Development of Control Terminal of Control System of Light Hydrocarbon Gas Generator Based on NB-IoT

Xu Zhao*, Wenzhi Zhang and Weiwen Tian
School of Mechanical Engineering, Inner Mongolia University of Technology, Huhhot 010051, China
*Corresponding author e-mail: 303270708@qq.com

Abstract. To improve the instability of light hydrocarbon gas supply station, the need for long-term maintenance and guard of staff, and improve the intelligence and automation of gas supply station, a perception terminal of light hydrocarbon gas generation device control system based on NB-IoT is designed. The data of liquid level, temperature, gas supply, and pressure are collected by STC15W4K56S4 low-power single-chip microcomputer. Based on the platform of the Internet of things, the remote transmission of data is completed by the BC95 module and local monitoring center. The experiment shows that the terminal can effectively transmit the collected data, respond to the command of the monitoring center, and complete the two-way communication between the terminal and the monitoring center, which has a high engineering value.

1. Introduction
China is in a new stage of rapid development of industrialization and urbanization, and the situation of resource shortage and environmental pollution is increasingly severe. Light hydrocarbon gas, a new type of environmental protection liquid fuel with high calorific value and clean combustion and emission, has been favored by people [1, 2]. On November 15, 2016, the first light hydrocarbon gas supply station in Tianjin was built for ventilation; Yelusheng, Inc also built nearly 100 gas supply stations in Beijing, Hebei, Shandong, Inner Mongolia, and other provinces.

However, the current control system of light hydrocarbon gas supply station's gas generation device is not highly automated, and it is unable to monitor and control the key factors in the gas generation device in time, resulting in the user's unstable gas supply in the use process, which requires long-term maintenance and watch by the staff [3].

Based on the current development of control system of light hydrocarbon gas generation device, this paper puts forward wireless monitoring control node and network architecture based on NB-IoT for the first time, and designs and develops wireless control terminal for monitoring real-time online data of gas generation device based on wireless communication and embedded technology. The equipment reduces the difficulty of data fusion, increases the number of information collection, improves the network independence of monitoring nodes, can connect various instruments and meters, can realize the unattended gas supply station, and is suitable for large-scale deployment.
2. Terminal architecture design
The structure of the control system of the light hydrocarbon gas generation device is shown in Fig. 1. The analog quantity input required by the control terminal mainly includes the liquid level, pressure, temperature, etc. the switch quantity input mainly includes the system start and stop, gas overpressure, air leakage, and other fault signals. The switch quantity output mainly refers to the start and stop of the corresponding solenoid valve. Each control terminal and connected sensor is a node in the system, and each node transmits data to the monitoring center separately and directly. All nodes and the upper monitoring center constitute the control system of the light hydrocarbon gas generation device.

The control terminal takes the stc15 processor of macrocrystal technology as the core, carries out sensor control, data acquisition, data processing, and interacts data with the NB-IoT communication module. The NB-IoT communication chip integrated in the monitoring terminal can establish a connection with the Internet of things platform of the operator and transmit data remotely. The monitoring terminal integrates a memory chip to store the collected historical data. Each part of the monitoring terminal is powered by a rechargeable lithium battery after being depressurized by the DC-DC power module. The human-computer interface includes LCD, LED light, buzzer, Hall magnetic induction switch, which can indicate the initialization, data transmission and network status of the equipment. The structure diagram of the control terminal is shown in Figure 2.
3. Hardware design of terminal function module

3.1. Processor module
At present, the embedded microprocessors commonly used in the market mainly include 8051 core 8-bit processor, ARM core 32-bit processor, MIPS core 32/64-bit processor, etc., taking into account the application, performance, and work. And cost factors, select the STC15W4K56S4 chip of Hongjing Technology as the core processor of the monitoring terminal. The processor integrates high-precision R/C clock, 8-channel high-speed 10-bit A/D conversion, 4K byte SRAM, 4 Independent high-speed asynchronous serial communication port, 1 set of high-speed synchronous serial communication port, on-chip resources are relatively sufficient to meet the design needs.

In this design, UART1 is used for ISP download, UART2 is assigned to MAX3222EEAP for RS232 serial communication, UART3 is assigned to 83485 for RS485 serial communication, UART4 is connected with NB-IoT communication chip, responsible for data communication; SPI and I2C are Alternate to Flash Chip W25Q32, ferroelectric memory chip MB85RC64 uses data storage; 2-channel ADC converter is used for A/D conversion; in order to display working status, 4 LED lights, LCD, 4 independent buttons for triggering manual command, button Confirmation The buzzer is controlled by universal IO.

