

# 50 tons of steel mill BOF steelmaking dynamic control system and the application of variable-frequency emergency power supply-gun incident oxygen converter steel to enhance the development of power

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## 1. Introduction

In recent years the computer level control of metallurgical process has been widely used in China, at present the several steel in different scale has realized the computer control. In order to improve the product quality and production, expand varieties reduce cost and consumption stable production process use at the converter computer process control has become necessary. After using dynamic steelmaking production which could increase the yield and quality efficient optimization for production process. the production line has rapidly improve the economic benefit of irremediable effect. Therefore. the dynamic steelworks 50 tons converter steelmaking control is imperative.

## 2. The authors summarized

Laigang 4 # converter for no subalance top-blown type annual production capacity of 50 tons in November of 2002 built and put into use through the expansion of transformation is currently capable of 800.000 tons of

production capacity it and generous billet caster productivity matching constitute the short flow line.

The bof dynamic steelmaking control system in January 2004 stable operation began to carry out the normal can perform dynamic steelmaking for data needs. This system mainly complete realized the production management including production operation status display and delivery etc; To begin. converting and converting the state tracking; To the relevant data are collected. and storage. records; Realize the main ingredient and accessories calculation and management; Realized to scrap steel. pig iron mixed and weighing management; Able totprint various reports and records. To manage the working time of converter; Realize the continuous casting machine laboratory with such computer communication.

## 3. Comparison and analysis of the situation at home and abroad

In order to improve the product quality and production expand varieties

**Abstract:** This article emphatically about laigang steel mills bof dynamic steelmaking control system. Detailed introduces the characteristics of the dynamic steelmaking converter characteristics and its key of technology is described.

**Key words:** Computer process level; Furnace gas analysis; Dynamic model; Static model.

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reduce cost and consumption stable production process use the computer to control the production of the process is more necessary than others so in the iron and steel industry the converter is the first to use computer control units. At abroad are widely used the computer control of converter domestic from 20th century 70's starts the converter computer control of large number of experiments. and achieved gratifying achievements. At present the domestic several steel in different scale of converter realized the computer control. The computer control of the production process is necessary. Converter steelmaking for compact production thus introducing high-performance computer control system is to improve yield and quality of the necessary conditions for for this we choose the static model and dynamic model.<sup>[1]</sup>

#### 4. Main characteristics.

##### 4.1 basic level to computer level data transmission program design

50 tons of converter data transmission control program through the use of Siemens company special programming software STEP7. and USES the LAD. CSF. STL three kinds of flexible ways weaves and become. Set of control procedures using modular/structured programming methods: control procedures. divided into several control every part of part of the control programs and data in different FC compiled respectively. FB and DB block. and the main program OB1 in each in turn calls to scan cycle realize the respective control functions; In addition. in each block. to show the annotation to detail. This programming method makes the program consulting. function of the expanded and modify easier greatly enhances the program's flexibility. readability. practicability and maintenance.<sup>[2]</sup>

##### 4.2 furnace gas analysis system for converter by gas

Such as CO and CO<sub>2</sub>. the analysis of O<sub>2</sub>Ar N<sub>2</sub>. to realize smelting process detection.

##### 4.3 data transmission control system of monitoring system

Has the data entry. display. transmission. since the diagnosis/alarm. historical trend for dynamic functions. and record the steelmaking provides accurate data and function of record on the original data.

#### 5.Key technology

##### 5.1 oxygen lance accurate positioning control

In converter steelmaking production, base control level oxygen lance positioning accuracy directly affect the end-point steel temperature and carbon content, at the same time, to manufacture safety and furnace life, gun age also has very big effect. Therefore, we will oxygen lance positioning as a key technical problem solving, hardware USES German TURCK increment encoder and Siemens FM450 high-speed counting template cooperate, complete oxygen gun position signal collection. Positioning data processing adopts combined method of point, line, to limit bits, to blow bits, open oxygen/closed oxygen bits, variable speed to accurately position of the key point, using 10 times a weighted average round-trip count value, using the method of offset ascension acceleration and decline accelerated steel wire coil Yang caused by elastic deformation of the positioning error. To vertical axis gun bits display data, then adopts automatic quantitative compensation and artificially calibration method combining gives processing: i.e. when oxygen lance ascension and decline in the process of reading, and, on the basis of coder

respectively, plus or minus a compensation quantity, the compensation amount of oxygen lance 1,000 times is back with the gun position errors reading the statistical processing results, with this data in oxygen gun compensation, working on their trip, can achieve + / - 2CM's positioning accuracy, can completely meet the precision requirement of gun a instructions. In addition, in order to enhance the system reliability, MMI set the gun by a calibration button, when control error is bigger, can use oxygen gun down to school on press school gun button to soft manual school gun, at positioning system automatic initialization, restore setting precision.<sup>[3]</sup>

