

Online Display System for Key Parameters of Aluminum Electrolysis Cells

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<https://doi.org/10.71659/icsoba2024-al012>

Abstract

The parameters such as voltage and control status in the aluminum electrolysis production process are important indicators of the operation status of the electrolytic cell, which are not only related to the stability of production, but also closely related to production safety. Due to the complex environment of the electrolysis potroom, it is impossible to observe key information about the operation status of the electrolysis cell on multiple inspection screens, which not only brings great inconvenience to production and management, but also poses certain safety hazards to operators near the electrolysis cell. In response to this issue, China Aluminum Zhengzhou Nonferrous Metals Research Institute has developed an online display system for key parameters of aluminum electrolysis cells. The system utilizes advanced microprocessors and Internet of Things (IoT) technology, including three major modules: digital communication, online measurement, and multi-dimensional display. The communication module can be connected to the electrolytic cell control system or other digital systems through fieldbus or General packet radio service (GPRS) network to obtain critical information on the operation of the electrolytic cell. The online measurement module can perform multi-channel analog data acquisition, achieving high-precision and high-speed acquisition of various electrolytic cell states; The multi-dimensional display module uses high brightness large digital tubes and three-color sound and light alarm lights to ensure that on-site personnel can clearly observe the display content from all angles of the electrolytic cell. This system utilizes information technology to achieve digital and intelligent monitoring of electrolytic cell safety, which is of great significance for improving inspection efficiency, reducing labor intensity, ensuring the safety of the potlines, and avoiding economic losses for smelters.

Keywords: Aluminum reduction cell, Cell safety, Internet of Things (IOT).

1. Introduction

The voltage, current, current distribution, flue gas flow rate, anode raising action and other key parameters of the electrolytic cell during the aluminum electrolysis production process not only characterize the current operating status of the electrolytic cell, but also are important parameters for the production safety of the electrolytic cell. However, in production, due to limitations in the space of the electrolysis plant and the size of the electrolysis pot, these key parameters can only

be observed on computers near the control box or within the local area network, which brings great inconvenience to on-site inspections and operators. Especially during operations such as aluminum production, pole replacement, and beam raising, a dedicated person is required to be on duty next to the control box to observe the status of the electrolytic cell and assist manual operations. The project team has developed an online detection and display system for key parameters of aluminum electrolysis pots to address the aforementioned issues. The entire system includes three major modules: digital communication, online measurement, and multi-dimensional display. The digital communication module includes two types of data interfaces: wired and wireless. On the one hand, the collected data is uploaded to the cloud, and on the other hand, it can be connected to other control and detection systems on site; The online measurement module uses high-precision and highly AD conversion chips to achieve multi-channel analog and digital signal acquisition, which can collect various electrolytic cell state parameters including voltage, current distribution, flue gas temperature, bus position, anode action, etc. Multidimensional display includes on-site and remote displays. On the one hand, high brightness large digital tubes and three-color sound and light alarm lights are used for on-site display, and on the other hand, remote access can be achieved through computers and mobile phones. The system utilizes electronic information technology to achieve multi-dimensional display of important parameters of electrolytic cells.

2. Network Architecture of Online Display System

After the online display system completes the collection of single slot information, the IOT module is used to send the data to the cloud server through GPRS network, and other network devices can access the cloud server through the Internet for remote observation. Figure 1 shows the network structure diagram.

