An Advanced DCS Control System for Low-Carbon Ferrochromium Production Line

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Abstract:
This paper introduces an advanced DCS system (Distributed Control System). It is the first fully computerized system for the process control of refining furnace in China. The hardware and software systems and some important control strategies are presented in this paper .The DCS system can be widely used in the production lines of low-carbon ferrochromium materials in China.

Keywords:
low-carbon ferrochromium, distributed control system, arc refiner, electrode

1 Introduction
Since American applied computer to a submerged arc refiner(23MVA)and achieved success in 1960's, many developed countries had applied this technology of computer in various ferroalloy production furnace. They have achieved the accomplishment as follow. The consumption of electricity saved by 3-5%, and the production increased by 10%; It also improved the control quality of produces by a large margin. In China, some factories have adopted the computer control technology in the control of electric furnace since 1980. On the basis of experience which obtained from the ferroalloy submerge arc furnace and the computer control in steelmaking furnace , we developed and studied the computer control system used in the production lines of LC Fe-Cr in the arc refiner (6300KVA) in 1990. The ferroalloy works is located in Jilin province. The computer system control has been applied in the refining process and resulted in large economic benefit. Since 1992,Meanwhile, it filled the gap in the field of computer control applied in the LC Fe-Cr producing in China .

2 The characteristics of LC Fe-Cr refining furnace and control demand
The production of LC Fe-Cr in refining furnace is intermittent. It demands that LC Fe-Cr contain 0.03-0.15% carbon content (The best carbon content is less than 0.03%). The refining process is divided into three periods: arc starting and charging period, smelting one, refining one. Each period has different characteristics and control demand.

2.1 Arc starting and charging period
It's about 5 minute from the beginning of electricity supply to the phase current tending to stability, and it's called arc starting, and charging period,
During this period, the characteristics are as follows :arc blowing-out led by unstable arc, switching-off led by overflow current and electrodes breaking.
It should not exist overflow current and switching-off or arc blowing-out, at the same time arc starting must be stable and quick during this period. The key to control is to limit the fluctuation of three-phase A.C currents in a rational range. So it needs to confine the range and frequency of the electrode movements strictly, and to control the electrode rising and descent smoothly . Meanwhile, it needs to control the charging speed for avoiding arc blowing-out. If the arc blowing-out occurs, it should be determine exactly and immediately which electrode arc blowing-out, furthermore start arc in time in order to prevent the accident of electrode breaking

2.2 Smelting Period
From 5 minutes aftei electricity supply to charge smelted over, it is called smelting period in refining technology.
The characteristics of the period are lower temperature, higher resistance of charge and the arc is submerged in unsmelted charge. This period is sub-merged refining process. The charge smelts over and the current tends to stability with the proceeding of refining process .However, many different charge collapses often

occur during this period.

The control demands are to keep the three-phase current balance and supply electricity in full load for cutting down the refining time, to prevent carburetion of LC Fe-Cr resulted from electrode and monitor the charge collapses exactly and raise or descend the electrode automatically.

2.3 Refining period

From charge smelted completely to tapping, it is called refining period.

The characteristics of the period are refinement by exposed arc, radiating heat process, high temperature and large fluctuation of current.

The control demands: three-phase electrodes supply electricity evenly in full load. When the consumption of electricity amounts to 85% of initialization, decrease the power input by 15% and determine the content of silicon in molten metal iron timely, as well as estimate the end of refining process exactly.

In a word, the difficulty of the control system is to control the arc starting and charging. Any operation of electrode by mistake should result in arc blowing- out, overflow current , breaker trip and electrode breaking. While during the smelting period, quick response to charge collapses could greatly improve the product quality, during the refining period decrease power input properly could reduce the power consumption.

