Design of high frequency AC/DC potential collector for buried steel pipeline based on DSP

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Abstract

To reduce the AC/DC interference during measuring cathodic protection of buried steel pipeline, an new-type buried steel pipeline AC/DC high frequency data collection system was developed. Embedded technology and the design of high-precision data acquisition method are adoped in this module, to realize multi-channel and synchronous data acquisition. The DSP chip of ARM series was used as the main control chip, generating the hardware and software design. The test result showed that the system was accurate and stable. The system can be not only used to the continuous collection of the pipe-to-soil potential, but also the identifying test of pipeline cut-off potential.

Keywords

Buried steel pipeline; Cathodic protection; AC/DC potential collector; Embedded system.

1. Introduction

The total mileage of oil and gas pipelines in the world has exceeded 230 * 10^4km. In order to prevent corrosion of the outer wall of pipelines, the anti-corrosion layer and the cathodic protection are used to protect facilities as the discharge protection are set according to the influence of the AC and DC interference on the pipeline[1-4]. During the process, it is necessary to measure and record the cathodic protection potential of pipeline to analyze and judge the effectiveness of cathodic protection.[5].In the measurement of pipeline cathodic protection potential, the accuracy of results is influenced by the AC and DC interference in the pipeline and the impulse voltage at the moment of the interruption of the constant potential instrument[6-10]. The effective potential of the cathodic protection of the pipe can be obtained at the right time [11-15].In this paper, the embedded system technology and high precision data acquisition design method are used to develop a new type of high frequency data acquisition system for alternating current and direct potential of buried steel pipe through multi-channel high speed data acquisition.

2. Pipeline cathodic protection and potential testing principle

Cathodic protection theory was introduced in 1938.The theory of cathodic protection: by applying a cathodic protection current to the protected object, the cathodic position of the pipe is negatively polarized to the anode position, there is no difference between different positions, and the reaction of corrosion battery is also it stops, as shown in Fig.1[8]. There are mainly two cathodic protection methods for buried steel pipelines: impressed current method and sacrificial anode method as shown in Fig.2.

Testing and evaluating the effectiveness of pipeline cathodic protection, one of the important indicators in the standard of GB/T 21447 is usually carried out: the measured pipeline / electrolyte potential reaches -850mV or more negative (relative saturated copper sulfate reference electrode). When the potential is measured, the effect of *IR drop* should be considered. The test data are mainly obtained by two methods: the electrical potential measurement and the polarization probe method. The cathodic protection potential data of electrical potential measurement was shown in Fig.3.

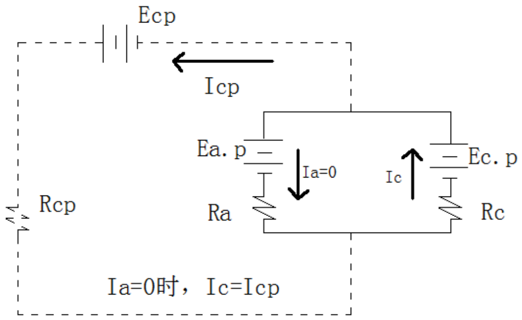


Fig.1 Basic principle diagram of cathodic protection

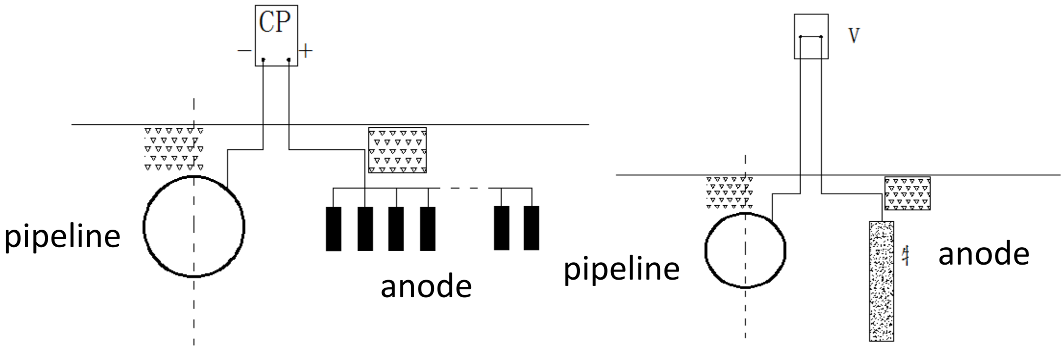


Fig.2 Schematic diagram of the principle of forced current cathodic protection

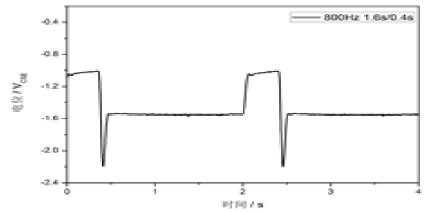


Fig.3 Schematic diagram of pass and break potential record for high frequency sampling pipeline