Gun a computation formula is as follows:

$$L \text{ litres} = (W + M - N \text{ liters}) \times (3.1416 \times D) \div S$$

$$L \text{ drop} = (W + M + N \text{ drop}) \times (3.1416 \times D) \div S$$

Among them:

L rises: the process of ascension actual gun position

L drop: decreasing process actual gun position

W: count template current count value

N rises: the process of ascension compensation quantity

N drop: decreasing process compensation quantity

M: initial calibration point count readings

S: encoder counted. A week pulse

D: to improve device volumes Yang roller diameter

##### 5.2 furnace gas analysis system

LianGangLu steelworks 4 bof dynamic gas analysis system is divided into three parts, namely EMG module, the SPS module and charts station. Including EMG

module used in DOS, mainly realizes data analysis; The SPS module runs on UNIX, mainly used for acquisition control valves (gas valves) parameters; Chart stood used to realize the display gases.

Bof dynamic steelmaking system from the exhaust gas analysis using Russia EMG - 20 - type 1 time of flight mass spectrometer, EMG - 20-1 is a time plain instrument, specially designed for the record steel-making convertor and or other smelting process emissions ms chromatogram and also analyzes the multiple constituents content and design. It belongs to process mass spectrometry, can discharge of flue gas for converter real-time, continuous monitoring, thus reach optimization parameters for smelting process and equipment monitoring, management, perfecting process purpose.

EMG - 20-1 in early January 2004 mass start the installation. Mass spectrometer installed in the super purification room of converter, using vacuum pump will analyze the exhaust gas suction mass spectrometer. Mass spectrometer after their arrival in gas 0.3 S time will come out from the exhaust gas analysis, including O<sub>2</sub>, CO and CO<sub>2</sub>, H<sub>2</sub>, N<sub>2</sub>, Ar six gases.

The principle of mass spectrometer to collect is will exhaust gas gas samples, through introducing ionization area, ionization electronic crash atoms and molecules to form a positively charged ions. After fixed accelerating field potential with the same initial function, the ion thrown. According to the different load ratios ion mass, in the absence of drift space ion to game separate. Ion separation rely on ions in the flight time without field drift with the correlation of qualitative load ratios. Has the same function in under the condition of the lighter than heavier ions ion with higher speed and can reach detector earlier. Through the

mass scale in time for these data record and map the processing can determine the mixed gas composition and percentage content. Now the content of the CO according to analysis to guide the converter gas can, according to the content of H<sub>2</sub> recycling can decide whether leaking oxygen lance.

The flight time pay-back of reflector, and longer ion of flying time by ion source, reducing the environmental cause ion initial energy dispersive problem, thereby improving the resolving power and sensitivity. The ions in the reflector by electrostatic ion lens of the same quality, has turned the flight time get ion together as calibration, ion. At the start of the high speed (energy) ions through a long flight route, so and slower ion reach detector in the same time.

### 5.3 static control model

Static control model is the main task of searching for the best according to the condition of raw material ratio, and according to the known to determine the scheme. Smelting ingredients The converter static control model is converter steelmaking computer terminal control core, its precision directly affect the end with temperature and carbon content of molten steel level of the shooting. According to different method of model and the static control model, a theory model, statistical type and experience. 50 tons, the steel of converter, constitutes furnace gas analysis indicated static model terminal control. The model based on the data from the exhaust gas analysis, and on the basis of realizing terminal control. The primary end point control parameters for: O, C, Mn, P, temperature, etc.

### 5.4 dynamic control model

The dynamic control model converter is static control model of the compensation accuracy.

