[Article ID] 1003- 6326(2001)06- 0960- 05

Microprocessor based protecting and monitoring system for transformer of electric furnace in nickel smelting process ①

LIAO Li-qing(廖力清), ZENG Ke(曾 可), LING Yu-hua(凌玉华),
YANG Xin-rong(杨欣荣), CHEN Yan-hui(陈燕辉)
(College of Information Science and Engineering, Central South University of Technology,
Changsha 410083, P. R. China)

[Abstract] In nickel smelting process, the working conditions and surroundings for the transformer of electric furnace are worse than general electric power transformer. It is difficult to meet the requirements on reliability and safety by the conventional centralized control protection. With the development of microcomputer and field-bus technology, it is necessary to design a new type of protection and monitoring system for transformer of electric furnace. A microprocessor-based protection and monitoring system was described, which uses the embedded high performance microprocessor 87C196KC-20 as its most important micro- controller unit & the technology of CAN (Controller Area Network) making it a fully distributed microcomputer system not only to perform all sorts of the transformer protection and function of automatic co-inciding and communicate with the monitoring host, but also to carry with it the function of protecting, measuring, and fault diagnosis for transformer of electric furnace.

[Key words] electric furnace transformer; microprocessor; microcomputer protecting; CAN field-bus
[CLC number] TP216 **[Document code]** A

1 INTRODUCTION

Electric furnace transformer is an important electric equipment in the process of nickel smelting, but the conventional/centralized protection cannot meet the need for reliability and security, and its preliminary equipment is evolving towards the direction of digital full distributed. The microprocessor based protection and monitoring system for depleted electric furnace introduced in this paper can not only be used to construct a new protection and monitoring system, but also be used to reconstruct the original system when the microprocessor based protecting and monitoring unit is located in the place originally left for relay protection equipment in the high voltage switch cabinet.

In this fully distributed and integrated automation system field-bus technology is used to realize the communication between the protecting and monitoring equipment and the host through CAN/82C200 and to realize the current quick-break protection of electric furnace transformer and other mothball protection through full digital algorithm; DELPHI language programming is also used to attain parameter displaying, modification and operation in the host monitoring interface.

It is well known that there are two kinds of treatment of copper sulfide and nickel sulfide: fire metallurgy and wet-process metallurgy. The main equipment used in this process are drier, drum furnace/boiling kiln, electric furnace, revolving furnace, air furnace and electric tank. Furnace smelting is an important process in smelting nickel, and its main equipment is depleted electric furnace. By adding liquid slag and solid reducing agent, the furnace can deplete the slag which contains considerable amount of cooper, nickel, and cobalt[1].

During electric furnace smelting, the most important index of technologically economic index is the productivity of the electric furnace, which depends closely on the power and utilization factor of electric furnace[2].

Compared with commonly used electric power transformers, electric furnace transformer has its specific characteristics: unreasonable working conditions; higher demand for rapidity, selectivity and reliability; high transformation coefficiency, this means high voltage in wire inlet, low in wire outlet; low secondary voltage while big secondary current which can be ten thousand ampere; high intensity of interior component to stand extra duty of current in a short time, thus to keep winding insulated and intact. Because when the current intensity is heightened or in short circuit, it will produce enormous mechanical stress in the transformer; The secondary voltage should have several voltage grade to fit for the technical need. Moreover, secondary voltage has important effect on index of smelting, in order to make electric furnace work with the most reasonable electric rule, there should be several voltage groups whose value should be determined by technical requirements, and the measure is adding auxiliary tap in the primary

① **[Received date]** 2001- 01- 02; **[Accepted date]** 2001- 03- 28

winding[3].