3.2. Power module
The monitoring terminal is powered by a 15V lithium battery pack and can output 5V to the outside. The battery needs to power the NB-IoT communication module through a DC-DC buck circuit to power other power devices through a linear buck. Shown in Table 1.

| Module                        | Voltage | Power chip | Technical indicators                          |
|-------------------------------|---------|------------|-----------------------------------------------|
| External power supply         | 5V      | LM7805     | 15V to 5V                                     |
| Communication unit            | 3.1V-4.2V | MP2303     | High current, high conversion efficiency, meeting communication requirements |
| Microcontrollers and other devices | 3.3V    | MAX1615    | Voltage stabilizing                           |
3.3. NB-IoT communication module

At present, the mainstream wireless communication technologies mainly include Wi-Fi, Bluetooth, ZigBee, GSM/GPRS and 2G/3G/4G. However, the first three belong to the short-range wireless communication technology, and the transmission range is limited. Although the latter two belong to the long-distance wireless transmission technology as well as NB-IoT, the uplink capacity of NB-IoT has been improved by 50-100 times, the signal coverage capacity has been greatly enhanced, with extremely low power consumption and low cost. This, NB-IoT is directly deployed in GSM network, UMTS network or LTE network, using a separate 180khz frequency band, to ensure the stability and reliability of data transmission. The success rate of traditional wired PLC meter reading data recovery is about 60%, and NB-IoT can ensure the success rate of data recovery by up to 99% [4-7].

The BC95-B5 used in the monitoring terminal is a high-performance, low-power NB-IoT wireless communication module independently developed based on Huawei Hisilicon Hi2110 chip. The working frequency band is 850MHz, and the telecom IoT card is used. The module mainly includes power supply, antenna, SIM card base, network status indicator light, MCU communication serial port, and the circuit schematic diagram is shown in Figure 3. The UART_TX and UART_RX pins are respectively connected with UART4 pin RXD4 and TXD4 of the STC15W4K56S4 chip.

3.4. Human Computer Interaction Module

To facilitate on-site debugging, the monitoring terminal is integrated with Jinpeng ocmj2x8c-5 Chinese graphic dual-purpose LCD screen with four independent buttons. The button can wake up the monitoring terminal, control the content of the LCD, set some simple parameters, and also has a button prompt buzzer to ensure that the button operation is effective. To ensure the waterproof performance of the monitoring terminal, the button uses a highly sensitive CMOS micro power Hall switch HAL-G248, which internally contains a chopper-stabilized circuit with bipolar sensing technology, which can work normally in the magnetic field South Pole or North Pole. When you use it, you only need to bring the magnet rod close to the chip to trigger the switch. The LCD and HAL-G248 schematic are shown in Figure 4. Among the working model of the LCD is serial communication, and the STC15W4K56S4...
devices communicating with the LCD through the STD pin, and controls the on and off of the LED through the LCD pin to control the on and off of the transistor Q1.

3.5. Analog input module
In this design, the high-speed 10-bit A/D conversion of the STC15W4K56S4 chip is used, and the TL431B is used as the external reference voltage source. Because the external sensor, such as the pressure transmitter, outputs 0-10V voltage, it does not need to amplify the circuit, but only needs the voltage follower for impedance matching. The voltage follower and the TL431B circuit are shown in Figure 5. The ADC1 and TL pins are connected to the chip A/D conversion pin. R20 and C4 can absorb the reflected signal on the third pin of the op-amp LM358D, reducing interference and improving the quality of the input signal.

3.6. Digital input module
To avoid the interference caused by electrical characteristics and harsh working environment, high-speed opt coupler 6N137 is used for input and output isolation. One of the switch input circuits is shown in Figure 6. By adjusting the resistance of the three resistors R70, R77, and R80, the turn-on voltage of 6N137 can be set. To protect the opt coupler and prevent large input voltage abrupt changes, Schottky diode IN5819 is connected in parallel across the current limiting resistor R77.

3.7. Digital output module
The switch output module is mainly used to control the start and stop of the solenoid valve. The solenoid valve is started and stopped by the magnetic force generated by the energization of the coil. When the coil stops, a large self-induction electromotive force will be generated. Therefore, the protection diode D14 is required to provide a path and a protection element. STC15W4K56S4 chip controls the on-off
control switch output of opt coupler IS181B through pin P3.6, and pin D1 and D2 are respectively connected with positive and negative poles of solenoid valve. The specific schematic diagram is shown in Figure 5.