3. Hardware design of high frequency data collector

Based on embedded ARM system, the hardware design frame of the buried steel pipeline potential high frequency data acquisition system is illustrated as shown in Fig.4. Voltage input signal channel selection module uses four-choice multi-channel selection switch to select the appropriate range of the input voltage signal. The pre amplifier module enlarges the selected signal to the appropriate amplitude, and then filters through the conditioning circuit to enhance the anti-interference ability of the signal[13].

The CPU part uses the DSP series STM32F407 chip. The chip can control the timing logic of the whole voltage measurement system, and filter, calculate, process, store and send the converted data sent by the former A/D conversion to display the output module. The main function of this part is to control the normal work of all the chips of the system, carry out the corresponding data processing operations, and send the results to the display to display the additional instructions of the user at the same time. This part uses external expansion memory to meet the requirements of large data volume.

The human-machine interface module is mainly composed of 4.2 inch TFT-LCD display and button interface circuit. The TFT LCD screen is controlled and displayed by the FSMC function of the STM32F407 chip. It can display the state of the current system in real time as well as the real-time measurement of DC or AC voltage value. The button interface circuit can carry out parameters setting, channel selection, interrupt operation and other special functions.The system also includes power module and temperature alarm module. The potential high frequency data acquisition system of buried steel pipeline is powered by the 3.7V lithium battery module. In order to provide the DSP chip with the working voltage, it needs to depressurization to 3.3V to supply the DSP. Considering the power loss of the system, the LDO series TPS7330 chip with low voltage difference can be used to reduce the voltage to DSP. The main function of the temperature alarm module is to monitor the external ambient temperature of the system, and the temperature of the chip is monitored to ensure the stability and security of the system.

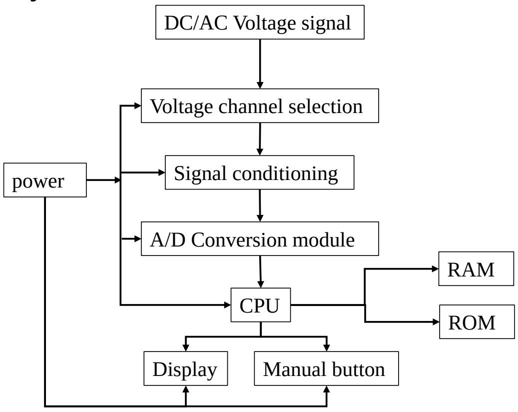


Fig.4 the hardware block diagram of the high frequency data acquisition system for buried steel pipelines

When the system works, the input DC or AC voltage signals are first selected by the channel selection module, and the ARM processor is responsible for selecting the appropriate range. Then the input voltage signal is adjusted and amplified by the front stage operational amplifier, and the input voltage signal is differential input. After the input signal is magnified by the preamplifier, the signal should be amplified and adjusted to stabilize the signal after the adjustment. Then the input analog signal is converted to digital signal through A/D conversion, and digital filtering is carried out. The filtered digital signal is sent into the ARM processing chip for operation to verify whether the appropriate range is selected. If the range exceeds the set value, then the range is selected back to the front stage operational amplifier to repeat the operation until after the conditioning. The signal meets the range and the error meets the requirement of 0.1%. Finally, send it to the 4.2 inch TFT LCD for output. the system can also set parameters, modify the measurement channel, manual range selection or GPS positioning operations.