3. Macro-plan

3.1 Distributed control system in hardware structure

According to the characteristics of many parameters input and output ,we apply the DCS system to the realization of automatic control in the refining process. Namely, all control functions are fulfilled by programmable controller ,the programmable controller can operate under the central supervision control and also can operate separately detaching from the industrial control computer. The collection of the system information and the data management of the process parameters are carried out by the central supervision. The programmable controller and central supervision are composed of the DCS system. The whole system structure is presented in Fig.1.

3.2 Establishing expert system on control strategy

There are many random factors in the refining process . such as overflow of current, breaker trip, large charge collapse, primary voltage fluctuation, etc. These can not be forecast at present. So it is difficult to establish mathematical model simulating refining process. However, the established expert control system which is

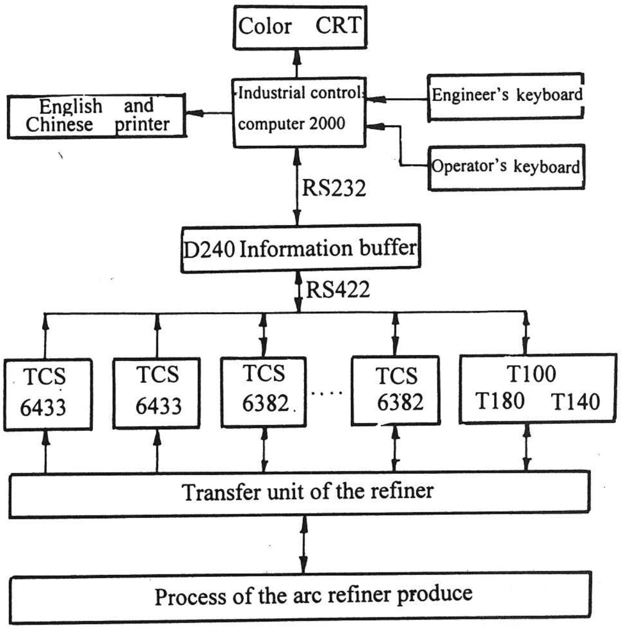

Fig .1 The schematic diagram of a DCS system structure

on the basis of the control regulation optimized by the engineer's experience and many experiment structures can meet with the software design of this system. Perfect expert control system can guarantee the determinative ability and control quality of the computer.

So we designed the software according to expert control system which established on the condition of each refining period. In refining process, computer chooses the control policy to realize completely automatic control in refining process according to identifying the refining condition.

4 Control system of LC Fe-Cr arc refiner

On the basis of DCS. system managing characteristics, The system is composed of three units: industrial control computer, programmable controller and process transmitting unit.

4.1 Industrial control computer

The Action industrial computer , as the supervisor, communicates with the programmable controller through RS-232 serial interface and fulfills the central supervision and management to the whole system parameters. In order to fulfill human-machine communication, the dynamic displaying menu is devised. It includes the dynamic historic tendency figure of the current, voltage, position of the electrode holder, process of the charge collapse, etc. It also includes dynamic digital displaying menu of the each heat parameter, process parameter and the displaying menu of the parameters relative to refining process and accident warning. The industrial control computer can monitor and modify the operating Mode , the pivotal parameters and the set point in the programmable controller. Some parameters disposed by the central supervision monitor are pointed out through CRT and a large screen display . They can be used for guiding refining process, such as refining time, accumulative quantity of electric consumption, silicon content, the complementary quantity of chromesilion alloy, etc. Some data records are set for accumulating experience and analysis the reason of the accident. There are dynamic database and static database in the industrial control computer. They can be used in storing the set point, measured values, output values, some related curves and experiential formula, etc.

4.2 Programmable controller

The programmable controller is composed of the data collecting station, the control station and the distributed I/O channel.

4.2.1 Data collecting station

The processor of software data ((TCS6433)1-2)can collect the data from all the parameters in the whole system process. These data are transported to industrial control computer through a signal buffer segregating unit (D240). So, the information of the whole process is collected in the central supervision, which makes it possible to realize monitor and management in the industrial control computer.