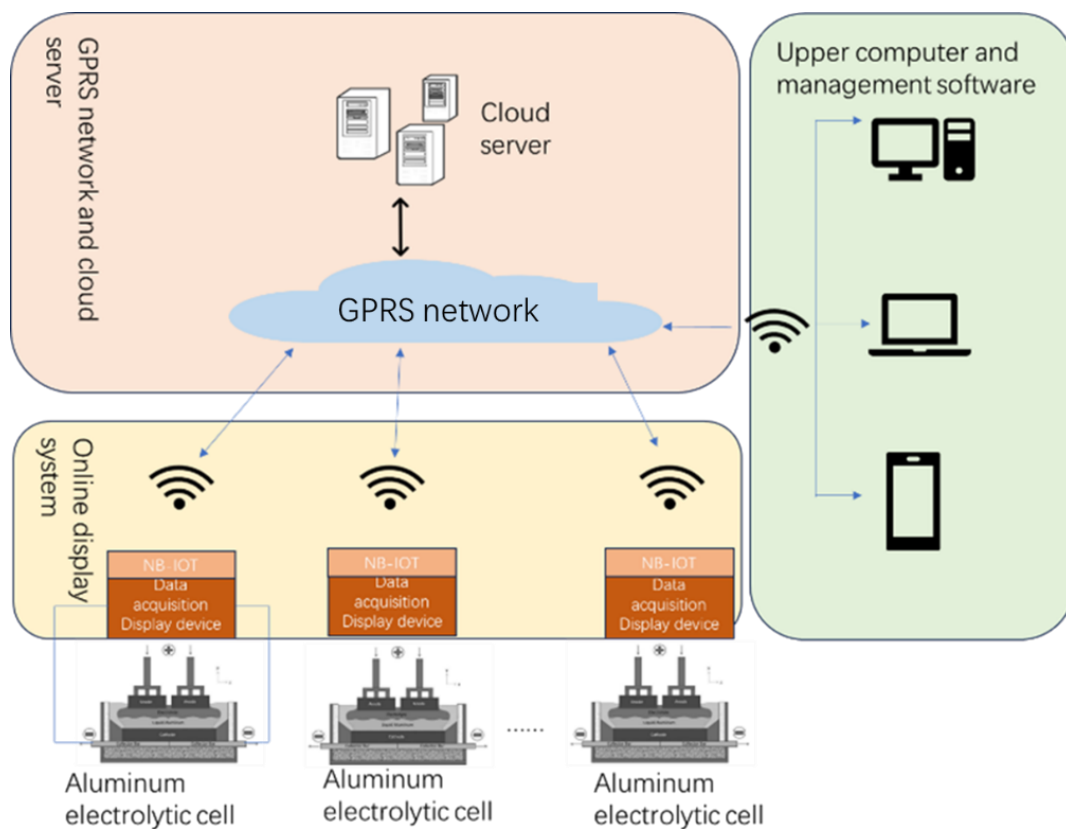


Figure 1. Network structure diagram.

3. Hardware Design of Online Display System

3.1 Power Conditioning Unit

Due to the harsh environment of the electrolysis site and the difficulty in laying the circuit, the online display system utilizes the voltage of the electrolysis cell as the power input. The short junction of the aluminum electrolytic cell is a device designed to bypass the electrolytic cell, where the anode and cathode of the electrolytic cell converge. During normal production of the electrolytic cell, the voltage at both ends of the short circuit represents the voltage of the electrolytic cell, and this location is concealed and does not affect daily operations. Therefore, this system uses this as the power point for the system. A reliable and stable power supply is the foundation of system operation, but when the aluminum electrolysis cell is working normally, the cell voltage is around 4 V. When there are abnormalities such as anode effects, the cell voltage will fluctuate between 20–30 V. Such a large fluctuation in voltage cannot be directly used as a system power supply. It is necessary to adjust the cell voltage to a suitable and stable voltage as the power input. The voltage reduction chips on the market cannot adapt to the large voltage fluctuation range of electrolytic cells, so the system has designed a switchable two-stage voltage reduction circuit conditioning unit. Figures 2 and 3 show power conditioning unit logic diagram and unit circuit diagram, respectively.