According to the material balance, energy balance, chemical kinetics, chemical thermodynamics theory, and establish the exhaust gas analysis results from C speed calculation model, change of temperature calculation model, the other element change with incremental calculation model calibration technology and neural network to the analytic result of system error correction and delay and improve the elimination of rate at the converter.<sup>[4]</sup>

The dynamic control model is determined mainly by furnace gas carbon module, temperature forecast module, spitting forecast module, coolant control module. Model to self-study, adapt to the realization of the function of improving precision and practicability is the key model. According to the specific ways of handling method of model of error can be divided roughly and numerical processing method and artificial intelligence method two kinds.

Numerical processing methods: Todd Harper ara said each prediction model for  $y = F(x) + \text{train a Type}$ , learn of a train in each furnace after blowing in actual data, and predict learning next furnace  $y - F(x)$  value.

In addition, still can use the dynamic control model and feedback calculation model based on feedback model, including the exhaust gas analysis results, analysis of the dynamic model according to the relative error trend, and determine the rules, so as to achieve the feedback quantity adjustment purpose of dynamic model error.

Artificial intelligence method:

Artificial intelligence method to simulate the human experts thinking and decision-making process, it can bring in human experience and improve model elastic, offsetting the traditional control model defects of the part.

## 5.5 management functions

Steelmaking production is logistics and information flow intensive production process, maintain logistics and information flow smoothly, it is an important link in production management, of dynamic refined system for process level control, information acquisition, processing powerful monitoring software, to realize part process level control function offers may, based on this situation, in automatic control system developed auxiliary management functions.<sup>[5]</sup> This function focus mainly on two aspects:

Production data acquisition and upload: realize this function is the basis of building a high-speed communications network, realized across the integrity of the data acquisition, and then through the network interface steel production management to the LAN. Steel mills 4 # converter system includes three subsystems: converter ontology subsystem, converter coal gas recovery subsystem, the converter the remaining heat using subsystem. The data collected for workshop and upload steelworks two levels of production management and organization, also provide basis for scheduling efficiency and optimizing technology further tapping provided support, effectively promoted production management level.

Operating instructions records and equipment state records: in a complex system's fault analysis and responsibility confirmation, there must be perfect primitive data record as basis for failure analysis, then phenomenon and equipment condition, the real reason for the failure, radically solving problems, avoid the same fault, reduce downtime, repeat the application of the function, indirectly results is that with the continuous production, fault decrease.

## 6. The technological requirement

Steelmaking converter oxygen lance motor currently used more ac motor, ac power normal by frequency convertor, realize when oxygen lance drop, oxygen blowing, ascending speed operation; The ac power accident when the power is must by another set of emergency power supply, emergency ascending oxygen lance and prevent the occurrence of equipment accidents.

According to some steel steel-making convertor and process requirement, power in communication accident emergency supply need power load as:

- (1) oxygen lance motor 1, voltage 380V, capacity 55kW;
- (2) oxygen lance brake motor 1, voltage 380V, capacity 0.33 kW;
- (3) (4) converter brake motor, voltage 380V;  
Capacity  $0.45 \text{ kW} \times 4 = 1.8 \text{ kW}$ ;
- (4) the accident control power, voltage, capacity 2.4 kW; 380V
- (5) request emergency power spare time for 1 hour.

Emergency power work has the following two kind of situations:

When the converter are steelmaking oxygen blowing, ac power suddenly have a power fail, the emergency power frequency inverter should first output to oxygen lance motor subjecting plugging turn form, and emergency power output of industrial frequency inverter control of the power supply, giving oxygen accident brake motor power supply, gun oxygen lance electrical, loose and emergency ascension to the top bits oxygen lance. Because of converter steelmaking, already in zero, emergency power does not need to give the converter brake motor power supply.<sup>[6]</sup>

Such as the steel converter is when the ac power suddenly have a power

fail, emergency power frequency inverter of converter should be output to brake motor, loosen the converter brake, by weight of converter pour back to zero. Because of the steel, oxygen lance has been in the top bits, emergency power does not need to give oxygen lance motor power supply.

