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Research Article

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Research on Preventing Over-grade Trip in Power Grid of Coal Mine Underground

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ABSTRACT

In order to solve the problem that schemes of preventing over-grade trip in power grid of coal mine can not satisfy the requirement of real-time, this paper proposes a scheme of preventing over-grade trip based on switched Ethernet. This paper analyzes the working principle of the protection system, makes a design of hardware for the intelligent interlock device, and finally conducts a real-time simulation of the preventing over-grade trip system. The results show that the scheme can meet the requirements of speed and selectivity of instantaneous protection to prevent the over-grade trip occurs.

Key words: mine supply system; over-grade trip; switched Ethernet; interlock device; real-time

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INTRODUCTION

The high-voltage power grid of coal mine underground usually uses the power supply system of unilateral power in multi-level trunk. Due to the distribution loop impedance is small, making the difference of short-circuit current amplitude between the beginning and end of each segment line is small, and it is difficult to meet the requirements of longitudinal selectivity by distinguishing short-circuit protection by the way of current amplitude [1]. Usually ,when the short-circuit fault occurs in lower line, short circuit current will exceeds the higher instantaneous protection setting value, resulting in over-grade trip [2-3]. In recent years, the use of anti-grade trip scheme of network communication becomes more and more popular. Reference [4] achieves instantaneous protection selectivity by using the RS485 serial network. Because of the low communication rate, requirements of speed can not be satisfied. Reference [5] used the longitudinal differential protection scheme in underground power line with multiple cascading branches. The connection is too complex. The reference [6] constructed interlock protection network of the CAN bus, real-time requirements cannot be met because information of detection and protection share the same CAN bus. The paper proposed a scheme of regional interlocking protection based on switched Ethernet. It has the advantages of high transfer rate, low latency, high reliability, and so on. The quick break locking signal and the detection control signal are relatively independent, so that it can meet the requirement of instantaneous protection of speed and selectivity to prevent the over-grade trip occurs.

DESIGN OF REGIONAL INTERLOCKING PROTECTION SYSTEM BASED ON SWITCHED ETHERNET

In recent years, Ethernet taking advantage of its high communication rate, good compatibility, easiness to expand, gradually enter the area of industrial control. Because the original Ethernet was not designed for industrial control, it is unable to meet the requirements of low latency and determinacy in signal transmission. Switching technology can overcome the disadvantage of uncertainty and poor immediacy of traditional sharing Ethernet, so that Ethernet is widely used in industrial control field [7]. Switched Ethernet connect each segmental network through the switcher,

between each port can be created multiple data paths at the same time, and the data transmission between the ports are no longer bounded by media access control protocol, providing a point-to-point connection between the source and destination ends, enabling the ports to monopolize the bandwidth to quickly complete real-time communications [8]. Therefore, this program uses a switched Ethernet network to integrate a network, using optical fiber as a transmission medium with long transmission distance and immunity to electromagnetic interference.

The program uses the design of switched Ethernet of tree structure and it is necessary to appendix intelligent interlock device with Ethernet communication interface to each integrated protection device to comprise a regional interlock system. Protection system diagram as shown in figure 1. In fig.1 IID is intelligent interlock device, IPD is integrated protection device.

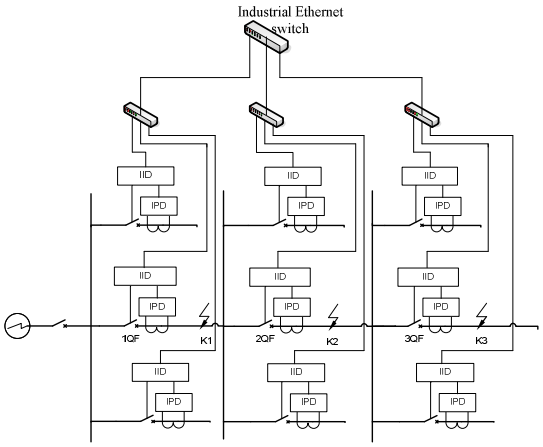

Fig.1: Interlock protection system diagram based on switched Ethernet

When a fault is detected, intelligent interlock protection device operates an interlock with a latency of 10ms on the action of instantaneous protection devices (except the last stage), while send interlock signal to all the superiors smart interlock device through the network. As receiving an interlock signal, each intelligent interlocking device will delay 10ms automatically, thus arrange all levels of protection operating time. This scheme can prevent over-grade trip and have back-up protection, with high reliability.

When the short-circuit fault occurs at point K3, protection 1, 2, 3 through the short-circuit current, intelligent interlocking device 1 to 3 can detect the fault, the corresponding protection lock. At the same time sends the interlocking signal to all superior interlocking devices. That is device 3 sends the interlocking signal to device 2 and 1, device 2 sends the interlocking signal to device 1.Therefore, the protection 2 received one quick break protection signals and one interlocking signal, delay 20ms. Protection 1 received one quick break protection signal and two interlocking signal, delay 30ms. Protection 3 did not receive the interlock signal, will output trip signal after 10ms. If the protection 3 refused to move, protection 2 will start after 10ms. If protection 2 also refused to move, protection 1 will start after another 10ms. Similarly, when the short-circuit fault occurs at point K2, protection 2 delay 10ms, protection 1 delay 20ms, and so on.