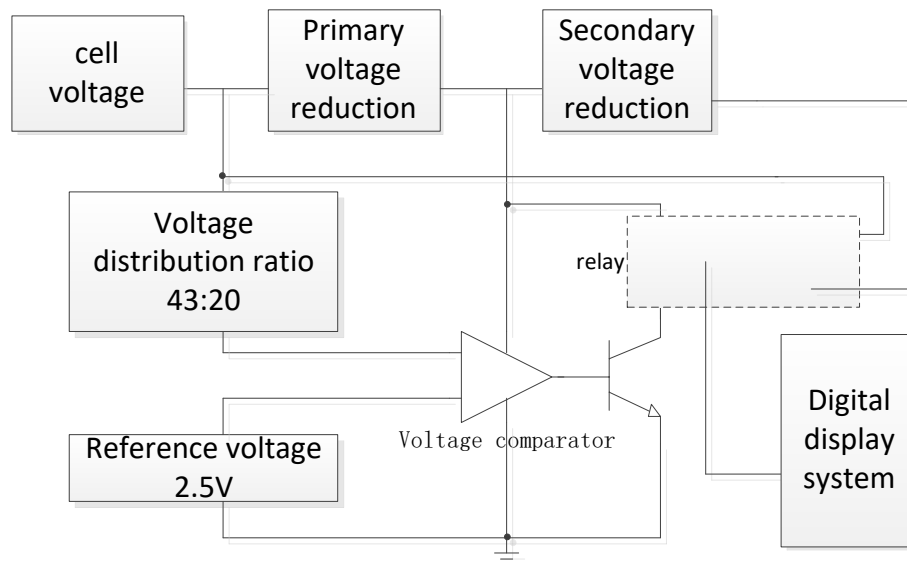


Figure 2. Power conditioning unit logic diagram.

Figure 2 is the logic diagram of the switchable two-stage voltage reduction circuit conditioning unit. When the voltage of the electrolytic cell is around 4 V, the same direction end of the voltage comparator is smaller than the reverse end, the operational amplifier outputs a low level, and the transistor is not conducting. At this time, the relay has no action, and the voltage of the electrolytic cell is directly input into the display and acquisition module through the contacts on one side of the relay; When the voltage rises to above 8 V, the input voltage at the same direction end of the operational amplifier is greater than that at the opposite end. The operational amplifier outputs a high-level drive relay to close, and the voltage after secondary voltage reduction is connected to the digital display system through the other side contact of the switched relay. Experiments have shown that the power conditioning unit can effectively ensure an output voltage between 3.8-5.5 V when the slot voltage fluctuates, and can serve as the power supply for the digital display system (Figure 3 shows the circuit schematic).

3.2.3 Smoke Temperature Collection

Temperature sensors generally use K-type thermocouples, with signals within the range of 0–50 mV. In order to adapt to AD conversion, the signal needs to be increased by 40 times. This system uses a universal operational amplifier LM385 for proportional amplification.

3.2.4 Anode Position Signal Acquisition

By installing a rotary encoder on the anode raising motor, the raising position information is collected. The rotary encoder will rotate along with the motor shaft and output a pulse signal to achieve precise measurement of the rotation angle. The height of anode raising can be obtained by converting the rotation angle to the diameter of the worm gear. Pulse signals belong to digital signals and can be directly collected by the processor after being isolated by optocouplers. Figure 4 shows the schematic diagram of the data acquisition unit

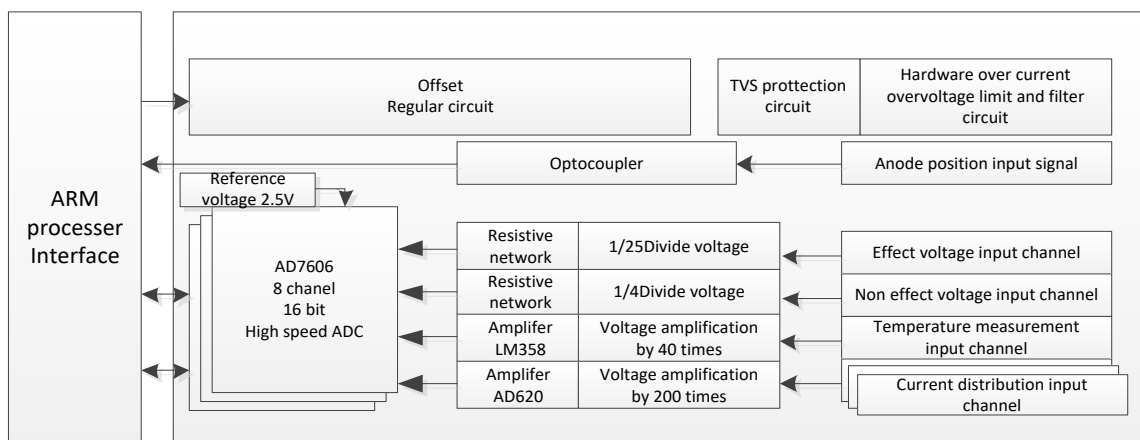


Figure 4. Hardware schematic diagram of data acquisition unit.

