Wireless Control System Design for Coal Transportation Plant Based on Two-part Tariff System

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Abstract. Under the current tariff policy, large industrial users, such as coal transportation companies, are typically charged a two-part tariff. This tariff policy limits the maximum value of the average load every fifteen minutes for a month, with an additional charge for electricity consumption when the threshold is exceeded. The article proposes a wireless monitoring and control system for coal transportation plants in response to this policy. First of all, the backup power supply and control circuit were added to the electric equipment of the coal transportation plant. Then build a ZigBee wireless sensor network, terminal and relay connected, coordinator and PLC connected. Finally, when the sensor monitors the actual electricity consumption is about to reach the maximum value set in the PLC, PLC sends a command through the ZigBee to control the relay action and switch to the backup power supply. The experimental results show that the wireless control system has a clear structure and effective strategy, which can reduce the basic electricity cost of the coal transportation plant.

Keywords: Two-part tariff; Wireless control; PLC; Large industrial power; ZigBee.

1. Introduction

Document No. 9 issued by the State Council in 2015 puts forward the spirit of further deepening the reform of the power system and promoting the sound and rapid development of China's power industry. Efforts should be made to solve the outstanding contradictions and deep-rooted problems in the power industry and to promote structural transformation and industrial upgrading [1]. The document proposed that China implement a two-part tariff policy for large industrial users with transformers’ capacity of 315 kVA and above [2], and this policy divides the tariff that customers have to pay into two parts - the basic tariff and the tariff of electricity. The basic price of electricity according to the user's maximum demand for charges, and when more than the maximum demand for a fixed value will be charged high additional charges, therefore, how to reasonably plan the maximum demand for electricity and reduce the plant's expenditure has an important research significance.

Based on the above problems, this paper proposes a wireless control system for large industrial users, such as the coal transportation industry. The control system designed in this paper consists of a programmable logic controller (PLC), wireless sensors, switching circuitry, backup power, and human-machine interface.

The working principle of the system is: increase the user side of the standby power supply, the current 15min average load within the system is about to exceed the maximum required consumption, it will be switched to the standby power supply, and no longer use the grid power supply; to the next 15min to switch back to the grid power supply, and the cycle repeats.
The backup power used in this system is photovoltaic panels, which will be replaced by a backup power supply when the maximum required amount of power is exceeded, thus reducing the use of electricity from the grid and reducing the electricity bill of large industrial users.

2. Introduction to the Two-part Tariff Policy
The two-part tariff is, for all practical purposes, a tariff that is divided into two parts: a basic tariff based on the customer's access to the system's capacity or demand, and a power tariff based on the amount of electricity counted in the customer's meter [3].

2.1. The Significance of Two-part Tariff
According to the current industrial situation in China, the implementation of two-part tariff policy in large industrial users - especially in the coal transportation industry - can give full play to the leverage of electricity prices and always urge large industrial users to use electricity-consuming equipment rationally. Besides, the implementation of a two-part tariff will improve power factor, increase equipment utilization, depress maximum load, reduce electricity expenses, increase grid load factor, reduce reactive load, and improve the grid's ability to supply electricity [4].

In the electricity market, the introduction of a two-tier tariff would enable consumers to bear a reasonable share of the fixed costs of electricity production. The basic tariff is calculated based on the capacity of the customer's electricity consuming equipment or maximum demand usage. The higher the equipment utilization or load factor of the customer, the fewer electricity bills he has to pay, and the lower his average electricity price.

2.2. Basic Tariff Calculation Method
According to the Jzsz [2008] No.187 document, large industrial users with the capacity of receiving electric transformers at or above 315kVA (including high-voltage motors not passing through transformers) should pay the basic electricity charges according to the capacity of 25 yuan /kVA or the demand amount of 37.5 yuan /kW. The basic electricity price is decided by the user and the power grid enterprise through negotiation, and the contract is signed. The basic electricity price is calculated and collected according to the contract value. If the actual maximum demand of the user exceeds 5% of the negotiated value, the basic electricity price of the excess part will be charged by double [5].

3. Overall Composition of the System
Based on the aforementioned two-part tariff policy, this paper designs a wireless control system for large industrial users to help them reduce their electricity bills.

The control system designed in this paper consists of a programmable logic controller (PLC), wireless sensors, switching circuitry, backup power, and human-machine interface. The main control unit of the system is PLC. The controlled part is the relay group. The main control signal is the power data, which is detected by the wireless power sensor arranged on the side of the consumer device.
The overall design of the system is shown in Figure 1. The relay group is used to control the switching of the standby power supply to achieve the purpose of reducing the user's electricity bill. In combination with the HMI and PLC, the target value (maximum required quantity) can be set directly in the HMI. PLC comparing the actual value (measured value of the sensor) and controlling the relay group via the ZigBee module, the backup power can be switched on and off to save electricity costs. The actual value of the system and the operating parameters of the backup power can be monitored in real-time to achieve early warning and recording functions.

