System Development and Application for Preventing the Explosion of Aluminum Reduction Cell Bypass Shunts

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Abstract

As a major safety accident, the explosion of the cell bypass shunts will cause a series of shutdowns and power outages if it happens, which will also bring huge economic losses to the smelter. At the present time, manual inspection is made to prevent these explosion accidents. Smelters lack a comprehensive and effective digital monitoring and early warning system. In view of this situation, a system to prevent the explosion of the cell bypass shunts has been developed by Zhengzhou Non-ferrous Metals Research Institute Co, Ltd of CHALCO. Three functional modules are covered in the system, such as data acquisition, research and judgment software, and communication linkage protection. In the data acquisition module, a PLC collects the status of hidden danger points and uploads the data. The research and judgment software carries out feature analysis of the uploaded data, which tries to find out the explosion potential in time, and issues the corresponding level of warning signal through the Internet of Things. For the highest hazard level, the system linkage protection function of the power supply start-up reduces the input power to ensure production safety. By taking advantage of information technology, this system provides the digital and intelligent protection of cell safety. As the result, it is very important for potline safety, and it avoids economic loss for the smelters.

Keywords: Aluminum reduction cell, Cell bypass shunts, Cell safety.

1. Introduction

As a major safety accident, the explosion of the cell bypass shunts will cause a series of shutdowns and power outages if it happens, which will also bring huge economic losses to the smelter. All electrolysis companies attach great importance to this and formulate various investigation measures and emergency plans to prevent them. However, at present, the accident has not been effectively curbed. On the one hand, due to the complex factors that caused the explosion of the cell bypass shunts, the hidden danger points are scattered and the incident is sudden, it is difficult to achieve a comprehensive, continuous and thorough investigation by manual inspection alone. On the other hand, the site lacks a set of digital and intelligent safety detection and protection system.

In response to this situation, Zhengzhou Nonferrous Metals Research Institute Co., Ltd. of CHALCO has developed a system to prevent the explosion of the cell bypass shunts, using information technology to prevent it, and eliminate unsafe hidden dangers, ensuring the safety of electrolytic production and avoiding major economic losses.

2. Accident Analysis and Identification

By classifying the causes of historical explosions of the cell bypass shunts, it is found that the causes mainly include: serious bias current in cell preheat, cell tap-out, abnormal contactor, high anode-to-cathode distance (ACD) in operation process, high anode effect voltage and non-technical reasons (non-technical reasons refer to natural disasters such as earthquake and flood, which are not discussed in this paper). Further analysis shows that before each accident, the data related to the electrolytic cell has its own characteristics. Therefore, through the collection, analysis and mining of the data related to aluminum electrolysis, the accident characteristics can be extracted to form a recognition algorithm to predict the explosion risk at the cell bypass shunts in advance.

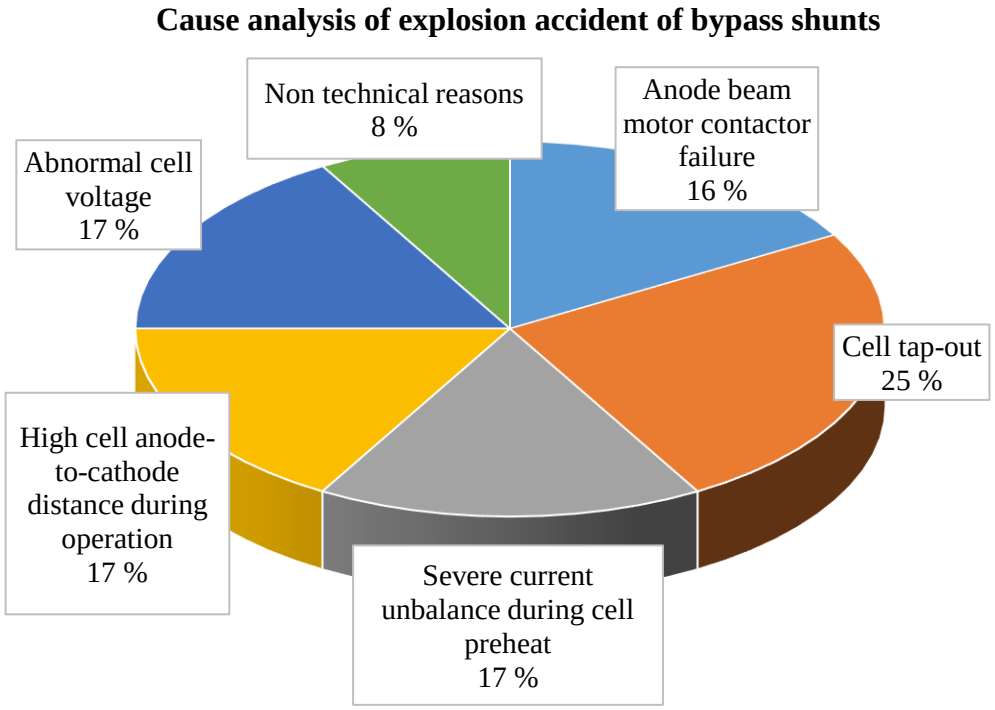

Figure 1. Classification of explosion causes of the cell bypass shunts.

