Application of Alpha Inverters in the Heating Furnace of Steel Mills

I. Project Introduction

Yuxi Xinxing Steel Co., Ltd. is a steel conglomerate in Yidi, Hongta District developed by the Kun Steel Group in its implementation of the Provincial Double Plan, during which the resource advantage of Yuxi has been adequately utilized. The company was built and put into production in commission on March 15th, 2005, and its main products include rectangular continuously casting, slabs, rolled deformed bars and medium/wide belts, which are sold in the markets of Yunnan, Sichuan, Chongqing and Guangdong with great performance. Under the favorable situation in which the state is making efforts to continuously improve the market economy system and also to accelerate reform and opening up as well as the scale development of the western region, Yuxi Xinxing Steel has grasped this opportunity, accelerated development, learned from successful experiences of excellent steel enterprises in both China and abroad, optimized its technical structure, and promoted technology progress, energy conservation and cleaner production; in this way, the steel products will have a more reasonable structure and significantly improved market competitiveness, and a qualitative leap has been achieved during the modern, intensive and highly effective industrial process, which has made major contribution to the sustainable development of the enterprise as well as energy conservation, environment protection and economic development of the Yuxi region. The inverter has been used in the fans of the 600,000-ton three-section beam-type steel billet heating furnace. The motor parameters are as the following:

Equipment Name	Fan Specification and Model	Rated Capacity of the Fan	Quantity	Technical Parameters of the Support Motor	
				Motor Model	Power (kW)
Heating furnace 1# air blower (centrifugal)	9-26No16D (right 90°)	69854m3/h	2	Y355M1-6	185
Heating furnace air induced draft fan (centrifugal)	Y9-38No16D (right 90°)	104784m3/h	1	Y355M2-6	200
Heating furnace gas induced draft fan (centrifugal)	Y9-38No16D (right 90°)	128069m3/h	1	Y355M4-6	250

II. Production Process

The medium/wide belt operation has adopted the three-section beam-type heating furnace, the air supply is regulated through the air inlet valve, and the air blower is designed to be one primary one plus one spare one to ensure 24-hour operation.

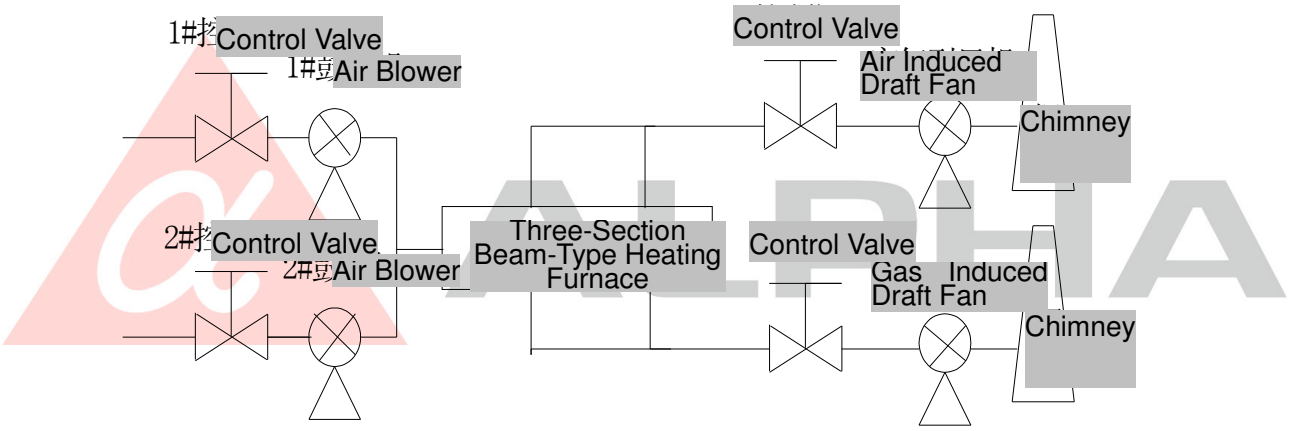
During normal production and heating of cold steel billets, the opening of the air inlet valve of the air

blower is 70~80% and the pressure of the air supply is maintained around 4.5kPa to ensure heating temperature of the hearth.

During heating of hot steel billets, the opening of the air inlet valve of the air blower is 50~60% and the pressure of the air supply is maintained around 4.5kPa. During heat preservation of the heating furnace, the requirement for air supply is smaller, and the opening of the air inlet valve should be reduced correspondingly. The pressure of air supply is maintained around 4.2kPa.