4. Digital Communication Hardware Design

In order to remotely access real-time data online, the NB-IOT IoT module is used in the system. The IoT module uploads the collected data in real-time to the cloud server through GPRS network. The Internet of Things uses QUECTEL BC260, which supports multiple communication modes such as SCOKET, MQTT, LWM2M, etc. The BC260 module uses AT commands through the serial port to achieve control and communication. This system adopts the LWM2M mode for communication, and the cloud platform uses China Mobile's ONE-NET IoT platform. The hardware connection diagram is shown in Figure 5.

In order to achieve better scalability of digital display boards, two fieldbus interfaces, CAN and RS-485, have been added to the circuit. CAN and RS-485 are two commonly used fieldbuses that can be used to connect with various digital instruments and systems (Figure 6).

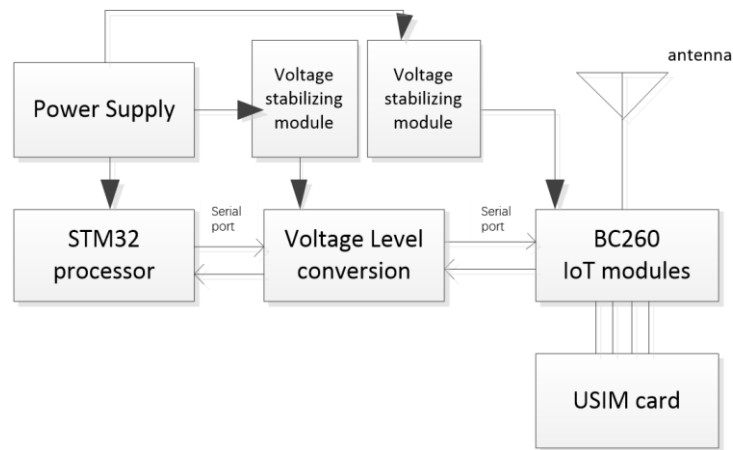


Figure 5. Hardware connection diagram of NB-IOT IoT Module.

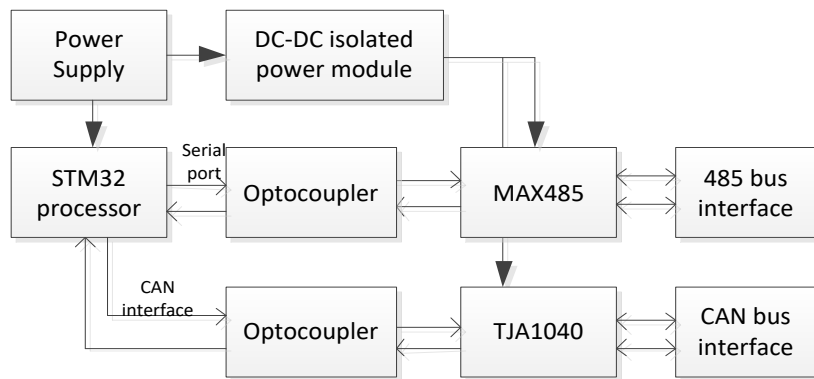


Figure 6. Schematic diagram of hardware connection for fieldbus expansion.

5. Hardware Design of Multidimensional Display Module

In order to ensure a good display effect, the system adopts a high brightness digital tube and three color alarm lights. High brightness numbers can ensure penetration in harsh environments within the electrolysis plant. The three-color alarm light can provide red, green, and blue alarms, accompanied by sound prompts.

