronic Engineering, Xi'an Shiyou University, Xi'an City, Shaanxi Province, 71006, China

*Corresponding Author: zhangqz@xsyu.cn

ABSTRACT

China is in the stage of rising water content in crude oil reservoirs, and the water content, temperature and pressure of the oil layer will have a significant impact on the efficiency of crude oil extraction. After adopting the layered injection technology, the contradiction between layers has been improved to a certain extent, but there are differences in the permeability of each oil layer, and the water injected into the oil layer with better permeability is single-layer surging, which leads to the increase of water content of the extracted fluid. Aiming at this problem, this study is devoted to designing a set of digital oil reservoir monitoring device, which can detect and analyze the water content, temperature and pressure parameters of each reservoir in real time, and then carry out systematic exploitation for different oil reservoir states. Through model simulation, hardware design, software development, and sensor production and improvement, a complete downhole oil formation structure model is built to simulate the real oil extraction process. The device utilizes electromagnetic conductivity method to design and produce a highly reliable water content sensor, combined with temperature and pressure sensors and filtering algorithms for parameter compensation, the measured data are collected and processed by microcontroller, and the interaction between microcontroller and host computer software is established by serial communication. PC adopts VOFA+ host computer to build a complete set of simulated oil extraction system with hand-automated integrated control and display interface.

KEYWORDS

Layered Oil Recovery, Moisture Content Sensors, One-Chip Computer, Signal Filtering.

1. INTRODUCTION

Technological advances in the petroleum industry have driven up oil and gas output rates. In order to maintain stable and high production, it is necessary to accurately grasp the downhole production situation, especially in the high water content stage. Accurately determining the location of oil and water layers and obtaining real-world data downhole are crucial to the macro grasp of oilfield distribution, reservoir dynamics and changes, which helps to improve extraction efficiency and production safety. The complexity of the downhole environment leads to large data errors, making it difficult to accurately analyze the reservoir location and reserves. In order to realize the dynamic monitoring and precise extraction of oil wells, it is necessary to improve the real-time collection of oil layer parameters, the selection of oil extraction schemes and the design of monitoring terminals. The layered oil recovery device designed in this work aims to accurately obtain oil layer parameters through non-contact online collection technology, determine the optimal oil layer using water content sensor to improve oil recovery efficiency, and combine with terminal monitoring technology to realize real-time monitoring of the oil layer.

In 2003, Alberta University of Canada proposed the application of nonlinear optimization algorithm in reservoir layered production, and in 2005, Stasolberg University of Norway proposed the layered oil recovery technology based on optimization control, and in 2006, China University of Petroleum (East China) proposed the intelligent management system of layered oil recovery for IOT wells, and in 2009, China Petrochemical Daqing Oilfield proposed the intelligent management system of layered oil recovery for IOT wells, and in 2009, China Petrochemical Daqing Oilfield proposed the intelligent management system of layered oil recovery for IOT wells. In 2009, SINOPEC Daqing Oilfield implemented fiber optic temperature measurement stratified oil recovery method. 2017, SINOPEC Shengli Oilfield implemented static-dynamic integrated stratified development technology. In 2022, the Norwegian Institute of Technology Trondheim and China University of Petroleum (Beijing) developed microbial enhanced recovery technology and integrated technology research, respectively.

2. TOTAL SOLUTION DESIGN

The stratified oil recovery system for oil formation parameter monitoring is mainly divided into three modules, namely, parameter acquisition module, stratified oil recovery module and monitoring system module. The parameter acquisition module mainly utilizes suitable sensors to measure and collect various parameters of the oil formation, the stratified oil extraction module simulates stratified extraction according to the actual stratum extraction device, and the monitoring system, as the realization of the final human-computer interaction interface, carries out the dynamic observation of the downhole situation with the help of the upper computer, and the schematic diagram of the specific monitoring system is shown in Figure 2.1.

