Design and Implementation of Wireless Network Control System for Briquette Production

Zheng Chen¹, a, Zhuguo Li², b, Chengzhao Chen¹, c

¹College of Arts & Science of Jianghan University, Wuhan 432200, China
²Hubei Radio & TV University, Wuhan 430074, China

a mosizheng@qq.com, b lzg440@163.com, c shiro220@qq.com

Abstract. With the implementation of the sustainable development strategy, the control system of industrial production also needs to be kept up with the pace of environmental protection and energy conservation. This paper discusses the design and implementation of wireless network transformation of briquette control system in chemical production. The hardware and software implementation scheme is designed for industrial wireless network control functions. The brief solution and the corresponding network architecture are designed. The security, routing and control performance of the network are tested. The results show that the system has good fault tolerance and real-time performance.

1. Introduction

With the implementation of the sustainable development strategy, the control system of industrial production also needs to be kept up with the pace of environmental protection and energy conservation. How to optimize the control system to adapt to higher requirements has always been the goal pursued by the industry [1]. Due to the continuous exploitation of coal mines, coal, which is the primary raw material for the chemical industry, has become an extremely important source of energy for plants throughout the world. Under the condition that it is difficult to obtain high quality lump coal, it is economical and effective to use the machinery to make pulverized coal into qualified coal rod. The production process of pulverized coal by particle size bonding and then mechanically pressing into different shapes of lump coal is called briquette.

Briquette is made of pulverized coal. In the process of production, binder and other additives are added to ensure the cold strength and thermal stability, thermal strength and activation of the briquette. The factors that affect the quality of briquettes are ash fusibility, which is characterized by ash melting point, volatile matter and moisture in coal. The moisture of coal is composed of the adsorbed free water on the surface and the crystal water in the coal mine. During the combustion process, excessively high volatile matter and crystal water will precipitate, which will lead to the thermal stability and strength of the damaged coal, causing the collapse and pulverization of the briquette in the furnace thereafter. To make a suitable coal for specific purposes, the first step is to analyze and measure the coal. In addition to the four industrial analyses of moisture, ash, volatiles and fixed carbon, the ash melting point of coal is also determined because it directly affects Future combustion process. There are many factors affecting the quality of coal briquettes. In the production process, various important process parameters must be monitored in real-time.
2. Node configuration & Software solution

This paper considers the wireless network control system based on wireless nodes, that is, the device uses the wireless node to perform local area networking, and then connects the small local area networks of each device together to complete the information network fusion task of the whole plant[2]. Equipments originally equipped with a controller such as an PLC is intended to increase the cost of the wireless transceiver unit to send operational information or to receive superior control commands. The device without the controller directly sets the wireless node to send and receive data, and the operating parameters of the collecting device are sent out, and the control command is commanded to direct the device to operate correctly.

Each device of the industrial wireless application is configured with different nodes as needed, and at least two wireless nodes are configured for each parameter point to facilitate data redundancy to ensure system reliability. Different types of nodes are assigned according to the operating conditions and control requirements of the equipment, as shown in Table 1.

| Table 1. Nodes allocation |
|---------------------------|
| Node Type                | Regular | Memory | Gateway |
| Vibrating filter          | ○       | ○      |         |
| Crusher                  | ○       | ○      |         |
| Mixer                    | ○       | ○      |         |
| Crane                    | ○       | ○      |         |
| Composition analysis     | ○       | ○      |         |
| Control adjustment       | ○       | ○      |         |

In the entire network control system, various tasks can be divided into three categories according to time: cycle-driven, event-driven, and emergency[3]. A cycle-driven task is a task that needs to be processed repeatedly every other fixed period, and the trigger time has a periodicity. An event-driven task triggers a certain operation by an event that occurs, and the time for triggering execution of such a task is not fixed, and may be long. Short emergency tasks need to be processed immediately when an abnormal situation occurs, and the trigger time is completely random. The six categories of tasks listed in Section 2 are divided by time as shown in Table 2. Although the control adjustment and consumption output calculation are both event-driven, the control adjustment needs to be calculated at any time, and the production and consumption measurement is generally triggered once a shift, one day, etc., and both are event-driven.

In addition to the need to equip the appropriate type and number of nodes as hardware support, the control system needs to perform appropriate overall and partial software design for the system, mainly for different settings of the upper computer and the lower computer. That is, the design of the human-machine interface program and the configuration of the network control function are implemented.

| Table 2. Tasks by time |
|------------------------|
| Task Type             | Cycle-driven | Event-driven | Emergency |
| Device Status         | ○            |              | ○         |
| Composition           | ○            |              |           |
| Control adjustment    |              | ○            |           |
| Productivity          | ○            |              |           |
| measurement           |              |              |           |
| Emergency dispatch    |              |              | ○         |
| Automatic recording   | ○            | ○            |           |

Industrial wireless network is the contact link of the whole plant or the whole workshop. It needs to complete the node network self-organization function, information transmission function and real-time control function. The self-organizing function and the information transfer function can download the
self-organizing network protocol similar to that discussed to the inside of the node, and then assign the task instruction to each node to implement communication. The real-time control function is a task requiring high control and other requirements. The gateway node is required to ensure the smooth flow of the network and ensure the real-time performance of the task. In the initial practical configuration, we encountered some problems that are not the same as the conventional control system.