To achieve the above program, the key lies in devising a reasonable and reliable signal transmission network between all levels of intelligent interlock protection device, timely and accurately transmit interlock signal within the first 10ms, so as to arrange operation time of all-leveled integrated protection devices.

DESIGN OF INTELLIGENT INTERLOCK DEVICE WITH ETHERNET INTERFACE

Intelligent interlock device is a key part of the preventing anti-grade trip system, mainly to complete the signal detection and logical judgment of the same level quick break protection and lower level interlock, as well as to delay lockout the same level quick break protection and summit interlock signal to superior intelligent interlock device and so on, to prevent multiple lines simultaneously trip.

Intelligent interlock device is primarily composed of 89C52 microcontroller, peripheral circuits, the trip circuit, the Ethernet interface circuit and the like. The microcontroller mainly analyzes the communication signal, and sends the interlock signal via the Ethernet interface module and to control the delay tripping of breaker by the trip circuit. Single-chip carries out digital conversion, calculation and judgment on signal.

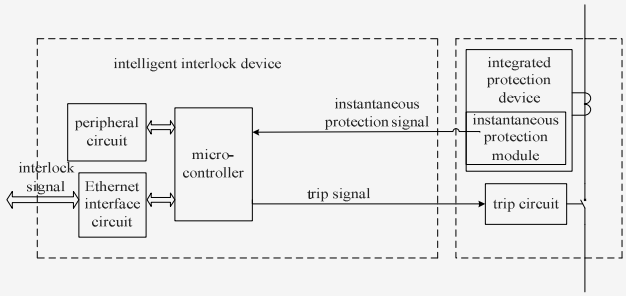

Fig.2: The structure of intelligent interlock device

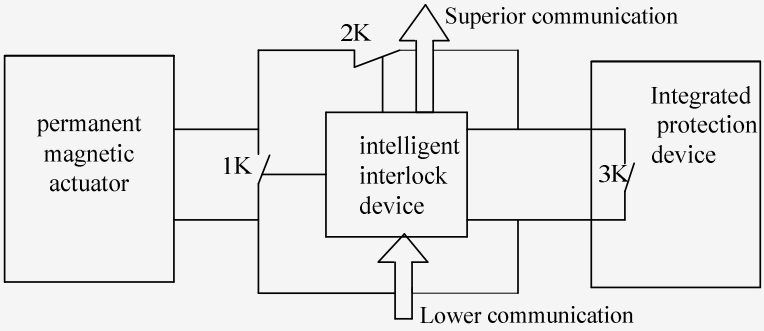

Fig.3: Intelligent interlock device connection diagram

Connection diagram of intelligent interlock device, original conventional high voltage protection and permanent magnetic actuator tripping circuit is shown in Figure 3. 1K is the normally open contacts of smart interlock exports relay. 2K is the normally closed contacts of relay which reflect the intelligence interlock device work state. 3K is the normally open contacts of integrated protection device instantaneous protection exports relay. When short circuit, integrated protection device instantaneous protection operates and the output contact 3K is closed. The intelligent interlock device start which detect the signal of interlock, logical comparison and logical judgment, 1K relay delay closure, and finally to achieve the purpose of preventing anti-grade trip . When smart interlock device malfunction, 2K relay coil de-energized, the normally closed contact closed, intelligent interlock device quit working, restore the original protection trip circuit. So intelligent interlock device failure does not affect the original protection devices operate properly.

SWITCHED ETHERNET REAL-TIME SIMULATION

Underground Coal mine usually use multi-stage type radial power grid consisting of short cables. The inlet and outlet protection devices of each level are relatively much and installation stage of grade and grade are relatively dispersed, thus this network utilize three tree topology, and the network simulation software OPNET Modeler simulate experiments to verify its immediacy. In this paper, simulation experiments employs the method of setting a plurality of communication nodes in the network sending and receiving data simultaneously to verify real-time and reliability of the network, indicating when multiple intelligent interlock device simultaneously sending signals , each interlock signal can reach within 10ms in a real-time and reliable manner. In order to ensure the absolute reliability of the system, we assume an extreme case the network with 64 nodes to send data simultaneously. The simulation network model is shown in Figure 4. The secondary level has eight switches, each of which connects to eight subordinate switching stations with a total of 64 nodes.

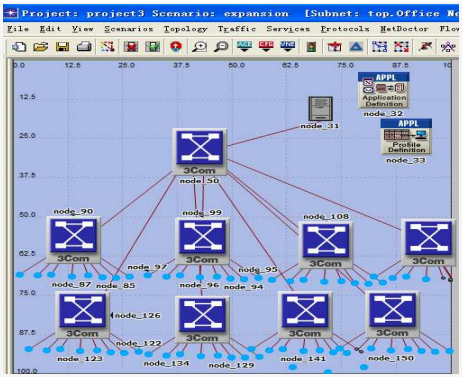

Fig.4: Model of simulation Network

The simulation experiment set the network data service by means of Application tool, and transmit date of 64bytes per 10ms , the time of the simulation test is set to 360s [9], the simulation data obtained of communication delay is shown in Figure 5 and 6.