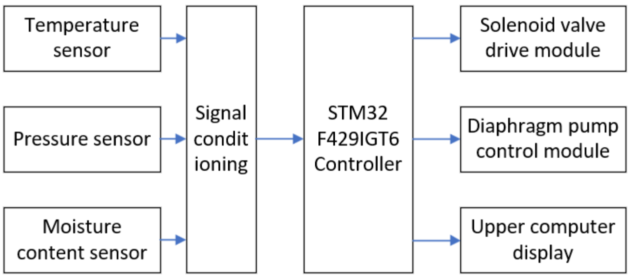

Figure 2. 1. Layered oil recovery online monitoring system schematic diagram

3. ONLINE MONITORING SYSTEM HARDWARE DESIGN

3.1. Main control module design

STM32F429 is used as the core of the downhole intelligent measurement and control tool, and the minimum system and power supply circuit of the microcontroller are designed, followed by the design of the main control hardware circuit of the stratified oil recovery system, including the temperature and pressure sensor circuits, the display circuit, the solenoid valve driving circuit, the diaphragm pump control circuit, and the signal amplification circuit of the water content module, and finally, the signal conditioning circuit of it is designed and Improvement. The parameter acquisition part is the data support foundation in stratified oil recovery, and the drive control module composed of solenoid valve and diaphragm pump is the power center of the oil recovery device.STM32F429IGT6 is a high-performance microcontroller for embedded systems, which is based on the ARM Cortex-M4 core with excellent processing performance and low-power consumption, and has a main frequency of 240MHz, a 2MB Flash memory and 256KB of It has 240MHz main frequency, 2MB Flash memory and 256KB SRAM, and also has rich peripherals which are easy to use, including USB OTG, CAN bus, SDIO, SPI, I2C, USART, ADC, DAC and other interfaces, which can satisfy the needs of different applications.

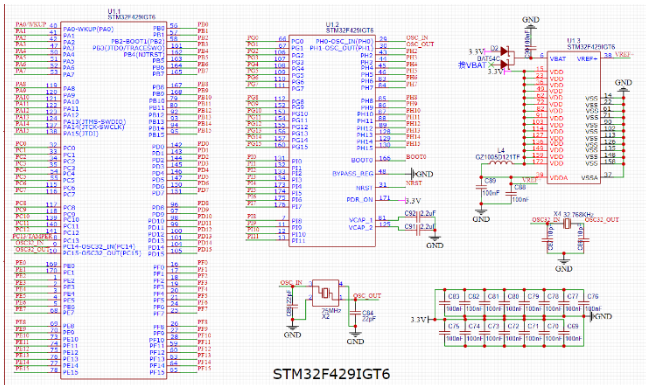

Figure 3.1. Main Control Chip Control Circuit Schematic Diagram

3.2. Temperature Data Acquisition

Select Pt100 platinum resistance as the temperature measurement element, its own high precision, reliable performance, vibration resistance, high pressure resistance characteristics to meet the temperature measurement requirements of the permanent device design. Measuring the resistance value of the PT100 sensor, the PT100 sensor can be formed into a bridge circuit and connected to the non-feedback input of the LM358 chip. In this bridge circuit, the PT100 sensor is connected to two resistors, which are called the compensation resistor and the adjustable resistor. The Wheatstone bridge differential measurement method used in the design is able to have a high response sensitivity to the small changes generated on the resistors. The circuit principle is shown in Figure 3.2.

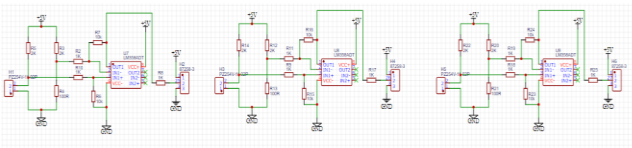

Figure 3.2. Temperature Circuit Schematic

3.3. Pressure Data Acquisition

Oil reservoir pressure measurement is the main parameter to characterize the oil field geological oil reserves and oil reservoir pressure. The instrument for pressure measurement can withstand the harsh environment of high temperature and high pressure, and the system can work stably and reliably for a long time, so as to obtain reliable data, and the measured pressure must meet the accuracy requirements. The block diagram of pressure acquisition is shown in Fig. 3.3.