3. Industrial wireless network architecture
Various data streams will be generated during the network operation. How to ensure the smooth and efficient transmission of data information is the foundation of the network[4-6]. We add data fusion functions to the network. The designed industrial wireless network architecture is shown in Figure 1, including the Sensor Execution Subsystem (SAS), Data Transfer Subsystem (DTS), Application Service Subsystem (ASS) and other subsystems. The corresponding relationship between the designed architecture and the Internet (Internet) protocol stack can be seen from the figure. The sensing execution subsystem completes the functions of the physical layer and the link layer of the traditional Internet. The data transmission subsystem is equivalent to the network layer of the traditional Internet. The transport layer, the application service subsystem corresponds to the application layer of the traditional Internet. These three subsystems are simultaneously connected to the configuration service subsystem (CSS) to complete the corresponding configuration services. For different functional nodes, different entities of the architecture can flexibly configure the protocol stack in different ways. The gateway node can be used as the control center of the local area to configure the protocol stack of the local area. The sensors and actuator nodes only need to implement sending and receiving. Simple features.

![Figure 1. Industrial wireless network architecture](image)

4. Network system performance test
The wireless network control system designed in this chapter aims to realize the system production control tasks and ensure the efficient completion of the data transmission and control tasks of the wireless network[7]. The main performance is the construction and stability of the network topology, and the reliable operation and routing of the nodes in the interference situation. Intelligence, communication security, etc. Regarding the topology, as discussed in Section 4, using deterministic clustering, the addition of new device nodes is also studied there. This section observes several other features of the system.
4.1. Node anti-interference communication performance
The primary obstacles affecting the implementation of wireless control in the industry are the ubiquitous communication interference and the safety of wireless channels, including high-frequency noise of large-scale mechanical equipment, interference from wireless systems in the same frequency band, etc., which need to be specifically designed. An effective security mechanism to ensure the security and efficiency of communication in the wireless network control system in the presence of interference. Figure 2 shows the test that the normal wireless communication is affected when the channel is interfered.

4.2. Routing performance
Under the condition of different node quantity and control loop quantity data, the transmission performance transmission performance and control performance of the designed network system are tested. Figure 3 compares the network performance before and after the data fusion function is enabled. As can be seen from the figure, the data fusion function has obvious effect on improving the packet loss rate performance of the network system. Figure 4 shows the impact of data fusion on routing performance during end-to-end multi-hop transmission. From the perspective of the entire testing process, data fusion capabilities help increase end-to-end throughput.

![Figure 2. Anti-interference security performance](image)

![Figure 3. Impact of data fusion on network performance](image)
5. Conclusion

This paper discusses the design and implementation of wireless network transformation of briquette control system in chemical production. Combined with the production process of briquette, the system requirements are studied. The hardware and software implementation scheme is designed to solve the common problems that may occur in industrial wireless network control functions. The brief solution and the corresponding network architecture are designed. The security, routing and control performance of the network are tested. The results show that the system has good fault tolerance and real-time performance.

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References

[1] A. F. Liu, Q. Zhang, Z. T. Li, Y. J. Choi, J. Li, and N. Komuro, "A green and reliable communication modeling for industrial internet of things," Computers & Electrical Engineering, Vol. 58, No. pp. 364-381, Feb 2017.

[2] X. M. Li, D. Li, J. F. Wan, A. V. Vasilakos, C. F. Lai, and S. Y. Wang, "A review of industrial wireless networks in the context of Industry 4.0," Wireless Networks, Vol. 23, No. 1, pp. 23-41, Jan 2017.

[3] F. G. Li, Z. H. Zheng, and C. H. Jin, "Secure and efficient data transmission in the Internet of Things," Telecommunication Systems, Vol. 62, No. 1, pp. 111-122, May 2016.

[4] T. Qiu, N. Chen, K. Q. Li, D. J. Qiao, and Z. J. Fu, "Heterogeneous ad hoc networks: Architectures, advances and challenges," Ad Hoc Networks, Vol. 55, No. pp. 143-152, Feb 2017.

[5] M. Chiang and T. Zhang, "Fog and IoT: An Overview of Research Opportunities," Ieee Internet of Things Journal, Vol. 3, No. 6, pp. 854-864, Dec 2016.

[6] H. Yang, J. Zhang, Y. Zhao, Y. Ji, J. Wu, Y. Lin, et al., "Performance evaluation of multi-stratum resources integrated resilience for software defined inter-data center interconnect," Optics Express, Vol. 23, No. 10, pp. 13384-13398, May 18 2015.

[7] X. Luo, Y. Yang, Z. C. Ding, S. Fang, S. Q. Li, and Ieee, "Lower Bound Capacity Based Scheduling in MU-MIMO System," 2011 6th International Icst Conference on Communications and Networking in China (Chinacom), No. pp. 191-195, 2011.