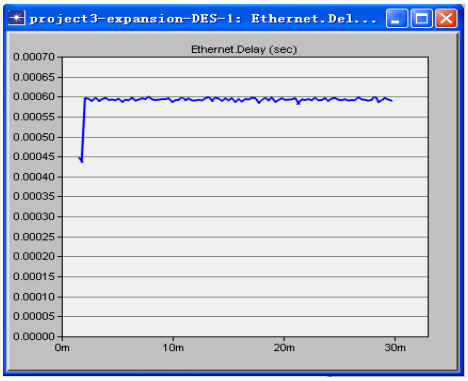

Fig.5: Overall communication delay of network

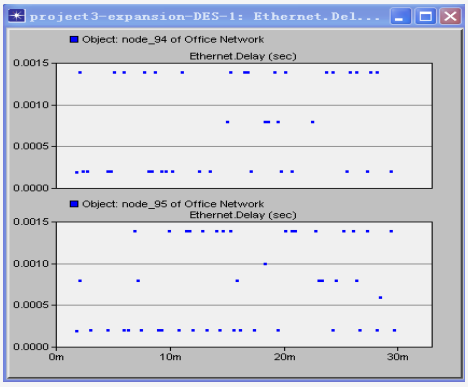

Fig. 6: communication delay of randomly selected two network nodes

Figure 5 shows the average value of the whole network delay, is the evaluation of the entire network environment. The figure shows the delay time curve is relatively small fluctuations, explain the network status is relatively stable. The maximum value of the delay is less than 0.65ms, although this value is small, but it does not accurately reflect the latency status of each node on the network to send and receive data. The need for transmission delay status of each node in the network is inspected to determine the network transmission time can satisfy the system interlocking signal transmission time limit. Figure 6 captures the sending and receiving delaying time data of the two network nodes. It is suggested that the delay of each network node are a series of discrete values, which are determined by the characteristics of the periodical transmission. Since the data transmission time of each node is random, the delay

of the two network nodes in the graph are not exactly the same, but in overall view, similarity is of high degree, indicates that the network owns high reliability and stability, whose maximum delay time is no more than 1.39ms, fully accorded with the time limits of 10ms latency of area Interlocking.

The system simulation test time prolonged to 100 hours, by observing the node to send and receive data flow, end-to-end delay and delay fluctuation test the stability of network long time operation were obtained Figure 7 and 8.

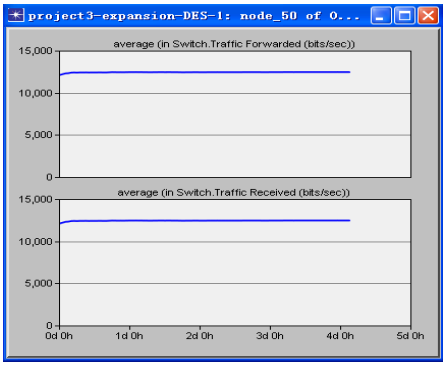

Fig.7 Send and receive data flow of network nodes

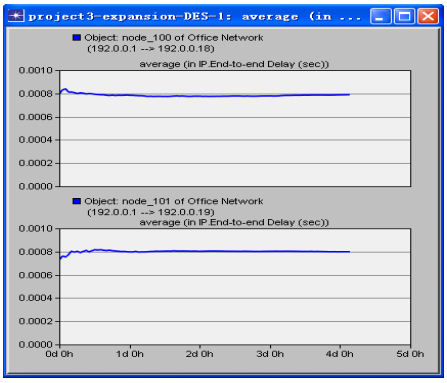

Fig.8 End-to-end delay of randomly selected two network nodes

It can be seen from Figure 7, after long time operation of network, the whole sending and receiving data flow is relatively stable. It is very suitable for interlock system, because it has the characteristics of small amount of data transmission, high requirements on the stability and reliability of data transmission. Figure 8 shows end to end delay and delay fluctuation average of the randomly selected two network nodes. The end-to-end maximum delay is less than 1ms, and tends to be a straight line. End-to-end transmission data between the various network nodes is very stable.

From the above simulation results, in extreme cases, while 64 network nodes to send and receive data, the system uses switched Ethernet in either the maximum delay time, the overall reliability of the network or end-to-end connection stability, etc., are able to meet system transmission signal reliability and real-time requirements.

CONCLUSION

In the solution of preventing anti-grade trip in underground power supply system based on Ethernet, intelligent interlock device is connected in series between the output interface of high-voltage integrated protection device instantaneous protection and the input interface of breaker tripping mechanism, without the need of changing the structure of the power supply system, possessing the advantages of simple connection, high reliability, meeting real-time requirements and so on. With the development of integrated protection technology, though the way of optimizing the design of conventional high-voltage integrated protection and the anti-grade trip intelligent interlocking functionality directly into the integrated protection device, simplifying preventing anti-grade trip to improve the reliability of the system, we can make more conspicuous the advantage of transmission capacity, high speed, real-time of switched Ethernet network.

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