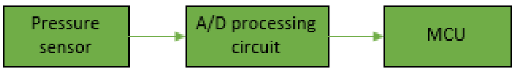

Figure 3.3. Pressure Data Acquisition Block Diagram

3.4. Moisture content sensor module

The conductivity of crude oil , dielectric constant of about 3, the conductivity of water , dielectric constant of about 90, oil and water between the conductivity and dielectric constant difference is large, so you can measure the different content of oil and water mixtures through the electromagnetic method, in the transmitting coil generates sinusoidal alternating the magnetic field, the magnetic field through the wall of the metal tube, in the tube with the role of the oil-water mixture, because oil-water mixtures with electrical conductivity, the alternating magnetic field will be able to make the It produces a certain intensity of eddy currents, which in turn produces a new alternating electromagnetic field, the secondary electromotive force is generated, the measuring coil to measure the oil-water mixture related to the secondary electromotive force can be indirectly get the water content in the mixture, while the temperature and pressure values can be compensated through the algorithm to transmit the water content sensor signal to achieve accurate measurement of the water content of the crude oil, the structure of the sensor is shown in Figure 3.4.

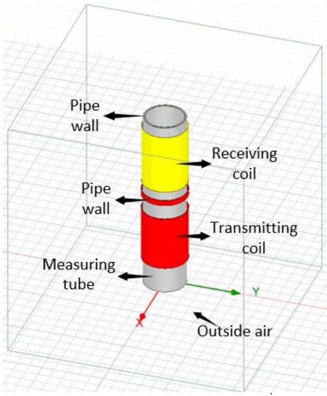

Figure 3.4. Sensor structure diagram

4. ONLINE MONITORING SYSTEM SOFTWARE DESIGN

4.1. Main program monitoring logic program

System software part of the main program design microcontroller internal overall logic execution. The system first initializes the program, automatic mode solenoid valve and pumping pump in turn with the start of the oil reservoir temperature, oil reservoir pressure parameters collected and stored, and then sequentially detect the water content of each layer, to determine the final suitability of the oil reservoir extraction location, and finally waiting to complete the oil extraction process. The logic of the monitoring main program is shown in Figure 4.1.

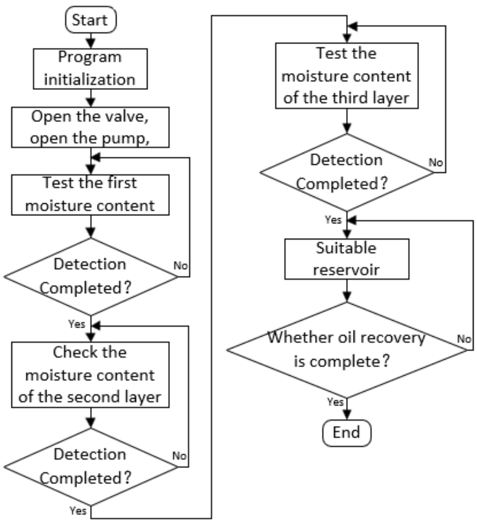

Figure 4.1. Main program flow chart

4.2. Water content sensor signal processing program

Sine wave signal transmitter part of the STM32103 microcontroller with its own DAC, the microcontroller contains two DAC converters, each converter corresponds to an output channel, can be set to 8-bit or 12-bit monotonic output, and each channel with DMA function. In this design, the 12-bit DAC1 is used to generate the sine wave signal, and the MATLAB software is used to program and simulate the sine wave data table with 512 samples per cycle, and at the same time, the timer trigger mode is enabled, which is used to accurately control the frequency of the sine wave, and the frequency and peak of the sine wave can be adjusted by changing the value of the sine wave table and the frequency of the timer, and at last, the DMA mode in STM32 is used to improve the signal transmission rate without occupying the time of the DMA function. Finally, the DMA method in STM32 is utilized to improve the signal transmission rate without occupying too much CPU resources. The processing flow of the sine wave signal generator is shown in Figure 4.2.