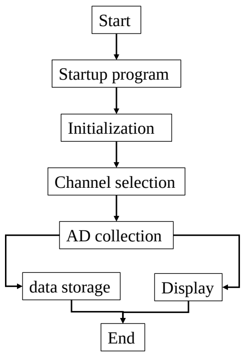


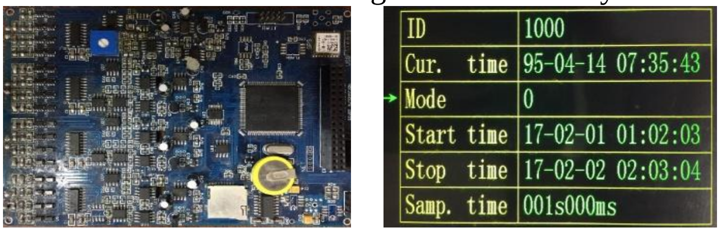
Fig. 5 general design block diagram of system software

4. Software design of high frequency data collector

The overall design is shown in Fig.5. The A/D conversion realizes the conversion of analog signals into digital signals and is read by STM32F407 through SPI bus. The LCD displays the system status and the measured parameters in real time on the TFT-LCD LCD screen. Data storage means using the external expansion memory to store the measured data for use or inspection. The overall operation flow of the software: after the system is on the power, the program starts to start. First initializes the configuration of the I/O port and the related register. Then, select the channel of the maximum range of the MAX309 chip, select the ADS8341 A/D conversion chip to start the A/D conversion; wait A/D After the conversion is completed, the converted digital signal is read by the CPU through the SPI bus. When the data reads are completed, the scale is then transformed into the actual electric parameter to drive the LCD liquid crystal display. And data is stored in external expanded data storage. CPU also completes the control of the power supply module's voltage regulator chip and the temperature monitoring module.

5. System debugging and results

The final measurement system is shown in Fig. 6.After the system initializes the power supply, it will first display some basic information about the voltage measurement system on the display panel.



(a) Design of the system (b) parameter

Fig.6 The system (a) design (b) parameter

ID is equivalent to the name of the voltage measurement system. The ID number can be used to distinguish different devices; the current time is used for real-time display of time; the start time and the end time represent the system. The time to measure and end the measurement is used for the extraction and analysis of the stored data in the future; the sampling time indicates the update frequency of the system data, which can be adjusted according to the actual needs of the industrial site.Input the voltage data of 0.9999V. The result is shown in Fig.10. It can be seen from Fig.7 that the measurement error is 0.0013V, and the error is within the design requirement.

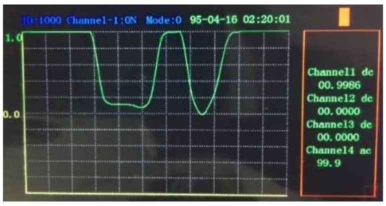
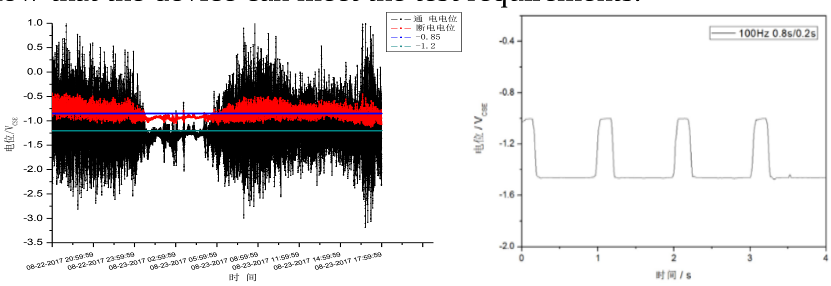


Fig.7 test results schematic

Fig. 11 shows the DC potential test results of the device on a dynamic DC interference pipeline. reflects the influence of the subway near the pipeline on the DC interference of the pipeline.The electrical potential test of buried steel pipeline is selected. Fig. 12 is the pass and break potential recorded by the sampling frequency of 100Hz when the potentiometer 0.8s passes through /0.2s. The electrical potential of the pipeline is about -1.5VCSE, and the power cut potential is about -1.0VCSE. The test results show that the device can meet the test requirements.



(a) (b)

Fig.8 The (a) fluctuation of buried pipelines under subway influence (b) buried pipeline with potential

6. Conclusion

The pipeline AC/DC potential test of buried steel pipelines is of great significance for ensuring the safe and reliable operation of pipelines. Through the design of embedded system, the filter circuit, the data acquisition and processing software, a data recorder with the function of continuous test and record is developed. The designed module can be applied to the continuous test of pipe-to-ground potential, and the characteristics of high-frequency data acquisition can also realize the identification test of pipe-to-ground potential. The test results show that the module test data has relatively low error and the stability in continuous recording, which fully meets the requirements of pipeline potential test.

Acknowledgements

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