Design of Remote Terminal of Air Compressor Based on STM32 and GPRS

Menglong Cao*, Junlei Fangb
Qingdao University of Science and Technology QUST Qingdao, China

*a41765730@qq.com, b1264508015@qq.com

Abstract. In this paper, a remote terminal of air compressor based on STM32 and GPRS is designed, which is used to collect data of air compressor in real time and upload data to server end through GPRS network. The power and signal physical isolation hardware design, to ensure the safety of equipment and terminal isolation, software using the exception handling and heartbeat mechanism, improve the stability of the remote terminal connected to the server. The data transmission protocol to streamline the security to improve the real-time and reliability of GPRS network transmission. The operation results show that the air compressor remote terminal has strong anti-interference ability, and the automatic dropping of the line can be automatically reconnected, and the comprehensive packet loss rate is about 0.23%, and the expected results can be achieved.

1. Introduction
The air compressor in China has experienced two stages of start-up and growth, and has entered a stable stage of development. Air compressor has been widely used in many departments and has become indispensable for certain industries. However, there are a lot of real-time data and various setting parameters that need to be recorded when the air compressor is working. Because the noise of the field equipment is very large, the technical workers cannot monitor the running status of multiple air compressors in the field for a long time [1]. Therefore, the rapid development of industrial IOT technology requires us to research and develop a set of high-efficiency and low-power wireless terminal equipment so that it can quickly and easily upload the operating parameters of on-site air compressors to the remote monitoring center in an accurate and real-time manner, and enables the technician to monitoring the running state for each air compressor, and can according to the requirements of control of its operation.

2. Overall Design of the System
As shown in Figure 1, the remote monitoring system is mainly composed of three layers, namely the field physical layer, the GPRS network layer and the monitoring application layer [2]. The on-site physical layer is composed of a plurality of PLC controllers and a remote terminal unit RTU. Data transmission between them is performed through a Modbus-TCP protocol, and a remote terminal unit establishes a network connection with a remote server through a GPRS wireless network. The GPRS network application layer transmits the on-site data to the server of the monitoring center through the GPRS mobile communication network. The remote monitoring center mainly includes a Web server.
and a database server, which can receive the data uploaded from the remote terminal unit in real time and analytical processing. The mobile office computer and the mobile phone device can access the Internet to learn the working status of the on-site air compressor from the monitoring platform in real time.

Figure 1. Remote monitoring system based on GPRS

The remote terminal unit collects the data of the air compressor at a certain time interval, and then packages the data through serial port according to the data transmission protocol. The GPRS communication link is established by the RTU through the base station and the GPRS gateway supporting node of the GPRS service support node to connect [2], then, through the established network connection, the packaged data of the field device is uploaded to the remote monitoring center connected to the Internet. When the remote monitoring center receives the data of the RTU, it sends a reply to indicate that the data is received successfully. At the same time, the RTU can also perform command transmission and remote control.

3. RTU Hardware Circuit Design
The whole control system of RTU has the characteristics of safety and low power consumption. The external power supply and the signal terminal all adopt isolation circuits to achieve physical electrical isolation between the external device and the RTU to ensure the safety of the device. RTU is mainly composed of microprocessor, data acquisition module, data transmission module, data storage module, status indicator and power supply. The system block diagram is shown in Figure 2.

Figure 2. RTU system diagram
The RTU microprocessor uses a 32-bit Cortex-M3 core STM32F103RCT6 chip with low power consumption. In a working period, RTU collects the operating data in the air compressor controller PLC through the serial port to serial port module, and stores the collected operating data in the SD card for viewing of historical data.

### 3.1. Power Design

In the whole power supply design, the external power supply 24V is completely isolated from the external power supply through the isolated DCDC module to ensure the safety of the power supply. The working voltage of the microprocessor STM32F103RCT6 is 2.0–3.6V, while the working voltage of the GPRS wireless communication module is 3.4–4.4V. In order to enable the modules to work properly, two power sources need to be designed for power supply.

The input 24V power supply outputs 12V power through the B2412LS isolation module. The MIC29302 regulator chip is used to reduce 12V power supply to 4V to supply the GPRS module SIM800C, while ensuring that the peak current is 2A; AMS1117-3.3 is used to step down the 4V power supply to 3.3V, and then to supply power to the STM32F103RCT6 and other parts. The entire power supply system is designed as shown in Figure 3.