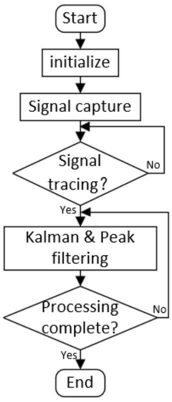

Figure 4.2. Flowchart of water content sensor signal processing

4.3. VOFA+ upper computer software design

VOFA+, an AI-based virtualization software, is mainly used for the development, testing and verification of embedded systems and cloud platforms. The software is able to simulate real hardware environments, including various sensors, actuators, and communication modules, etc., to help developers quickly build prototypes, debug code, and perform system performance testing. In addition, it provides rich simulation and testing functions, including code coverage analysis, code static checking, simulation testing, automation testing, etc. It helps users to quickly locate problems, improve software quality and shorten the development cycle, realize online monitoring and control of oil layer parameters, and complete the final realization of the goal of human-computer interaction interface. Its monitoring interface is shown in Figure 4.3.

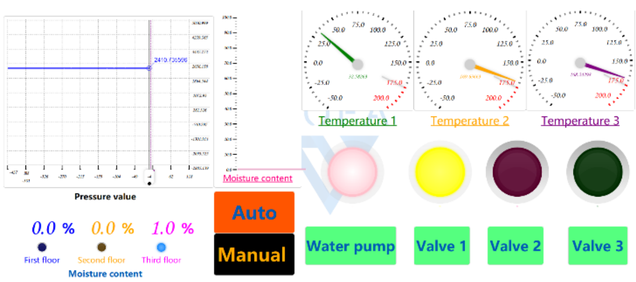

Figure 4.3. VOFA+ monitoring interface diagram

The monitoring interface can realize dynamic monitoring of water content, temperature and pressure parameters of each layer, as well as automatic and manual control and observation of the status of the drive module in the oil recovery process, which simplifies the operation process, is easy to manipulate in real time, and improves the efficiency and safety of the operation.

5. ONLINE MONITORING SYSTEM ANALYSIS AND TESTING

5.1. Moisture content subsystem testing

The foundation of the metal pipe is set as follows: the inner diameter of the pipe is 32mm, the outer diameter of the pipe is 36mm, the wall thickness is 2mm, the relative permeability μ_r of the pipe is 6000, the relative permeability inside and outside of the pipe is 1.1, the resistivity of the oil-water mixture is 0.001-0.1, and the resistivity of the air is about the resistivity of the vacuum . Transmitter coil 100 turns, material 0.9mm purple copper enameled wire, can load 5.4A current. Shield coil 10 turns, diameter 0.9mm, and the transmitting coil in series, receiving coil 500 turns, for 0.2mm copper enameled wire, receiving and shielding coil spacing 100mm, shielding and receiving coil spacing 10mm due to the thickness of the insulating varnish is only 0.06mm, the relative permeability of the copper wire is 1, so the insulating varnish effect can be ignored.

After software simulation and experimental demonstration, it is found that the water content sensor system transmitting coil sine wave excitation frequency 240HZ, excitation current constant current 4A, 100 turns of transmitting coil, 10 turns of shielding coil, 500 turns of receiving coil, the distance between transmitting coil and shielding coil is 100mm, the distance between shielding coil and receiving coil is 10mm when the maximum amount of useful signal. The test data is shown in Table 5.1.

Table 5.1. Water Content Voltage Test Data Sheet

Voltage Water Content	**Theoretical voltage value (V)**	**Measured voltage value (V)**	**Relative error (%)**
0	1.6990	1.6973	17
10	1.6992	1.6987	5
20	1.6994	1.6999	5
30	1.7001	1.7012	11
Voltage Water Content	Theoretical voltage value (V)	Measured voltage value (V)	Relative error (%)
40	1.7012	1.7019	7
50	1.7023	1.7026	3
60	1.7038	1.7047	9
70	1.7055	1.7052	3
80	1.7059	1.7069	10
90	1.7061	1.7062	1
100	1.7062	1.7062	1

The amplified useful signal in the table is 1.7062-1.6990=7.2mv, and the relative error rate is calculated from this. The fitted curve corresponding to the theoretical test value is shown in Figure 5.1.