Data collecting station fulfills the transformation between physical constant of process parameters and engineering constant. At the same time, it set the up-and-down warning limit ,and improves the human-machine communicative function.

Furthermore, it also improves the computer operator's level.

4.2.2 control station

In order to realize distributed control function, the intellectual loop controller ((TCS6382)1-3)controls the three electrodes of arc refiner respectively. TCS6382s complete the automatic control in whole refining process according to the control policy determined by the expert system on the basis of different refining condition . The adjustment of transformer tapping switch ,larger collapse disposal and charging control are completed by another special intellectual loop controller(TCS6382-4). In order to intensify the function of control station, TCS6382 is designed the function such as: the conversion of manual-automatic operation, the automatic selection of control strategies on reducing power load , and initial data revision, etc. It is also designed compelled manual operation function. For example, when one phase electrode operates under abnormal condition (It can't start arc normally, or has low voltage, etc.)in refining process, the control station of this electrode system only converts automatic operation to manual and can't affect the whole system operation state. It embodies the advantage of DCS as well as reflects that expert system has reliable function to dispose the especial refining condition.

4.2.3 The distributed I/O channel

The intelligent I/O device T100,as the data collecting station, communicates with industrial control computer through RS-422 standard interface and constructs the distributed I/O channel. The transfer and logic control of all distributed in the system are fulfilled by the channel. The distributed parameters in the refining process are overflow current and breaker trip, lower limit of the electrodes holder, drop to zero voltage, transformer gas, cooling water pressure low ,etc. are the important parameters used to judge the condition of the arc refiner bye the computer. The channel transferring these information is an important part of the system.

4.3 Process transmitting unit

The conversion of the refining process and the computer system information is carried out through this transmitting unit. This system chooses the converter in a series of TCSD(e.g. converter of current, voltage, power, temperature, position, etc.), the instruments which are designed specially(e.g. the position of the electrodes holder, thermo- sensibility inspector of the charge collapse and the instrument based on thermo EMF principle for measuring silicon content before the refiner, etc.).

5 Control strategy

Expert control strategy is the basis of the expert control system. Through adequate demonstrations and contrasting experiments, we establish the expert control strategy, such as: the arc starting and the charging, the disposal of the large charge collapse, reducing load automatically, switch on automatically when overflow occurred, etc. The following brief description is only to the control strategy of the arc starting and the charging and the disposal of the large charge collapse.

5.1 Arc-starting and charging control strategy

The change of refiner condition is complicated in the arc starting and the charging period, such as: unstable arc and large current fluctuation, arc blowing out, over load and breaker trip of over current, electrode breaking, etc. The electric parameter reflecting this situation most directly is each phase current. So the current is the controlled parameter in the period. During the arc starting and the charging the experiment of manual operating is follows: Do not move electrode when the current within a certain wider limitation , while the current greater than the set point ,start charging procedure, the current less than another set point ,descend the electrode a jog and stop charging , current greater than a certain value uplift the electrode a jog . During this period ,do not in pursuance of the balance of electrode current in three phases , but only in pursuance of ensure there are certain current and could charge continuously. The current in fact is controlling parameter, while the current directly related to the electrode position . So the speed and frequency of the electrode motion must be limited and adjusted strictly in the period. These can guaranteed to uplift or descent electrode smoothly, and to utmost reduce the large fluctuation of the current.

Setting the dead area of the current can limit the frequency of the electrode movements. But how to set the dead area of the current influences the control quality directly. Because there are mechanical gearing in this system, small dead area and high frequency of the motion can damage mechanical device and cause vibration of the system easily. If the dead area is too large, the electrode would not be uplifted or descent in time. it should cause overflow, breaker trip and arc blowing out.

On the basis of many optimal comparative experiments, we decide to establish the arc starting and charging expert

control strategy on the principle of low speed and nonlinear control with dead area.