![Figure 3. The power module schematic diagram](image)

#### 3.2. GPRS Wireless Module Design

The SIM800C module is the latest GPRS wireless communication module produced by SIMCom in late 2015. It supports 4-band GSM/GPRS, and the working frequency bands are GSM850, EGSM900, DCS1800, and PCS1900MHZ. It also integrates the TCP/IP protocol and provides users with the standard AT command [3]. The SIM800C is designed with power-saving technology with a low current of 0.6 mA during dormant state. It has stable and reliable performance, low power consumption, and high performance-to-price ratio. Sending simple AT command through the serial port can configure it to be in different working mode, which is simple. The schematic diagram is shown as in Fig. 4.
4. System Software Design

4.1. Main Program Design

In order to achieve STM32 collection of PLC data of air compressor controller and data communication with SIM800C wireless transmission module, first need to build a development platform, add the required library functions and configuration files in the project, and then initialize the STM32 configuration [4], including configuration input and output GPIO, asynchronous serial communication, interrupt controller, basic timer, serial peripheral interface (SPI) and SDIO interface. The SIM800C module is controlled by software to start and sends an AT command to establish a TCP connection with the server. When the SIM800C serial port returns CONNECT OK, the TCP connection is established successfully. After the connection is established for the first time, a well-defined data handshake protocol is sent, indicating that the communication between the server and the RTU is normal and data transmission can be performed.

The establishment of the TCP connection of the SIM800C mainly has two functions. First, send data to the server. Collect the data in the air compressor PLC controller through the serial port to the serial port module, and send the AT+CIPSEND=<length> command through the serial port. ‘Length’ indicates the number of data to be sent and wait for the response “>”. After the serial port sends the length data the SIM800C will send the data to the server and return SEND OK. Second, receive the commands issued by the server. When the TCP connection is configured, the receive data display IP header is set by sending the AT+CIPHEAD=1 command. When “+IPD, <length> : <data>” is received, it means that the command issued by the server is received, and length indicates that the length of the received data, data represents the received data. By parsing the issued data, the data in the air compressor PLC controller can be modified accordingly. The main program software design flow chart shown in Figure 5.
4.2. **SIM800C establishes TCP connection**

When establishing a TCP connection between the RTU module and the server, first pull down the PWRKEY pin of the SIM800C for at least 1 second and then release it to enable the SIM800C module to boot. When the serial port detects RDY, it means that the startup is successful. The serial port sends the command AT+CREG? When the returned <stat>=1 or 5, the registration network is successful. The serial port sends AT+CPIN? When the serial port detects OK, the SIM card is in place. The serial port sends the AT+GSN to query the IMEI serial number of the SIM800C as the identification ID of the RTU device. When the serial port sends AT+CIPSHUT, the serial port detects that the mobile scene is closed successfully. When the serial port sends AT+CGCLASS="B", the serial port monitoring to OK indicates that the GPRS mobile platform is set as B, which supports packet switching and data exchange. When the serial port sends AT+CGDCONT=1, "IP", "CMNET", the serial port monitoring to OK represents the setting of PDP context and Internet access protocol. When a serial port to send "AT+CIPSTART= < mode >, < IP address >, < port >" or "AT+CIPSTART= < mode >, < domain name >, < port >", a serial port monitoring to said "OK" to establish a TCP connection with the server success, including mode = TCP, IP address or domain name is the IP address or domain name to connect to the server, the port to connect to the server port number. The AT commands for configuring the SIM800C module are shown in Table I.