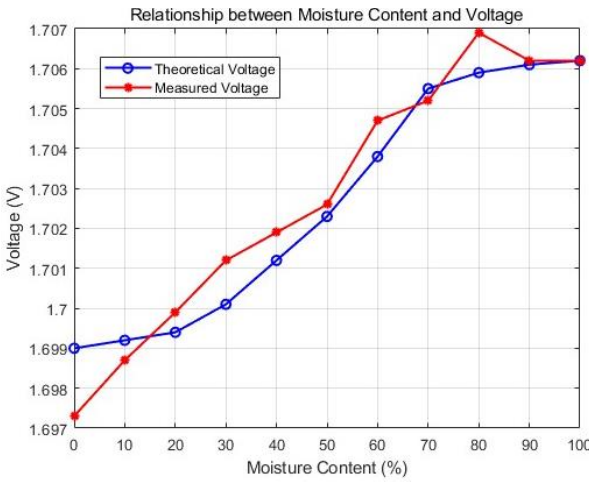

Figure 5.1. Moisture Content-Theoretical Voltage Fitting Curve

5.2. Temperature Sensor Subsystem Testing

The temperature-pressure relation is fitted according to the pt100 temperature-pressure relation, and the temperature-voltage relation is given by:

$$y=51.2x-0.0. \tag{1}$$

where y is the temperature (℃) and x is the voltage (v). The temperature experimental test data are shown in Table 5.2.

Table 5.2. Temperature and Voltage Test Data Sheet

Voltage / temp	**Theoretical voltage value (V)**	**Voltage value (V)**	**Relative error (%)**
0°	0	0	0
20°	0.394	0.399	0.76
40°	0.781	0.780	0.13
60°	1.173	1.173	0.00
80°	1.562	1.565	0.19
100°	1.951	1.952	0.05

Through the comparison and analysis of the table, it can be seen that the actual temperature value of this test and the theoretical value of the existence of the error within the range of 0 to 0.76%, the relative error is relatively small, the measurement is more accurate, high precision, in line with the applicable standards for the measurement of stratigraphic temperature.

5.3. Pressure sensor subsystem testing

A common approach to the pressure output value of Keyes thin-film pressure sensors is to use linear fitting, i.e., to establish a linear relationship between the measured piezoresistor value R2 and the measured pressure P, as follows:

$$P=a*R2+b. \tag{2}$$

where ab is the fitting coefficient, which can be obtained by experimental measurements and fitting techniques according to the actual performance of the pressure sensor and the usage scenario. To calculate the actual pressure value, the piezoresistor value R2 is first calculated using the previously mentioned partial pressure equation:

$$R2=(1023-A0)*510/A0. \tag{3}$$

where A0 is the 12-bit AD sampled voltage value, and then the resulting R2 value is substituted into the pressure calculation formula:

$$P=-20*R2+4220. \tag{4}$$

Calculations can be made to obtain the actual pressure value P. Experimentally measured pressure resistance values and theoretical values are shown in Table 5.3.

Table 5.3. Pressure Resistance Test Data Sheet

Resistive Stresses	Theoretical resistance value (Ω)	Measured resistance value (Ω)	Relative error (%)
300g	80.05	80.23	0.22
1000g	18.51	18.59	0.43
2000g	12.13	12.04	0.74
3000g	9.25	9.11	1.51
4000g	8.44	8.51	0.83
5000g	7.49	7.45	0.53
6000g	6.09	6.12	0.49

By comparing and analyzing the table, it can be seen that the actual pressure value of this test and the theoretical value have an error within the range of 0 to 1.51%, the relative error is small, the measurement is more accurate, the accuracy is high, and it is in line with the applicable standards for the measurement of stratum temperature.

6. CONCLUSION

This design proposes a set of downhole real-time on-line monitoring oil recovery simulation device, through the electromagnetic conductivity method based on the water content sensor, layered oil recovery control and human-computer interaction interface, but also be able to automatically and manually control and observe the state of the drive module in the process of oil recovery, to simplify the operation process, to realize the real-time monitoring of the production parameters of the formation, to help the field site to make accurate decision on the layered oil recovery, and to enhance the recovery efficiency. efficiency.