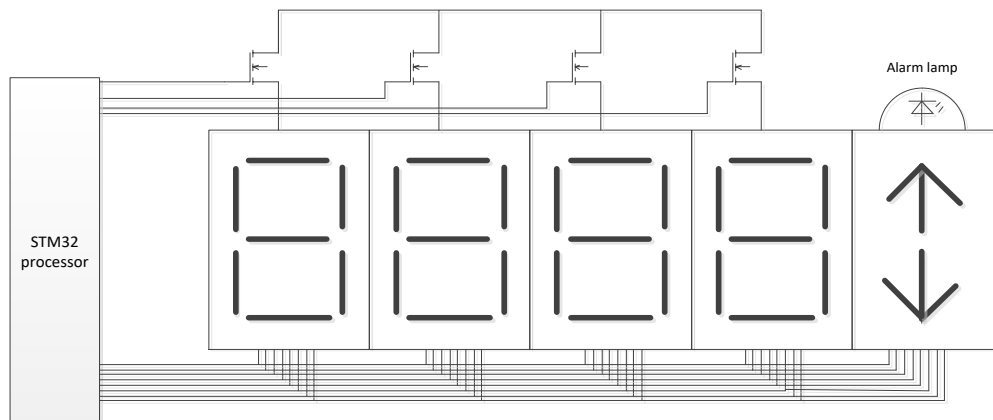


Figure 7. Hardware schematic diagram of data display unit.

The driving current required for digital tubes and alarm lights is relatively high, so MOS tubes are added to the hardware for current expansion to ensure the display brightness of the digital tubes. The digital tube adopts a dynamic driving method, and the processor refreshes each digital tube at an extremely high speed. Due to the visual persistence characteristic, people observe without flickering.

6. Software Design

The control software adopts an embedded real-time operating system as the foundation, divides multiple task threads as needed, and processes them separately through task scheduling. The task includes data collection tasks; Data conversion tasks, digital tube drive tasks, IoT module communication tasks, fieldbus communication tasks, alarm tasks. The data collection task lacks the conversion value of the AD sampling chip, which is called every 1ms; The data conversion task restores the collected data by installing hardware conditions, deduces the actual physical parameters, and stores the parameters in the cache area; The digital tube drive task is called once every 1ms to refresh the display content of the digital tube; The IoT communication task is called every 5 seconds, and the parameters of the cache area are uploaded to the cloud; The fieldbus task is called every 1 second, continuously checking whether the query statement has been received and responding in a timely manner; The alarm task is called once every 100ms, continuously checking whether the parameters in the cache area have exceeded the limit. When the parameters are abnormal, an alarm signal is output in a timely manner. The control algorithm flowchart is shown below. Control algorithm flowchart is shown in Figure 8.