2.1. Identification Technology of Severe Current Unbalance during Cell Preheat

During the start-up stage of cell preheat, if the temperature distribution is uneven or the anode is abnormal, a large current will concentrate on one anode or its flexible connection, forming a serious problem. Excessive current will melt the electrical transition joints, which will lead to a vicious cycle of current overload, resulting in the burnout of the electrical transition joints one after another and the explosion of the short-circuit shunt. Through the study of historical data, it was found that when serious unbalance of the current occurs during preheat, the resistance balance of the whole electrolytic cell is destroyed and the cell voltage variation is abnormal. Therefore, the serious current unbalance during the cell preheat can be identified in advance according to the variation relationship and characteristics of voltage and current during the preheat.

2.2. Identification Technology of the Cell Tap-Out

In case of the cell tap-out, the bath and liquid aluminum continue to flow out, and the anode may separate from the bath at any time, creating an open circuit, resulting in the explosion of the cell bypass shunts. The leaked high-temperature bath or aluminum stream may also damage the cathode busbars, causing an open circuit. Through the research on the relevant data before the tap-out accident, it is found that the Fe and Si contents of the cell will fluctuate abnormally ahead of time, and the pressure drop at the bottom of the cell and the temperature of the steel collector bar will change accordingly. The tap-out can be identified in advance through the comprehensive analysis of the above data.

2.3. Research on the Identification Technology of the Anode Beam Motor Contactor Fault

Contactor failure will lead to wrong action of anode beam raising motor, open circuit of electrolytic cell and explosion of the cell bypass shunts. The investigation shows that the contactor output action of the control system has its fixed time sequence. The rationality and correctness of the contactor action can be comprehensively judged by collecting the contactor action signal, three-phase electrical phase sequence, anode beam displacement and other signals, by which the contactor fault can be identified.

2.4. Research on the ACD Anomaly Identification Technology During Operation (aluminum tap-out, ACD change and anode beam raising)

During aluminum tapping, anode changing and anode beam raising, there are a lot of manual operations and equipment actions. If the anode action does not follow the target voltage change according to the set cycle and threshold, the anode may be pulled out of the bath and the shunts will explode. The danger can be identified in advance by tracking the voltage trend and anode beam position during the operation process, combined with the cell voltage target value during the operation.

2.5. Abnormal Cell Voltage

When the anode effect voltage is too high or aluminum is rolling, the excessive voltage will accumulate at the bypass shunts, which may cause short circuit explosion at any time. The abnormal situation of cell voltage can be identified by tracking the amplitude and fluctuation of cell voltage.

3. System Design and Development

The above accidental causes comprise most of the factors that may cause bypass shunt explosion. Through the integration of the above explosion hazard identification technologies, a set of online detection, early warning and linkage system is built to prevent shunt bypass explosion of aluminum reduction cells.

The system includes three parts: data acquisition, research and judgment software, and communication linkage protection. The data acquisition module can carry out on-line continuous acquisition and transmission of the cell status and control system data. In case of an explosion risk, the information is shared through the early warning system, relevant personnel is notified to take targeted protection measures, start the communication linkage protection function in case of the highest risk level signal, and notify the power supply control room to reduce the input power and prevent shunt explosion. The system structure diagram is shown in Figure 2.