4. Wireless Control System Design

4.1. Control System Hardware Design

4.1.1. Hardware composition. The hardware control equipment is based on ZigBee wireless network system, with ZigBee coordinator nodes and terminal nodes forming a star network structure [6].

The connection between the upper and lower ZigBee networks is through a serial port. The wireless power sensor is installed on the electrical equipment, and its measurement data is received by the ZigBee coordination node, which is connected to the PLC through a serial port. The PLC central control module collects data from the field sensors and automatically matches the operating state of
the switching circuit with a present threshold value. The main control link of the system is implemented by the PLC so that even if the PC is not turned on or abnormalities occur, the field equipment can still run normally.

4.1.2. ZigBee wireless communication protocol. ZigBee is a low-power LAN protocol based on the IEEE802.15.4 standard. The chip and wireless network developed based on this protocol have great application prospects in the market. It is a very practical technology for wireless communication which can be widely used in the field of automatic control and remote control.

The communication function of the wireless control system described herein is implemented based on the ZigBee communication protocol. The wireless communication system uses a distributed network structure with one coordinator and two terminals (monitoring terminal and control terminal), and the coordinator is responsible for summarizing the information from the routers and terminals. At the same time, the routers distributed in each node act as repeaters for each other, enabling a wide range of data transmission during large-scale use. The coordinator communicates with the PLC via the Siemens CP340 serial communication module and transmits the data from the wireless sensor network to the PLC for analysis and processing.

4.2. Control System Software Design

4.2.1. PLC programming principle. The PLC programming software used in this article is Portal, a fully integrated automation software released by Siemens Industrial Automation Group [7].

According to the two-part tariff policy, the system needs to judge the maximum consumption of the electrical equipment through the electricity forecast in advance, and this value is set as the PLC judgment threshold. Once the preparations are complete, we can design and write the PLC program.

The main work of PLC in this control system is as follows: after the electrical equipment starts, PLC gets its power consumption in real-time, and through certain calculation and comparison with the threshold value, when the real-time data within 15 minutes is greater than the threshold value, switch to the standby power supply, and then switch back to the grid power supply after the clock reaches 15 minutes; If the power consumption does not reach the threshold within 15 minutes, it will be continuously supplied by the grid.

The specific PLC workflow is shown in Figure 3.
System initialization

Communication is Working?

The PLC notifies the stop

The sensor transmits power data

The real-time data is greater than the threshold?

The clock reached 15 minutes?

Connected to the Power grid

Re-communicate

Shutdown

End

Connect to backup power

Y

N

Y

N

Y

N

Figure 3. PLC work flow chart.

Finally, the ladder program is written according to the above PLC workflow and downloaded to the PLC for execution.
4.2.2. HMI design. According to the system requirements, the HMI consists of system main screen, system control screen, system parameter setting screen, and data recording screen. You can go from the system main screen to each sub-screen, and each sub-screen can return to the main screen in one step.

Displays on the home screen the maximum demand of the system, whether the power-consuming equipment is operating normally and the amount of power it consumes in real-time, whether the backup power is on and the amount of power it supplies. In addition to this, the home screen also has a button that points to open other screens.

The specific settings are shown in Figure 4.

![Figure 4. The main screen of HMI based on WinCC.](image)

The system control screen is mainly used to control the operation of the controlled device and display the operating status of the switch circuit. The switching threshold of the relay group can be set in the screen (maximum amount of system required).

The system parameter setting screen is mainly to set the internal parameters of the relay group and to display the set parameters.

The data recording screen mainly records possible equipment operation, equipment fault, overload, parameter abnormality, and system fault.

5. Conclusion

In this paper, based on the existing distribution station control system and PLC control, in response to the two-part tariff policy, by adding backup power and control circuit to design a wireless control system.

The hardware is equipped with PLC, back-up power supplies, and switch circuits to create a monitoring and control framework that combines a PC, PLC, and in-plant power supply.

Software design is based on Siemens Portal software, PLC control instructions are designed by writing ladder diagram program; HMI is designed by Portal's built-in WinCC, easy to interact with the upper computer and monitoring program.

The wireless control system described herein transmits power information in real-time through a wireless power sensor, and the PLC is designed to control the timely switching of backup power, thereby reducing the electricity bill of large industrial users. At the same time combined with sensor monitoring, image transmission, and other technologies to achieve intelligent and remote monitoring and control, this system has broad application prospects.

Acknowledgments

I would like to express my gratitude to all those who helped me during the writing of this thesis. I acknowledge the help of my supervisor, Prof. Du, who has offered me suggestions in academic studies. In the preparation of the thesis, she has spent much time reading each draft and provided me with advice. Without her patient, insightful criticism and expert guidance, the completion of this thesis
would not possible. I also a special debt of gratitude to all the professors in college, from devoted teaching and enlightening lectures I have benefited a lot and have prepared for the thesis. I should finally like to express my gratitude to my friends and classmates for their valuable suggestions and critiques which are of help and importance in making the thesis a reality.

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