2 RELAY PROTECTION OF TRANSFORMER AND HIGH-VOLTAGE SWITCH CABINET

2.1 Relay protection of transformer

Faults with transformer can be two kinds: internal faults of oil box and external ones[4]. The internal faults include: phase short circuit and switch short circuit between windings; earthing short circuit of directly earthed system side windings. An internal fault is dangerous, because the electric arc in the fault point can cause damage to the insulator and iron core, and make the insulator strongly gasify, at worst it may result in an explosion. Phase short circuit and earthing short circuit between leading-out wire of winding and drivepipe can be categorized as external faults. Transformer's abnormal working status includes extra duty, overcurrent resulting from exterior short circuit, neutral-point overvoltage resulting from exterior earthing short circuit, over excitation resulting from oil surface depression and voltage or frequency depression. According to these faults and abnormal working status, transformer should have relevant protection measures.

Relay protection of transformer mainly includes gas protection, longitudinal differential protection, current quick-break protection, over burden protection, zero-sequence current protection and so on. Gas protection is to show all kinds of internal faults and oil surface depression, among them light gas protection acts on signal while heavy gas protection is used to switch off the circuit breaker at both sides of the transformer. Longitudinal differential protection is to show all kinds of circuit faults of transformer winding, leading-out wire and drivepipe, and this is the main protection of transformer. Together with gas protection, current quick-break protection indicates all the faults of transformer winding and leading-out wire and drivepipe of transformer's power supply. When transformer power supply is directly earthed system, the complete Y-junction should be adopted, and when the power supply is indirectly earthed system, the two-phase incomplete Y-junction should be adopted. Over-burden protection is used to protect transformer from overcurrent resulting from extra duty. The location of the over burden protection equipment should be determined by load condition of both sides of windings of the transformer. All overburden protection equipments act on the signal through the same time-electric-relay. As to transformers in directly earthed system, zero-sequence current protection should be equipped to indicate over-current resulting from exterior earthing of transformer, and be used as back-up protection for interior earthing short circuit of transformer[5].

Besides the main protections stated above, there should also be corresponding measures with the abnormal working status such as oil surface depression and temperature promotion.

2.2 High-voltage switch cabinet and its action

High-voltage switch cabinet is the whole set distribution equipment, and in factory, it is widely used to control and protect high voltage electric equipment such as transformer, high-voltage line and high-voltage motor. Its protective function is realized by interior protection equipment, it is shown when faults arise it can safely and quickly eliminate them which means when in abnormal working status, it can emit signals to make sure that the equipments are always functioning safely and properly.

For interior and exterior fault of transformer the tripping action of the high-voltage switch cabinet should take place, especially for overcurrent resulting from exterior phase short circuit the tripping action should be time-lagging and for over-burden, oil surface depression and temperature promotion, only signals are given. Furthermore, the basic actions of high-voltage switch cabinet should comply with four requirements: selectivity, quickness, sensitivity and reliability[6].

3 GENERAL DESIGN SCHEME

Considering the features of depleted electric furnace, relay protection of transformer and automation requirement of factory power supply system, we design a protecting and monitoring system for transformer of electric furnace as shown in Fig. 1[7].

3.1 Structure and function

This system is composed of monitoring host computer, protecting units, alternating current UPS and microcomputer controlled direct-current power supply, which is free of maintenance. There is only one shielding communication pair cable connecting the switch cabinet which contain protecting unit and control room which contain host computer and power supply.

3.2 Configuration and function of host computer

IPC is selected as host computer. It is composed of all-in-one CPU card (Pentium-550, 64MB EMS memory, 512KB Cache, EIDE integrated floppy drive interface, two serial ports and one parallel port, AGP based graphic accelerator and 8MB display memory); high speed isolating CAN intelligent communication card (exchanges message with all protecting units) and sound card which are inserted in PCI bus; WindowsNT 4.0 workstation simplified Chinese edition, and software is written with object oriented Borland Delphi, which is easy to display graphics, print report (QuickReport), and operate database