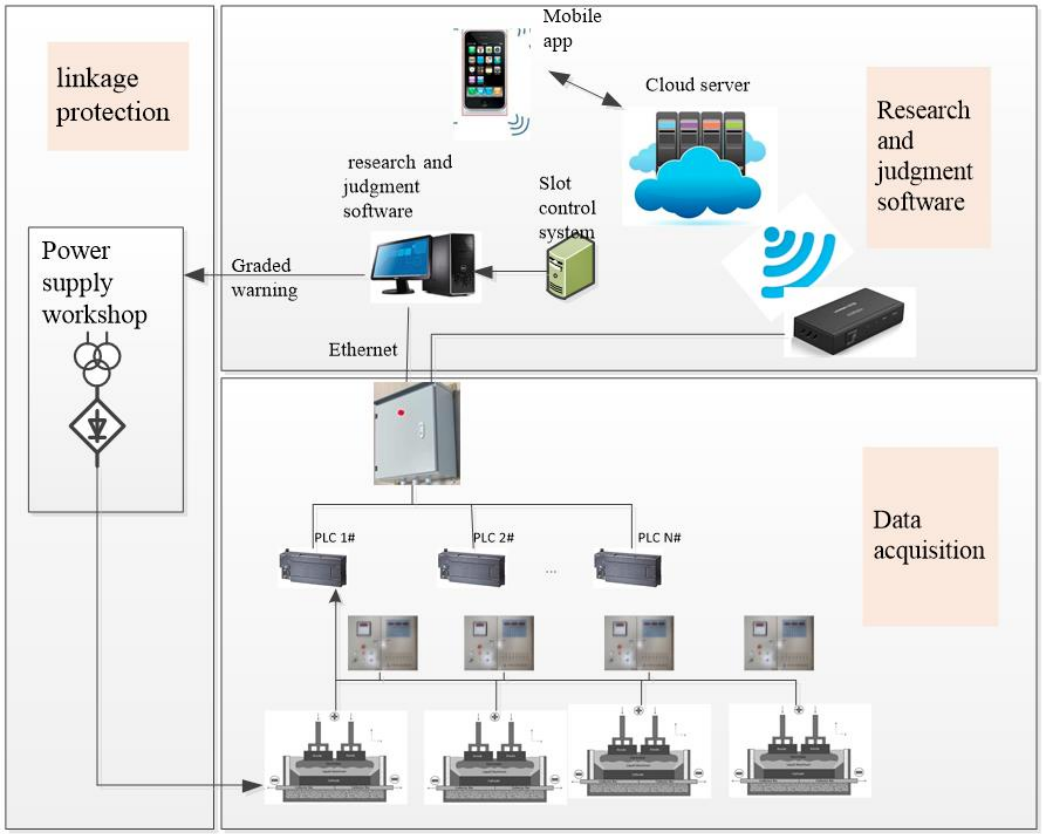

Figure 2. System structure diagram.

3.1. Data Acquisition Module

The data acquisition module includes acquisition equipment and transmission equipment; it mainly collects and transmits the data related to the cell and control system, and provides data support for the upper-level computer and research and judgment software. The acquisition equipment is developed with PLC as the main body, which can collect multi-channel digital and analog signals. When there is a shunt explosion risk, the on-site audible and visual alarm can also be carried out.

One acquisition device can carry out real-time online signal acquisition of six cells. The data collected include: cell voltage, cell current, contactor status, three-phase electrical phase sequence, operation status of control system, anode beam displacement and cathode steel collector bar temperature.

3.2. Research and Judgment Software

While receiving the data of the acquisition module, the research and judgment software integrates the control and process data, and calls the identification algorithms such as serious current unbalance, cell tap-out, contactor failure, high ACD during operation and abnormal cell voltage according to different states of the cell, so as to find hidden dangers and send early warning signals in advance. At the same time, the research and judgment software has the basic software functions of network communication, interface display, real-time curve, alarm information query, user management, basic setting, parameter setting, file transfer protocol (FTP) service, voice alarm and so on.

Figure 3. Software interface and mobile app interface.

In order to expand the scope of early warning and carry out information sharing, the cloud service platform is built by using Internet of Things technology, and the corresponding mobile app is developed. The research and judgment software can upload the operation data and alarm information to the cloud database through the general packet radio service (GPRS) module. The mobile app can query the real-time operation data of the cell through the cloud database, and can also receive the downloaded information from the cloud service platform to produce the real-time and comprehensive coverage of early warning information.

3.3. Communication Linkage Protection Module

In case of emergency for a cell, it is necessary to reduce the input power to ensure the safety of the potline. This window period is very short, and a slight delay may cause disastrous consequences. At present, the communication is mainly through telephone, walkie talkie and other communication methods; all of these are inefficient and waste valuable rescue time. In view of this situation, the system design has a communication linkage protection module to actively inform the power supply control room to reduce the input power of the potline to prevent explosion accidents and ensure the safety of the cells.

Figure 4 shows the structure diagram of the communication linkage protection system. It can be seen from the figure that the communication linkage protection function can be started in two ways: one is that the operator starts the emergency stop button according to the site conditions. The other is that the research and judgment software responds to the highest-level risk signal according to the identification results and notifies the power supply control room to reduce the input power.