## 7. Emergency power allocation

According to the above process requirements, emergency power allocation should be:

- (1) 75kW can frequency inverter 1 (consider, oxygen lance maximum load, 60s) 150% overload ability
- (2) 3kVA industrial frequency sine-wave inversion 1 (by oxygen lance electrical motor entire pressure start-up and ac contactor coil biggest suction and power to consider)
- (3) charging module by 2 sets (output current 10% of battery capacity calculation
- (4) free maintenance of lead-acid batteries 1 group (battery capacity according to load current and reserve time calculation)<sup>[7]</sup>

## 8. Emergency power principle design and parameters are calculated

### 8.1 principle design

Because in the ac power normal oxygen lance motor, by a frequency convertor, control power and oxygen gun electrical motor, converter brake motor are made by communication power supply, only the ac power outage, oxygen lance motor, power and oxygen gun control brake motor, converter brake motor before the emergency power supply, so the emergency power design into the off-line.<sup>[8]</sup>

Oxygen lance motor inverter and emergency power frequency inverter can respectively through two output ac contactor oxygen lance motor power supply for two contactor, by



operating chain systems and control, contactor coil respectively by the ac power and emergency power of sine-wave inversion power frequency power supply, the ac power normal oxygen lance motor, by the original control system work, the ac power accident near power in the machine oxygen lance operational accidents box ascension button and accident loose converter brake button. <sup>[9]</sup> The oxygen lance ascend to limit automatically stop, pour turned to zero stop converter. Emergency power system main circuit and control circuit .

## 8.2 parameters are calculated

(1) it can frequency inverter technology parameters

But frequency inverter adopts Siemens vector type inverter, its electric parameters for:

Input: DC510V (15%) ~ 650V (+ 10%)

Output: 0 ~ 3AC380

Rated frequency

Input: dc

Output: 0 ~ 50Hz

Rated current

Input: 174A

Output: 146A

Overload current: 198A

Overload time: 60S

(2) industrial frequency sine-wave inversion technology parameters

Dc input voltage: 180 ~ 300V

Dc input current: 13.6 A

Exchange bypass input voltage: 380V + 15%

Exchange bypass the input current: 4.5 A

Switching time: 5ms acuties

Ac output voltage: 380V + 3%

Ac output current: 3.6 A

Overload ability: 120% 1min; By 150% 10s; 200% 1s

(3) inverter capacity calculation

A) can frequency inverter capacity calculation

Oxygen lance motor capacity for 55KW and rated current about 110A, consider oxygen lance scrape over load conditions, current slag 165A < 1.5 times as 198A (inverter overload current), reason inverter capacity can satisfy.

B) industrial frequency is energy inverter capacity calculation

The inverter load is oxygen lance dlectrical motor (direct start) and control of the power supply, brake motor capacity oxygen lance 0.33 kW and rated current about 0.66 A, according to 8 times directly starting current calculation for the 5.28 A, inverter rated output current is 3.6 A, overload 1.5 times current 5.28 A 5.4 A >.

Control power load for oxygen lance motor, oxygen lance dlectrical brake motor, converter input motor contactor coil, because they are not working at the same time, so can at maximum coil suction and power consideration, oxygen lance for input motor contactor 250A coil suck for 1430W, current and power for 1430W / 220V = 6.5 A, suck and time 0.5 s; And inverter overload ability: 1s, already allow current 200% for 3.6 \* 2 = 7.2 A > 6.5 A.

Because oxygen lance dlectrical motor start-up and contactor operation is not performed at the same time, so can press maximum load calculation by the above consideration, and can be seen inverter capacity can be satisfied.

(4) battery capacity and the number of series only calculated

A) battery capacity calculation

Battery pack is when communication accident, as when the power of 2 sets of inverter power supply for provide

the energy input load capacity, batteries by inverter output the maximum load current and duration decision.

By Siemens inverter technology parameters rated ac output current knowable: for 146A, the dc input current 174A, then for oxygen lance motor working in rated current 110A, the dc input current 174A / 146A for 110A x = 131A.

By industrial frequency sine-wave inversion technology parameters in that circumstance, rating: dc input current inverter for 13.6 A. So two set of inverter general dc input current as 144.6 A. Both the batteries need to provide for maximum sustained current 144.6 A, and lasts for 60min. According to the two data can be computed the capacity of the battery.

According to the constant exile battery electric capacity, the known condition calculated for:

Second-ranking single battery rated voltage: 12 v

Second-ranking single battery run after the globe voltage: 10.8 V

Electric current: Washington 144.6 constant exile for A

Second-ranking discharging duration: 1h

144.6 A discharge capacity for Washington 144.6 Ah... 1.0 h =

In figure 4 battery discharge curve can be obtained corresponding 12 x J20 curves were, again by figure 5 battery capacity curve can draw capacity 60%; Asking for a battery capacity in the following formula, C: 60 percent 144.6 = 100% x C...