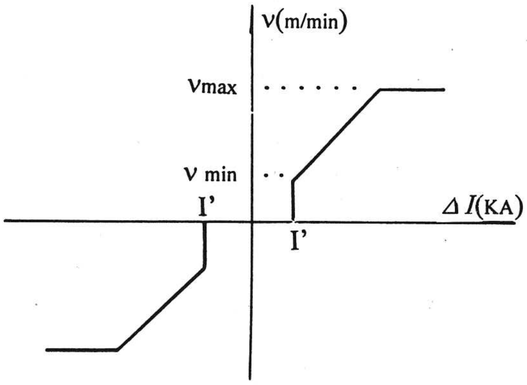

Fig.2 The nonlinear curve of electrode rise and fall

Electrode rise-and-fall nonlinear control curve is presented in Fig.2. In which, γ is the electrode rise-and-fall speed, $\Delta I'$ is phase current deviation, $\Delta I'$ is phase current dead area (Vmax = 0.8m/min, Vmin = 0.4m/min, $\Delta I' = \pm$ 1.5kA).

The control strategy process of the arc starting and the charging is presented in Fig.3. After accepting the order of starting refining, at first electricity is supplied. The electrode system station controls electrode's descent automatically. The electrode system is controlled according to nonlinear curve as soon as one electrode starts arc. The charging system station controls automatically whether meeting the condition of the charge's falling (three-phase phase current (I_A, I_B, I_C), each one is above 10KA). If so, the charging process is controlled according to the charging control strategy. When the arc starting and charging finished, it will switch to control strategy of the smelting period.

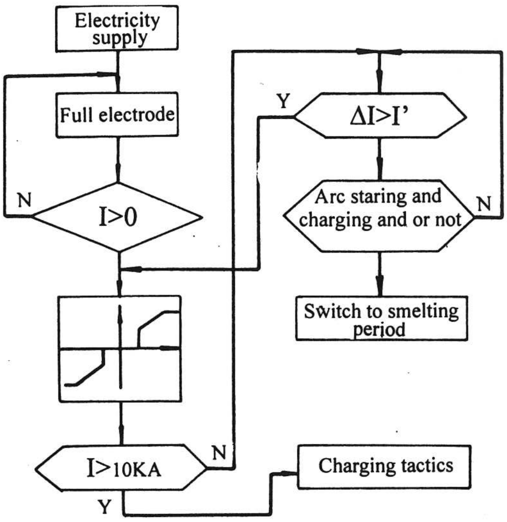

Fig.3 The process flow diagram of arc-starting and charging control strategy

5.2 Strategy for disposal of large charge collapse

The situation of charge collapse often occurs in the refining process. The capacity (γ) in the bath and the volume of gas are unchanged before and after the charge collapse, so the gas temperature (T)increases and that leads to the pressure (P) in the refiner increasing. We can use following equation to describe the physical process.

$$P \cdot V = n \cdot R \cdot I$$

V, n and R are constant, so

$$P = (n \cdot R/V) \cdot T = K \cdot T$$

In the formula, $K = (n \cdot R / V)$ is a constant. So we can find that the pressure (P) has a linear relation to temperature (T) in the refiner. We can use temperature sensor (It is also called charge collapse probe) to monitor the process of the charge collapse.