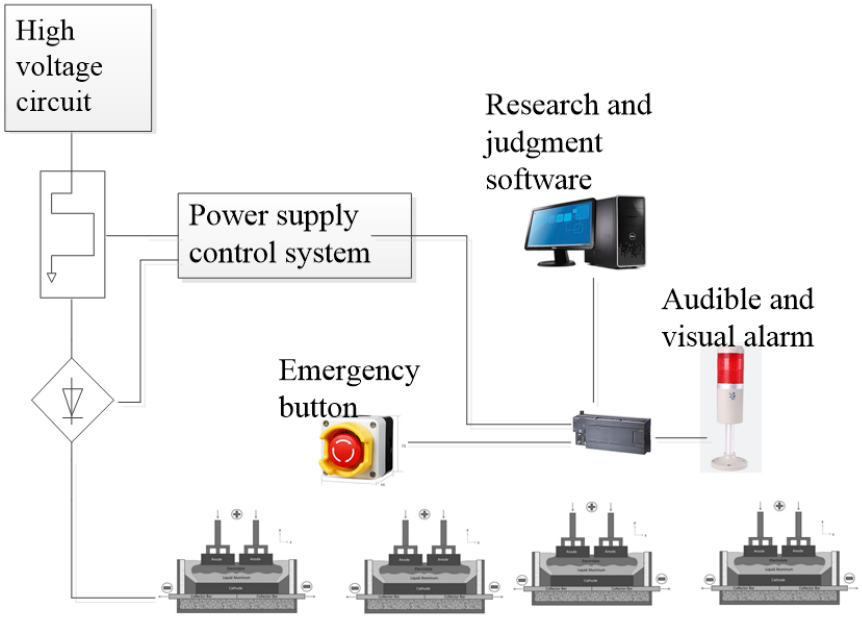

Figure 4. Structure diagram of communication linkage protection module.

4. Field Application

At present, the system has been applied in the potline of Zunyi Aluminum plant. The system operates stably. It can correctly identify and alarm hidden dangers such as serious current deviation of the cell, cell tap-out, high cell ACD and contactor failure, and plays an important role in ensuring the safety of the potline, avoiding major economic losses and ensuring personal safety.

The project team conducted a one-month functional verification of the system. During the verification, the combination of system alarms and manual active supervision was used to verify the accuracy of the alarm content. The following table shows the contents of system alarms and on-site troubleshooting during unverified period.

Figure 5. Field installation of signal acquisition and signal transmission equipment.

Table 1. Statistical troubleshooting of risk alarm.

Alarm time	Cell No.	Alarms	Causes	Conclusion
2020.9.11 19:16:51	1619#	Risk of tap-out of the cell	The Fe content in molten aluminum rises above the set threshold, and there is a risk of cell tap-out.	Correct
2020.9.12 08:43:25	1621#	Contactor failure	The reverse connection of the three-phase electrical phase sequence causes the motor to operate incorrectly.	Correct
2020.9.13 13:03:50	1612#	High operating ACD	Manual incorrect operation during aluminum tapping caused the interpolar distance to be too high.	Correct
2020.9.16 22:18:50	1608#	Contactor failure	The contactor does not move and the motor cannot be raised or lowered.	Correct
2020.9.18 01:35:25	1605#	High operating ACD	The voltage fluctuates when the anode is replaced, and the ACD is too high after the anode is raised.	Correct
2020.9.19 01:30:29	1623#	High operating ACD	The voltage fluctuates when the anode is replaced, and the ACD is too high after the anode is raised.	Correct
2020.9.20 20:03:32	1626#	Contactor failure	The contactor is stuck, causing the motor to operate incorrectly.	Correct
2020.9.23 01:48:31	1607#	Contactor failure	The contactor is stuck, causing the motor to operate incorrectly.	Correct
2020.9.25 04:44:24	1614#	Abnormal voltage	The anode effect voltage is too high to cause an alarm.	Correct
2020.9.28 14:13:50	1608#	Contactor failure	The contactor does not move and the motor cannot be raised or lowered. Replace the contactor	Correct

It can be seen from the above table that the system alarms were accurate during the verification period, which was in line with the actual situation on site, and there were no false alarms; manual investigation did not find other hidden dangers, and there was no hidden danger of under-reporting.

5. Conclusions

Through the data acquisition module, the comprehensive, continuous and on-line acquisition of explosion hazards at the cell bypass shunts is achieved by the explosion prevention system of the cell bypass shunts. It realizes the predictive identification and real-time early warning of explosion risk through research and judgment software. Timely prevention of explosion accidents is realized through communication linkage protection. The system has thorough troubleshooting, accurate analysis and timely early warning. For the first time, a comprehensive collection, multi-dimensional research and judgment, predictive identification and risk early warning of explosion hazards of cell bypass shunts was implemented. It is an important tool to prevent explosion accidents, ensure safety of aluminum potlines, improve the ability of disaster prevention, reduction and rescue, and ensure the safety of life and property of electrolytic aluminum enterprises.

6. References

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