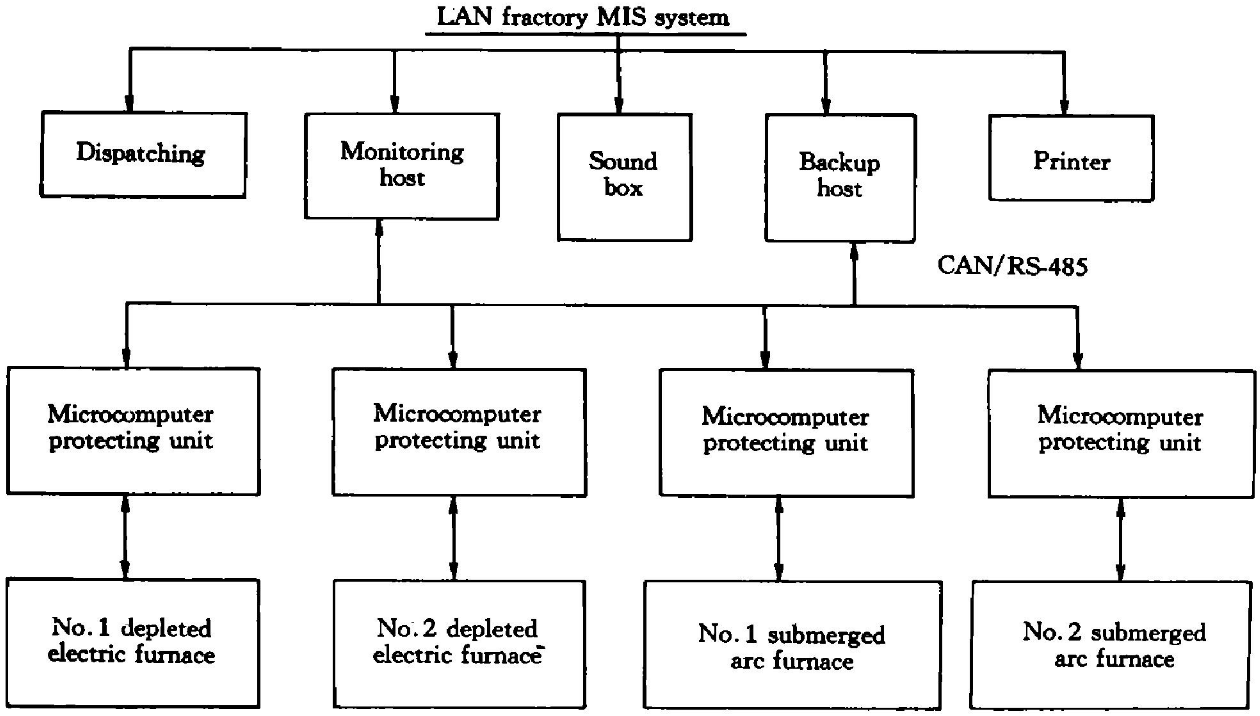

Fig. 1 System construct

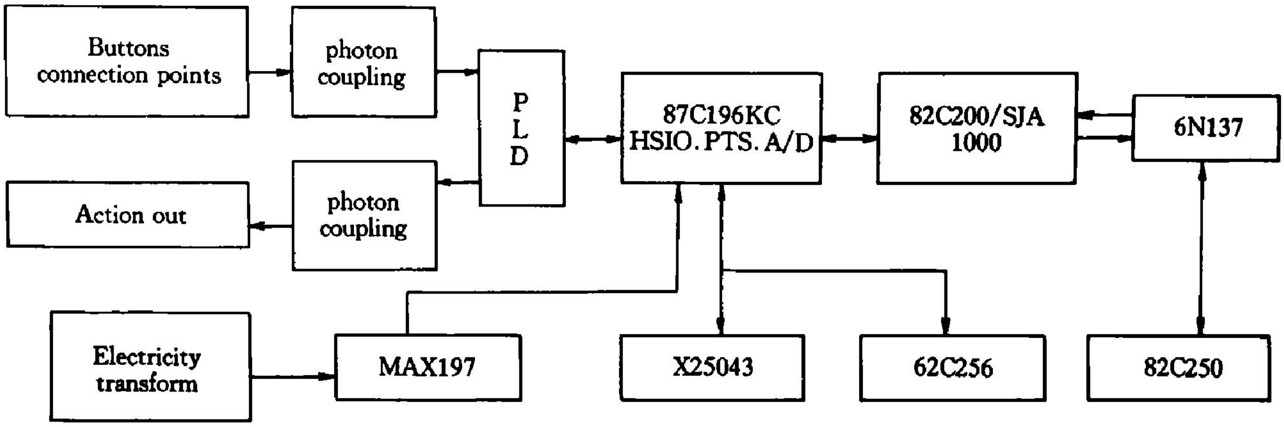

Fig. 2 Protecting unit

(BDE), they also have special functions such as switch operation, parameter setting and password checkout. In order to increase reliability, there can be two monitoring host computers, another used as the auxiliary one.