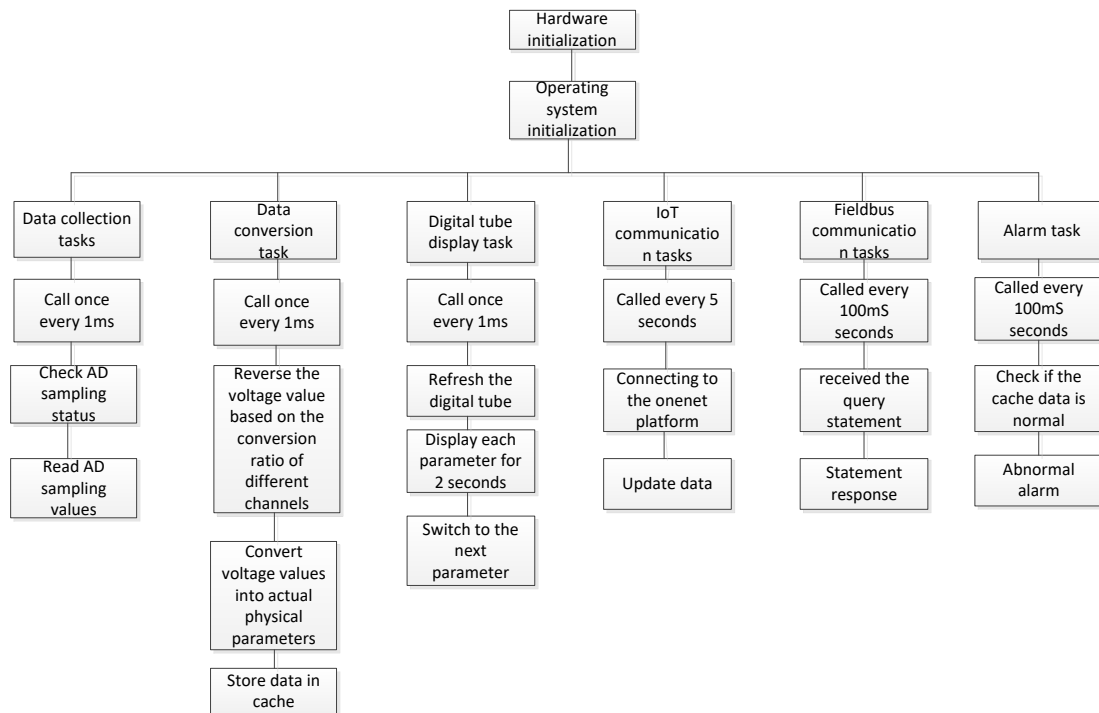


Figure 8. Control algorithm flowchart.

7. Application Effect

At present, the system has been applied in aluminum electrolysis cells and operates stably. It can correctly identify and timely alarm signals such as cell voltage, current distribution, flue gas temperature, anode position, etc.



Figure 9. On site installation and application of equipment.

The project team conducted a one-month functional verification of the system, during which manual inspections and system records were used to verify each other. The experiment showed that the collected data was accurate and alarms were timely. This system is installed at the top of the electrolytic cell, making it convenient for on-site workers to understand the real-time production status of the electrolytic cell, detect abnormal conditions of the electrolytic cell as early as possible, handle faults in a timely manner, stabilize electrolytic production, and prevent anode effects. Table 1 compares the monthly statistical mean of the operating status of the electrolytic cell before and after the system is put into operation.

Table 1. Comparison of system application effects.

	Average voltage (V)		Voltage difference (Working voltage-Set voltage) (mV)		Frequency of anode effect (No/pot-day)		AE duration (s)		Noise time (s/day)		Noise (mV)	
	Be-fore use	After use	Be-fore use	Aft-er use	Be-fore use	After use	Be-fore use	Aft-er use	Be-fore use	After use	Be-fore use	After use
First work area	3.942	3.937	15	8	0.12	0.11	87	83	534	498	22	18
Second work area	3.887	3.88	9	8	0.14	0.12	76	74	633	567	19	16
Third work area	3.958	3.948	-1	2	0.1	0.09	94	86	567	529	34	29
Fourth work area	3.989	3.985	12	10	0.08	0.08	85	83	498	456	25	20
mean value	3.944	3.938	8.75	7	0.11	0.1	85.5	81.5	558	512.5	25	20.75

From the table above, it can be seen that after the system was put into use, the average voltage decreased by 6 mV, the Duration of effect shortened by 4 seconds, and the frequency of anode effect decreased by 0.01 time per battery day. This indicates that on-site operators can observe

the trend of anode effect in the electrolytic cell as early as possible through the system, handle it in advance, and effectively suppress the probability and duration of anode effect occurrence; After being put into use, the working voltage difference (set voltage) of the electrolytic cell decreased by 1.35 mV, the oscillation time of the electrolytic cell decreased by 45.5 seconds per cell day, and the electrolytic noise decreased by 4.25 mV per cell day. This indicates that the system plays an important role in helping on-site managers detect abnormalities in the electrolytic cell as early as possible, inspect and handle them in advance, avoid the deterioration of abnormalities, improve the stability of the electrolytic cell, save energy and reduce consumption, and improve current efficiency.

8. Conclusions

This system utilizes information technology to achieve online collection, local display, and real-time uploading of key parameters of electrolytic cells; The system does not require additional power supply lines and directly utilizes the voltage of the electrolytic cell as the input power source, making it easy to install; Internally extended fieldbus interface for easy connection with other instruments and digital systems. This system is beneficial for improving the efficiency of cell inspection, reducing labor intensity, ensuring the safety of the electrolytic cell series, avoiding production accidents, and is of great significance to electrolytic production.

9. References

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