**Table 1. Part of the AT command for SIM800C**

| Instruction         | Function                                      |
|---------------------|-----------------------------------------------|
| AT+CIPCLOSE         | Close TCP or UDP connections.                 |
| AT+CGCLAS           | Set the GPRS mobile platform category.        |
| AT+CGDCONT          | Set the PDP context.                          |
| AT+CIPCSGP          | Set to GSD or GPRS connection mode            |
| AT+CIPSTATUS        | Query current connection status               |
| AT+CIPSEND          | Send data                                     |
4.3. Exception Handling
When establishing the connection between the SIM800C module and the server, the serial port of the module may send PDP DEACT, IP INITIAL due to the influence of signals. In these cases, it is generally difficult to establish a connection with the TCP Server [5]; when the connection has been established, it may be due to Signal interruption or server disconnection caused the SIM800C module to behave abnormally. The module's serial port reported an error with TCP CLOSED and the connection was interrupted. In the software design, the AT+CIPSTATUS instruction is used to check the current connection status every 5 seconds when the SIM800C and the server have not yet established a connection. When the value of ConnectStatus in the memory is not 1, the connection is unsuccessful. AT this point, the AT+CIPCLOSE=1 command closes the connection and the AT+CIPSHUT command closes the moving scene, and then sends the AT+CIPSTART command to re-establish the connection between the SIM800C and the server. The software flow diagram for connection exception handling is shown in figure 6.

![Figure 6. Exception handling software flow chart](image)

4.4. Heartbeat Package Mechanism
After SIM800C module and TCP connection to the server, since mobile GPRS network operators Settings, if in a certain time interval between the client and the server does not have any data exchange, and has set up a good network connection will be disconnected, suspension has good connections [6], resulting in data transmission failure. To solve this problem, a custom heartbeat package mechanism is added to the monitoring platform and RTU with data exchange. Every 30 seconds RTU sends a heartbeat data assurance server and RTU's online connection. If the heartbeat data is sent more than 3 times, the server does not respond and the connection is disconnected. The RTU automatically restarts and re-establishes the TCP connection with the server.

5. Data Transmission Protocol Design
The establishment of RTU data transmission protocol is divided into two parts, uplink data transmission protocol and downlink data transmission protocol. The response mechanism adopted by the data transmission protocol has a one-to-one correspondence between the sending instruction and the response instruction. The upstream data transmission protocol is that RTU packs the data
according to the established protocol, and sends real-time data, user setting parameters, factory setting parameters, frequency conversion parameters, and maintenance and protection parameters of the collected air compressor controller PLC to the server; The downlink data transmission protocol is the data of the user to modify the controller PLC of the air compressor through the remote monitoring platform, and can control the operation and stop of the field equipment.

6. Experimental Verification
Set up NetAssist on the notebook computer and use the network debugging assistant to set up the TCP Server to simulate the remote server platform. As shown in Fig. 7, the stability and accuracy of the RTU transmission data are experimentally verified. After the simulated server goes offline and the TCP server is disconnected. RTU automatically reconnects to the server when the heartbeat is sent more than three times and does not receive a response from the server.

![Figure 7. Test receive data](image)

Through the RTU work 24h, the collection data upload time interval is 20S, each uploading data byte size is 22 bytes, which verifies the packet loss rate and accuracy of RTU data transmission. Table 2 shows the statistics of the number of times RTU loses data within 24 hours.

According to the experimental data, the total packet loss rate of RTU transmission data within 24 hours is 0.23%, and the packet loss rate reaches a maximum of 0.30% between 12:00 and 15:00, and the packet loss rate was 0% between 0:00–3:00 and 21:00–24:00. It can be concluded that at 9:00 to 15:00 may be at the peak of the use of the network, RTU data transmission packet loss rate increased.

| Time  | Should upload packets times/time | Total number of packet loss/times | Packet loss rate/% |
|-------|---------------------------------|----------------------------------|--------------------|
| 3:00  | 540                             | 0                                | 0                  |
| 6:00  | 1080                            | 1                                | 0.09               |
| 9:00  | 1620                            | 2                                | 0.12               |
| 12:00 | 2160                            | 4                                | 0.19               |
| 15:00 | 2700                            | 8                                | 0.30               |
| 18:00 | 3240                            | 9                                | 0.28               |
| 21:00 | 3780                            | 10                               | 0.26               |
| 24:00 | 4320                            | 10                               | 0.23               |
7. Conclusion

The air compressor remote terminal based on STM32 and GPRS designed in this paper has been verified through experiments that the remote terminal has strong anti-jamming capability and can be disconnected automatically after being dropped. The total packet loss rate is about 0.23% within 24 hours, and the data transmission speed is fast. The streamlined and secure data transmission protocol can solve the safety and real-time upload of on-site air compressor operating parameters to the remote monitoring center with good application prospects.

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