![Figure 6. Digital input circuit](image)

![Figure 7. Digital output circuit](image)

4. Terminal software design

4.1. Overall design of the program

The control program of the control terminal can be divided into three parts: data acquisition, data transmission, and man-machine interface. After the terminal is powered on, it first enters the pin configuration, including IO port, serial port, SPI, I2C, timer and interrupt pin configuration. Then send at instruction to the BC95 module, complete module initialization, wait for the module to complete the connection with the telecom IoT platform, and establish the connection with the local monitoring center through the telecom IoT platform to transmit data. Wait for the connection to be established before entering the main program to transfer data. If there is no instruction from the monitoring center, the timer starts to read the data of the access sensor one by one every 10ms and then outputs the detected sensor data uniformly after 10min. The main program flow chart is shown in Figure 8.
4.2. NB-IoT transmission control program design

4.2.1. BC95 module configuration process. The bc95-b5 module used in the detection terminal is a telecommunication system. Due to the limitation of telecommunication, at present, it only supports the COAP transparent transmission mode. COAP (constrained Application Protocol) is an HTTP like protocol applied to Internet of things devices, with message-based two-way communication (M2M); the network transmission layer is changed from TCP layer to UDP layer; it supports reliable transmission, data retransmission, block transmission; it supports IP multicast and other features suitable for low-power, resource-limited Internet of things scenarios [8].

![Main program flow chart](image)

**Figure 8.** Main program flow chart

The IoT card can only be connected to the operator's IoT cloud platform. Before using the detection terminal, the telecom IoT platform must be configured, including registration, creation of applications,
online development of configuration files, development of plug-ins, etc. After the full transparent transmission mode, the BC95-B5 module can be configured to interact with the platform. The process of configuring the BC95-B5 module is as shown in Figure 9, including the module registration network and data transmission.

Figure 9. BC95 module configuration process

4.2.2. BC95 module configuration process. The data transmission format of the BC95-B5 module is AT+NMGS=<length>, <data>, where length represents the decimal length of the message, and data represent the hexadecimal data to be transmitted. To facilitate the identification of the monitoring Center, a unified transmission data format is defined, as shown in Figure 10.
5. Experiments and results
To verify the realization of the function of the control terminal, the terminal is externally connected with the diffusion silicon pressure sensor and the air supply solenoid valve. The physical figure of the terminal is shown in Figure 11. After the control terminal is powered on, the detected pressure information and the status of the solenoid valve will be uploaded every 10 minutes. The validity of the data monitoring function can be verified by the data received by the upper monitoring center. The data of the monitoring center is shown in Figure 12. Adjust the gas pressure to exceed the threshold value of 0.5MPa, the monitoring center will pop up an alarm dialog box, click the button to close the air supply solenoid valve, the result is as shown in Figure 13, the pressure decreases, and the overpressure signal disappears, indicating that the air supply solenoid valve has been closed. The experimental results show that the terminal can effectively transmit the monitoring data to complete the control instructions of the monitoring center in real-time.
6. Conclusion

In this paper, a control terminal based on NB-IoT for the control system of light hydrocarbon gas generation device is designed, which adopts the be95 module made in China and can transmit information in a long distance. The experimental results show that the monitoring terminal can transmit the detected data in real-time and stably, respond to the instructions of the monitoring center, and it is small in size, waterproof and easy to install. It provides a method for the control system transformation...
and upgrading of light hydrocarbon gas generation device, which has a certain practical significance in engineering.

Acknowledgments
This work was financially supported by Research on Complete Equipment and Control Method of Light Hydrocarbon Gas Centralized Gas Supply (201601018).

References
[1] Hu J., Zhu F., (2013) Light gas-fired gas into a new gas source for the "coal to gas" project. Energy Research and Utilization, 05: 19 - 20.
[2] Lu X., (2008) Light hydrocarbons: the rise of the fourth generation of gas. China Petroleum and Petrochemical, 26: 40 - 41.
[3] Wang G., (2019) Research and analysis of the light hydrocarbon gas supply system. Hebei University of Engineering.
[4] Feng Z., Sun H., Yu M., (2019) Design and Implementation of Urban Ground Well Intelligent Monitoring System Based on NB-IOT. Journal of Shenyang Aerospace University, 4.
[5] Xiao Z., Zhang Y., (2017) Analysis of NB-IoT and its development strategy. World Telecommunication, 01: 63 - 65.
[6] Wang D., (2018) Technical Advantages and Network Deployment Analysis of NB-IoT. China New Communications, 20 (14): 121.
[7] Li J., (2017) Research on NB-IoT Networking Scheme. Mobile communication, 41: 14 - 18.
[8] Liu D., (2019) CoAP Protocol and Actual Deployment Application of NB-IoT Internet of Things. Information & Communication, 07: 236 - 237.