An Optimization Method for Network Communication in Aluminium Smelter Reduction Shops

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Abstract

In recent years, aluminium producers have increasingly prioritized the development of smart factories, implementing advanced technologies such as real-time data acquisition and feedback systems for cell control, as well as intelligent unmanned cranes capable of multi-machine coordination. These innovations have significantly raised the bar for network communication, demanding higher levels of flexibility and stability. However, the unique structural layout, production processes, and strong magnetic fields in aluminium smelter reduction workshops pose challenges that simple network communication systems struggle to overcome. As a result, there is a pressing need for a communication solution that is both reliable and adaptable to these demanding environments.

To address this challenge, this paper proposes an optimization method for communication networks tailored to aluminium production workshops, focusing on network architecture and the characteristics of communication nodes. First, a Software-Defined Networking (SDN)-based approach is introduced to optimize the network architecture of electrolysis workshops. By segmenting the network into distinct functional areas and implementing customized communication solutions for each, the flexibility of the on-site communication network is significantly enhanced. Furthermore, an evaluation method is developed to assess the importance of communication nodes. This method analyses the impact of local node failures and the subsequent redistribution of network loads on production communication, enabling the identification of critical nodes for targeted protection. Research demonstrates that this approach not only ensures the stability of the communication network but also improves its flexibility, ultimately reducing communication costs in production.

Keywords: Electrolytic aluminium, Network architecture, Node importance, Communication solutions.

1. Introduction

Around 2005, aluminium smelters worldwide began transitioning from traditional bus architectures to Industrial Ethernet in order to reduce deployment costs and enhance the communication efficiency of control backbone networks [1]. However, inherent limitations such as complex device structures and poor interface compatibility have hindered Industrial Ethernet's performance in meeting multi-service demands under the complex working conditions of aluminium smelting [2]. Consequently, developing dedicated network optimization methods for aluminium electrolysis workshops is a significant engineering value.

To address this technical bottleneck, this paper proposes an innovative network communication optimization solution for aluminium electrolysis workshops. The solution implements a dual-dimensional optimization strategy: at the network architecture level, it achieves intelligent configuration and flexible scheduling of hardware resources through subnet division and hierarchical modular design; at the data transmission level, it establishes a dynamic node criticality evaluation model to implement differentiated resource allocation strategies based on service priorities, thereby significantly improving system operational reliability while maintaining network flexibility.

2. Dedicated Network Architecture Design for Aluminium Electrolysis Production

With the continuous expansion of network node devices and growing demands for differentiated network transmission services in industrial environments, industrial communication technologies have evolved from fields systems to Industrial Ethernet. Currently, aluminium electrolysis plants in China are progressively upgrading their industrial Ethernet networks [3].

In typical aluminium smelting plants, two separate networks are typically deployed: an industrial intranet and an industrial extranet. The extranet primarily consists of office terminals, servers, and routers, handling routine office data transmission and internet connectivity. The intranet comprises sensors, controllers, and switches dedicated to transmitting production data and controlling equipment operations. The two networks are currently isolated to ensure the safety of production. However, with the increasing integration of AI-assisted operations, video image processing, and unified business management, data exchange between different networks has become essential, making the traditional dual-network model increasingly inadequate [4]. Therefore, optimizing the structure of field communication networks is critically important.

To address these challenges in production network systems, this paper proposes an efficient and flexible network architecture for aluminium electrolysis workshops based on Software-Defined Networking (SDN) principles, aiming to enhance transmission reliability and flexibility. SDN technology separates the data plane from the control plane, simplifying network management and control processes. This facilitates centralized network management and resolves compatibility issues caused by diverse protocols and hardware during cross-network data interconnection.

Figure 1 illustrates an SDN-optimized plant-wide network architecture for aluminium electrolysis plants, which is structured into three layers: the aggregation layer, access layer, and device layer. This design fully addresses the requirements for high real-time performance, reliability, and multi-service coordination in aluminium electrolysis production processes.

The device layer includes various field equipment such as robots, sensors, overhead cranes, pot controllers, electrolytic cell monitoring systems, and office terminals. These devices are widely distributed across key production areas, continuously collecting critical process parameters (temperature, current, voltage, material levels, etc.) and executing control tasks (anode adjustment, crane scheduling, fault detection, etc.). This layer generates massive industrial data, serving as the primary data source for the entire plant.

The access layer consists of data acquisition terminals, industrial switches, and network management devices. It handles network access for terminal equipment and is functionally divided into multiple domains (production, monitoring, security, office, etc.) to achieve logical isolation and resource management.

The aggregation layer primarily features core routers and SDN controllers that centrally manage resources from all access domains. It aggregates vast amounts of production data from various workshops and uploads them to cloud platforms for real-time monitoring and intelligent decision-making.

aluminium electrolysis workshops. This helps achieve centralized network control and improves interoperability among various types of network data, addressing issues caused by protocol and hardware incompatibilities, thereby enhancing networking flexibility. On this basis, a transmission optimization method based on node-importance ranking is proposed. This method uses the node residual load capacity to measure the importance of nodes in the network, thus reserving more bandwidth and buffer resources for critical nodes and reducing network instability caused by temporary node failures.

7. References

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