The exhaust volume of gas and air is regulated through the air inlet valve. During normal production and heating of cold steel billet, the opening of the air inlet valve of the gas smoke exhaust fan is 70~85%; during normal production and heating of hot steel billet, the opening of the air inlet valve of the gas smoke exhaust fan is 50~60%; during heat preservation of the heating furnace, the opening of the air inlet valve of these two fans is 30%.

The opening of the air inlet valve of the air smoke exhaust fan and gas smoke exhaust fan should be regulated in accordance with the speed and size of steel rolling to ensure even temperature in the hearth. The smoke exhaust temperature of these two fans should be controlled within 100℃, and there should be alarm if it exceeds 180℃. The process diagram of the fan of the heating furnace is as the following:



III. Transformation Plan

The model of the motor and fan for the air blower and gas induced draft fan and air induced draft fan of the three-section beam-type heating furnace should be selected and matched in accordance with the maximum production capacity of the heating furnace. Because actual production capacity has not reached maximum production capacity and for a long time, flow control has been conducted through valve regulation and increase of fluid resistance in the pipe network, the system has low efficiency, high power consumption and serious waste of electric energy.

Because normal production requires continuous and stable air supply, there is little variation in air volume and pressure. At this moment, throttling loss can be eliminated through regulation of the fan rotation speed by the inverter, and in the meantime, the operation efficiency of the fans is increased. Although the operation efficiency of the motor might be reduced due to an increase in its load rate, however, because the operating power of the fan has a huge decrease, the loss of the motor has been reduced, and finally, the operating power of the motor has been significantly reduced as well to realize the purpose of energy conservation.

1. The principle of frequency-conversion speed regulation:

In accordance with the basic principle of Electrical Machinery, the rotation speed of motor satisfies the following relation formula:

$$n= (1-s) 60f/p$$

Where: P- Motor pole pairs
F- Motor operation frequency
S- Slip

From the formula, we can see that the synchronous speed N1 of the motor is in proportion to the operation frequency of the motor N, because under general situation the slip S is very small ($<$ 0.05), so the actual rotation speed N of the motor almost equals the synchronous speed N1 of the motor. Therefore, through regulation of the power supply frequency F of the motor, we can regulate the actual rotation speed of the motor.

And in order to change the frequency, we must change the voltage of power supply. In accordance with the electromagnetic relation of AC (alternating current) motor:

$$E=4.44fw\Ø$$

Where: E- Motor electromotive force
f- Stator frequency
w- Winding coefficient
Ø- Air gap main flux

During speed regulation of the asynchronous motor, the main flux Ø should be constant, so that the u/f curve can maintain constant. Therefore, during change of the frequency, the voltage of power supply changes as well.

2. Speed regulation and conservation principle of the fan

Due to complexity of the internal fluid of the fan, their performance cannot be accurately calculated only based on this theory. Therefore, the operating situation of the fan can only be calculated in accordance with similar theories of Fluid Mechanics through experiments and simulations. Through application of similar law in the fan with different rotation speeds, we can get the following formula:

When the fan changes its rotation speed, its rotation speed n, flow Q, pressure (lift) H and shaft power P have the following relation:

$$\frac{Q_1}{Q_2} = \frac{n_1}{n_2}$$

$$\frac{H_1}{H_2} = \left(\frac{n_1}{n_2}\right)^2$$

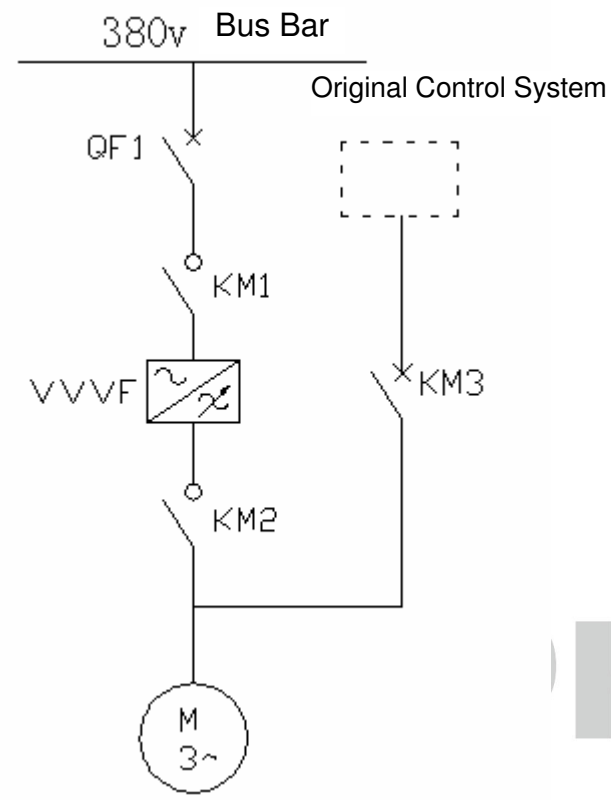
$$\frac{P_1}{P_2} = \left(\frac{n_1}{n_2}\right)^3$$