3.3 Full digital microcomputer protecting units

Fig. 2 shows the protecting units constitution, and this is the base of the whole protecting and monitoring system. It is composed of micro-controller basic system, signal input/output loop, communication interface and corresponding software, all these components are placed on one printed substrate by using VLSI technology and CPLD. In this basic system, Intel 87C196KC-20 served as MCU for this chip has high calculation speed (0.1 μs per clock period), powerful real-time processing ability (HIS, HSO, PTS) and 488 B RAM that has no register bottleneck and its processing speed is two or three times faster than Intel 8098. Program can be solidified in chip 16KB EPROM (OTP)[8], and an extended serial EEPROM is served as operation parameter memorizer, another 32 KB SRAM stores recorded wave data.

Considering the reliability, the protecting units pair with power equipment. So they can work independently, complete full digital data measuring, logical calculation, faults judging, protection and manual operation and they can also communicate with epigynous computer, sending equipment working data and receiving settings. Due to they are isolated from the host computer, these units will resume working when the host stops. When more control protection equipments are needed, just adding a unit within the equipment switch cabinet, and it can work immediately. If a unit is out of function, cease the equipment and change corresponding units, this procedure will not affect other units functions[9].

3.4 Communication

In order to realize communication between protecting units and monitoring host, this system chooses CAN field-bus to construct local network. CAN is the shortened form for control area network, it was first brought forth by a Germany Company Bosch, and was used to communicate between gauging component and executing component in a car. Now, the bus criterion of CAN International Standard Organization (ISO) has been constituted as the international standard. CAN is working in the multi-host mode, so by initiative, any node of the network can transmit message to other nodes at any time. This mode has flexible communication and does not need to know some node information such as address. So using this feature, we can construct multi-backup system. The node information in the CAN network can be divided into several PRI to meet different real-time requirements. CAN field-bus is a serial communication network. It chooses short frame structure, and has short transmit time, low error rate. When there is a grave flaw with the node, it can be shut down automatically, so CAN has a strong anti-interference ability. Compared with general communication bus, CAN has higher reliability, real-time ability and flexibility. CAN controller is mainly made up of protocols that realize CAN field-bus and micro-controller interface circuit[10,11].

The communication protocol of this system is carried through CAN communication controller 82C2000/SJA1000, and this controller has all the characteristics needed to the request of high performance. By simple connecting, we can get all the function of physical layer and data-link layer of CAN field-bus protocol, while function of application layer is completed by micro-controller. 82C250 is chosen as the connection circuit which links 82C200/SJA1000 and physical field-bus, it can provide differential protection and receiving function for field-bus[12].

4 SOFTWARE ALGORITHM

4.1 Alternative current sampling algorithm

In the three-phase alternative current circuit, voltage and current measured are always virtual value. The virtual value of voltage and current can be calculated by

$$U = \sqrt{\frac{1}{N}\sum_{i=1}^{N} U_i^2}$$

$$I = \sqrt{\frac{1}{N}\sum_{i=1}^{N} I_i^2}$$

$$P = \frac{1}{N}\sum_{i=1}^{N} U_i^2 \times I_i$$

For above algorithms, we assume that the sampling number per period is N, discrete voltage sampling value is U_i, discrete current sampling value is I_i.