C = 100 x 144.6/60 = 241Ah so choose 240Ah batteries.

B) battery <http://www.studa.net/pc/> series only count < >

Series only several N depends on the input dc voltage inverter with

maximum and minimum housings. Uninterrupted power supply in normal operation, the system in charging, the battery only floating number should be:

$$N = U_e / 6U_f (12V/\text{single battery})$$

Type: N for battery series only number

$U_e$  inverter input or frequency converter rated voltage dc circuit among

$U_f$  monomer battery recharging voltage float

The 12V/single battery in for example, monomer battery charging pressure  $U_f = 225$  float, single battery V float charging pressure  $U_f = 13.5$  V.

Siemens input voltage inverter for:

$$U_e = 510 \sim 650V + 10\%, \text{ namely } U_e (\text{min}) = 510V *$$

650V and 715V is inverter can work normally under the voltage limit cap and take average:  $U_e = (459V + 715V) / 2 = 587V$ .

$$\text{Then } N = U_e / 6U_f = 587V / 6 \times 225 V = 43.48 \text{ only. Take } N = 42 \text{ only.}$$

Float fast-recharging, battery pack terminal  $U_d = 42 \times 225 V \times 6 = 567V$ . Voltage in the device allows range.

### 8.3 emergency power equipment composition and principle diagram

Emergency power of the principle diagram. Emergency power composition:

(1) circuit breaker: 1QF: ac input circuit breaker; 2QF: industrial frequency inverter input circuit breaker; 3QF: industrial frequency inverter output circuit breaker; QS: frequency inverter input switch;

(2) contactor: dump: ac input contactor; 2KM, 4KM: frequency inverter output contactor; 3KM: inverters contactor (user equipment); 5KM: converter brake input motor

contactor (user equipment);

(3) TR: isolation transformer;

(4) CM1, CM2: high-frequency switch charging module;

(5) DC1, DC2: free maintenance of lead-acid batteries group;

(6) 1NB: frequency inverter;

(7) 2NB: industrial frequency inverter;

(8) VF: converter (user equipment).

## 9. Frequency conversion emergency power working condition

### 9.1 ac power to normal operation

When communication power supply, normal battery charging module to float charging, also on by ac supply 2NB inverter 2NB output (note: bypass input power is preferred), in exchange for control of power supply; 1NB inverter in thermal ready for starting state by user frequency convertor, motor. <sup>[10]</sup>

### 9.2 ac power cut operation

When the ac power blackouts, dump contactor disconnect, charging module to stop work; 2NB inverter power supply input by communication power supply, ensure the battery switching to external control power uninterrupted; Meanwhile external linkage system outage start signal (users) started 1NB inverter, output contactor 3KM disconnect, 2KM connected by 1NB power supply, the user motor. At this time, 1NB 2NB operation is sustained by battery pack discharge of inverter, batteries provide a stable dc voltage, because when won't because the ac power blackouts and impact load work.

### 9.3 ac power recovery operation

In ac power back to normal, emergency power not be artificially operation can then be automatic restart, battery charging module began to supplement, when power is

restored to recharge the normal operation condition, waiting for the next use.

## 10. Closing

But frequency conversion emergency power is used exclusively motor load output voltage and output frequency variable exchange uninterrupted power supply, and traditional UPS or industrial frequency emergency power, can reduce power compared the design capacity, overload ability, high reliability. Compared with the traditional diesel generator, start time quick, no noise, no pollution, simple maintenance, can unmanned automatic operation, but the computer monitor. Is a new type of industrial power worth extending.

According to the system into the actual effect in nearly a year, the dynamic see steelmaking control system design is reasonable, control advanced, the function is rich, safety operation is stable and reliable, and perform well in the process of the converter, ensure the production level control of the line, and achieved very good economic benefit. This control system has a certain since expansion, self-learning function, in this industry, and other related industries with high application value. Enter the normal production, after the system still exposed some problems, such as: system of individual equipment control functions and network communication ability still need according to production requirement to do further modification, supplements and perfect. Only the practical problems, according to the production further modification, perfect soft/hardware, satisfy requirement of production, can cause the system more tend perfect.

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