From the above formula, we can see that flow is in proportion to the rotation speed, the pressure is in proportion to the square of rotation speed, and the shaft power is in proportion to the cube of rotation speed. Therefore, decrease of rotation speed can significantly reduce energy consumption. The energy conservation principle of the fan is to use the speed regulation device to replace the ventilation door to regulate the flow, reduce throttling loss, and save energy. A fan is a mechanical device to transmit gas, which transfers the shaft power of the motor to mechanical energy. Fans usually have small starting torque and a light load, thus having great potential.

3. Transformation Plan:

The control mode of the air blower of the heating furnace is mainly in accordance with the air volume requirements of the heating furnace, and the air induced draft fan and gas induced draft fan are mainly controlled through regulation of the valve opening in accordance with temperature of the induced air and hearth. Due to the simple process of the combustion-supporting air blower and induced draft fan, there is no necessity to conduct closed-loop control, and in the transformation plan, it is considered to keep the air inlet valve fully open after adoption of the inverter, and rotation speed of the fan is regulated through manual operation in accordance with the production requirement. The system can change the induced air volume at any time to adapt to change and to maintain normal and cost-effective operation of the fan, in this realizing the purpose of stable control, convenient operation and energy conservation.

In addition, in order to ensure the system stability, the current control equipment and operation mode of the air blower are maintained. The control circuit is equipped with power frequency/frequency conversion switch, and selection of the frequency/frequency conversion is operated manually to realize the frequency/frequency conversion operation of the combustion-supporting centrifugal fan. Because there is one primary and one spare air blowers in the heating furnace, the conversion transformation has adopted a control mode of one motor drives two inverters, and manual switching function between the 1# and 2# fans is also set.



Main Circuit Diagram

State	Current (A)	Voltage (V)	cosΦ	Power (kW)	Average Power (kW)
During heating of cold steel billet	235	370	0.79	120.5	171.2
	241	370	0.79	123.2	
During heating of hot steel billet	405	350	0.87	218.5	
	413	354	0.87	222.4	

In order to reduce the labor intensity of the worker on duty, after transformation, the start/stop, power frequency/frequency conversion switch and speed regulation control of the combustion-supporting air blower and induced draft fan have all adopted concentrated and remote operations. Current PLC computer control systems will still be used, and current PLC module spare points will be used to modify the program of the control system in the combustion control computer to add the regulation

operation function of the air blower and induced draft fan as well as the display function of the output frequency and output current of the inverter.

IV. Analysis of the Operation Energy-Conservation Effect

Take gas induced draft fan for example:

FIG. Inverter under Operation

After transformation, the motor operation parameters of the gas induced draft fan are:

State	Current (A)	Voltage (V)	cosΦ	Power (kW)	Average Power (kW)
During heating of cold steel billet	120	375	0.95	74.05	102.2
	125	375	0.95	77.13	
During heating of hot steel billet	210	370	0.95	127.84	
	212	370	0.95	129.06	

In accordance with the above actual results of application:
It has an average energy conservation rate of more than 40%, and it takes about a little more than one year to recover the cost.

V. Other Effects Brought by Application of the Inverter

1. Low Maintenance

After adoption of the frequency-conversion speed regulation, no matter under what process condition, the system can operate under a state close to the rated state at any time through regulation of rotation speed. Due to a slow start and decrease in rotation speed, the service life of many components and parts has been correspondingly increased, and in the meantime, impact on the pipeline has been significantly reduced, and a large amount of maintenance cost has been saved.

2. Reduce Impact on the Power System

After adoption of the inverter, the system has realized a soft start, the start current of the motor is far smaller than the rated current, the start time is correspondingly increased, which has no impact on the power system, and the mechanical damage to the motor from the starting mechanic torque is reduced, which has effectively increased the service life of the motor.

3. Improve the Working Environment

Under the precondition to satisfy the requirements of the production process, the noise of the fan is reduced by reducing the rotation speed of the fan, especially the loud noise generated by load change during phase-switch of the heating furnace; rotation speed of the fan during the load change is reduced through the current amplitude-limit function of the inverter, and the noise decrease of the fan is obvious, which has significantly improved the working environment of the employees.