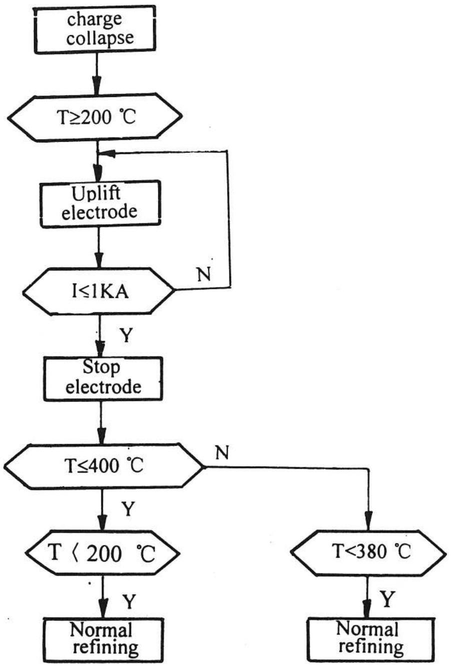

Fig.4 The process flow diagram of charge collapse control strategy

To prevent molten bath from rising and brushing the electrode, that can cause carburetting of the refining alloy, so three-phase electrode should be uplifted in time when charge collapse occurs. When the charge collapse is finished, the electrode should be fallen to the normal position. At the end of charge collapse, If it does not switch to the normal refining control strategy in time, that should influence the current input and prolong the refining time.

Charge collapse probe installed at the gate of arc refiner. When the sensor temperature is above 200℃(T>=200℃), uplift the electrode and keep phase current under 1000A (I<=1000A). In order to converting normal refining control strategy at the end of charge collapse, this process is divided into two condition:

1): The peak temperature T max<400℃, and when the temperature drops to 200 ℃ (T<200 ℃), fall the electrode and resume normal refining.

2): The peak temperature T max>400 ℃, and when the temperature drops to 380℃ (T<380℃), resume normal refining. Control station TCS6382-4 makes the decision of charge collapse disposal according to the identification to charge collapse condition and the control strategy of charge collapse. The station gives out charge collapse disposal instruction to the electrode control system station. The instruction has priority and the electrode control system station carries it out at once. Meanwhile, when it receives the instruction of charge collapse coming to an end, the electrode control system station resumes normal refining process. Fig 4 is process diagram and Fig 5 is the curve of charge collapse disposal.

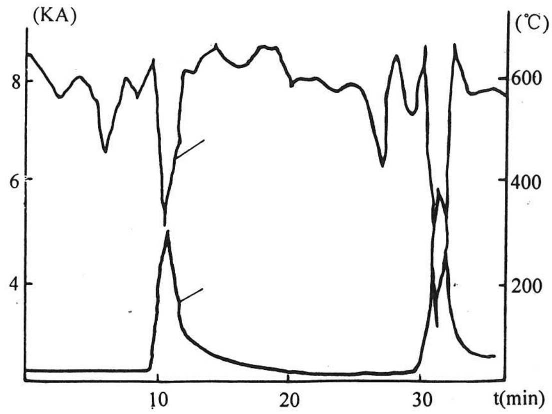

Fig.5 The recorded current curve of charging collapse

The expert control strategy applied in the factory indicates that it disposes charge collapse timely and exactly, and it can meet the demands of process.

6 Conclusion

The 6300KVA Low-Carbon Ferro-chromium refining process control adopted the advanced DCS control system. The system solved the controlling difficulties of the arc starting and charging, guaranteed to have no arc blowing out and few breaker trip , and avoided the accident of the electrode breaking. It also checked and disposed the charge collapse of the arc refiner successfully, and reduced the carburetting led by alloy. The consumption of refiner lining is monitored reasonably .With special developed instrument for immediate measuring metal silicon content before the refiner, the system can calculate complementary chromium-silicon quality automatically , realized the whole metallurgical procedure automatic controlling. To use the system, it made three-phase electrode power tend to balance. It reduced non-balance rate by 5.68% compared with manual operation. The consumption of electricity decreased by 5.68% per ton .

References

1. Browman. B, Ironmaking and Steelmaking, 1982,187--198.
2. Robert SR. Wsochaeky, Jr.M.R, Electric Furnace Proceedings, Vol.34, 1976, 25-33.
3. W.L.Wilberm, Elec. Furn.Proc, 1974, 101.
4. N.H.Keyser. Electric Furnace Proceeding, 1983, 175-180.
5. Huo Naili, Ferroalloy, 1987, 28.