REFERENCES

[1] Jialiang Qian. Research on intelligent stratified test mining system [D]. Xi'an Petroleum University, 2017.

[2] Chen Xin. Application of embedded data acquisition system in oil and gas wells [D]. Northeast Petroleum University, 2016.

[3] Zhang Fan. Design and research of oil wellhead pressure and flow rate data acquisition system [D]. Northern Nationalities University, 2013.

[4] Huang Junchao. Non-contact electrical impedance detection and its application in the measurement of gas-liquid two-phase flow parameters [D]. Zhejiang University, 2020.

[5] Shi Yuhui. Experimental study of electromagnetic method for measuring the flow rate of high water-containing oil-water two-phase flow[J]. Experimental study of electromagnetic method for flow measurement of high water content oil-water two-phase flow[J]. 2011, 35(03): 206-209.

[6] XIA Minghua, ZHANG Jiangwei. Research progress and development trend of crude oil water content determination methods[J]. Chemical Management, 2014,(26): 161.

[7] Zeng H. Research on all-electric downhole formation fluid intelligent control device[D]. Xi'an Petroleum University, 2015.

[8] Sui Microwave, Zhang Shicheng. New progress on field application and theoretical modeling of downhole real-time temperature monitoring[J]. Logging Technology, 2011, 35(06):502-507.

[9] HE Daoqing, ZHANG He, CHEN Haiyun. Sensors and sensor technology[M]. Beijing:Science Press, 2014: 65-69.

[10] QU Yuan. Research on the measurement of water content of crude oil by electromagnetic conductivity method[D]. Shenyang University of Technology, 2013.

[11] Li Pengfei. Research on downhole flow control system for intelligent wells [D]. China University of Petroleum (East China), 2017.

[12] Gao Feiming,Xiao Guohua,Wang Jinzhong et al. Research and application of oil well layering test technology[J]. Petroleum Machinery, 2020, 48(07): 111-116.

[13] ZHAO Bufan,DI Weina,LI Jing. Fracturing fluid technology tracking and patent analysis[J]. Contemporary Chemical Industry, 2019, 48(02): 326-329.

[14] Hao Guangwei,Shao Yang,Lan Tianqing et al. Progress in the application of smart wells in oil and gas field development[J]. Contemporary Chemical Industry, 2019,48(08): 1759-1762.

[15] LAN Yu,BAI Jie. Design of temperature measurement system based on Pt100 sensor[J]. Mechanical and Electronic. 2013(10): 44-46.

[16] TIAN Ji. Research on gas-liquid two-phase flow measurement by long-throat venturi and near-infrared spectroscopy[D]. Hebei University. 2018.

[17] LI Qi-gui,DU Xuelin. Measurement of oil-water two-phase flow rate by differential pressure method[J]. Journal of Petrochemical Higher Education. 2015(02):1-28

[18] Chen D. Research on crude oil water content measurement based on BP neural network[D]. Shenyang University of Technology,2016.

[19] Zhai Yuanyi. Research on ultrasonic flow-pressure measurement method for hydraulic small pipe diameter [D]. Xihua University. 2016.

[20] HAN Hongjun. Research on the testing technology of complex dielectric constant of water-bearing crude oil [D]. Xi'an Petroleum University,2019.

[21] He GQ. Research on measurement technology of crude oil water content [D]. Xi'an Petroleum University,2017.

[22] Du Shengjie. Research on crude oil water content measurement system and temperature effect of high frequency electromagnetic method[D]. Xi'an Petroleum University,2020.

[23] Chang Li ,Zhang Biao. Treatment of primary induced electric potential of crude oil water content measurement by electromagnetic conductivity method[J]. Journal of Shenyang University of Technology,2017,39(05):518-523.

[24] Huang Junchao. Non-contact electrical impedance detection and its application in the measurement of gas-liquid two-phase flow parameters [D]. Zhejiang University, 2020.

[25] Xiang Hengfu, Sun Baojiang. Exploration of intelligent completion technology standard[J]. Drilling Process, 2017, 40(02): 52-55.