4.2 Protection algorithm

Protection algorithm is used to realize inverse time-lag feature of transformer protection. The so-called "inverse time-lag feature" meaning time-lag of action is in direct proportion of regulated power of current, the greater the entered current, the shorter the time-lag. Formulas for realizing inverse time-lag feature are listed as below, I_i is the setting value of current, t_p is delay setting of over-current, N is the serial number of chart.

1) Extreme inverse time-lag feature:

$$t = \frac{80t_p}{(I_d/I_p)^2 - 1}$$

2) Unusual inverse time-lag feature:

$$t = \frac{13.5t_p}{(I_d/I_p)^2 - 1}$$

3) General inverse time-lag feature:

$$t = \frac{0.14t_p}{(I_d/I_p)^{0.02} - 1}$$

4) Unusual inverse time-lag feature cluster:

$$t = \frac{0.85 + 0.8 \times (N - 4))}{(I_d/I_p)^{0.02} - 1}$$

5 APPLICATION AND CONCLUSION

This system has been running smoothly for more than one year in a smelting plant of Jinchuan Non-ferrous Metal Industrial Company. It has the combination of powerful microcomputer monitoring system, full digital microcomputer protection technology and high- speed network communication technology. What is most special is that all functions of protection, measuring, controlling, signaling and communication that used to be set independently now has been integrated in one unit in this system and it is located at the space where the relay protection were placed in the high-voltage switch cabinet, so it is the real distributed configuration.

As to the special request of the transformer of electric furnace, the micro-controller and alternative current sampling algorithm technology we introduced has realized high quantity protection and monitoring function such as fault wave recording, harmonic analyzing and online diagnosis which conventional relay protection equipment can by no means accomplish so the hidden troubles of power supply system and facility can be eliminated.

[REFERENCES]

[1] CHUAN Jin. Non-ferrous Metal Industrial Company Nickel Smelting [M]. Beijing: Employee Education Teaching Material Editorial Office of China Non-ferrous Metal Industrial Parent Company, 1988. 26- 58

[2] ZHANG Chuan-fu, LIU Hai-xia, ZHONG Da-long, et al. Thermodynamical analysis of smelting process of nickel sulfides concentrate [J]. Trans Nonferrous Met Soc China, 1999, 9(4): 805- 811.

[3] MEI Chi. The hologram simulation of modern industrial furnace and kilns [J]. Journal of Central South University of Technology, 1999, 30(6): 592- 596.

[4] Elder L A. Economic optimisation of an Australian rural electricity network using automatic circuit reclosers with remote monitoring & control [J]. IEEE Transmission and Distribution Conference, 1999, 1: 310- 313.

[5] CHEN Ji-sen, XIONG Wei-qun. Relay Protection of Electric Power System [M], (in Chinese). Beijing: Water Conservancy and Electric Power Publish Company. 1992. 171- 200

[6] Kischefsky J A. Microprocessor-based recioser control: new technology distribution system protection capabilities [J]. IEEE Transaction on Power Apparatus and System, PAS, 1999, 10: 3030- 3037.

[7] LIAO Li-qing, CHEN Ji-da, DAI Yu-xing, et al. Switch cabinet based full distributed microcomputer protection and monitoring [J]. Natural Science Transaction of Hunan Normal University, 1998(9): 40- 44.

[8] SUN Han-fang. Inter Single-chip 16-bit Microcontrollers [M]. Beijing: Publishing House of Aero & Astro University, 1995. 144.

[9] BAI Yi-cheng, LU Xuan-bing. The distributed and centralized data collection system of microsounding [J]. Journal of Central South University of Technology, 2000, 31(2): 184- 187.

[10] WU Kuan-ming. Theory and Application System Design of CAN Field-Bus [M]. Beijing: Publishing House of Aero & Astro University, 1996. 309.

[11] LIU Jian-she, QIU Guan-zhou. Treating methods of water waste in nickel smelting [J]. Journal of Central South University of Technology, 1997(4): 333- 335.

[12] CHEN Song-qiao, ZHANG Ren-ying. New technology of data exchange in industry control [J]. Trans Nonferrous Met Soc China, 1996, 6(2): 133- 137.

(Edited by LONG Huai-zhong)